Syllabus: Advanced Statistical Theory, 36-709 (Spring 2019)

1 Class Information

Instructor: Sivaraman Balakrishnan
Email: siva@stat.cmu.edu
Office Hours: Tuesday 11:30am - 12:30pm in Gates 8213.

TA: Heejong Bong
Email: hbong@andrew.cmu.edu
Office Hours: TBA.

Lectures: Tuesday and Thursday, 9:00am - 10:20am, PH 226A.

Class Website: https://www.stat.cmu.edu/~siva/709/main.html

2 Overview

This course will cover a variety of advanced topics in non-asymptotic theoretical statistics. Topics that we will cover include:

- Empirical processes and their statistical applications
- Matrix estimation
- Sparse estimation
- Non-parametric estimation
- Minimax lower bounds

Once we cover this core material, if time permits, we will also cover some exciting recent developments in robust estimation, functional estimation and minimax theory for hypothesis testing. The primary aim of this course is to introduce modern tools and techniques from theoretical statistics.

2.1 Textbooks

We will primarily follow the textbook:

- "High-dimensional statistics: A non-asymptotic viewpoint" by Martin Wainwright.

For some portions, in addition to various recent research papers, we will also use:

- "An introduction to nonparametric estimation" by Alexandre Tskybakov.

For some topics we will also provide other references (from recent research papers).

2.2 Piazza

We will use Piazza to answer questions. Please sign-up at the following website:

`https://piazza.com/cmu/spring2020/36709/home`

Since the class has limited TA support, please try to use office hours as far as possible for questions.

3 Grading

Your grades will be determined using the following weighting scheme:

1. Homework assignments (60%)
2. Course project (20%)
3. Scribe duties (10%)
4. Class attendance and participation (10%)

4 Scribing

Starting from Lecture 2, students will need to sign up to scribe. The students will take turns to transcribe the notes of every lecture using the latex template available at

`https://www.stat.cmu.edu/~siva/709/main.html`

The scribe has to attend class, take good and accurate notes, check for mistakes and inconsistencies, write them up in latex, add references and expand the material if appropriate and after consulting with me. The resulting pdf and latex files have to be submitted for my approval within one week. The pdf files containing the lecture notes will be posted on the class website.

To sign up to scribe please visit the following Google doc, before noon on Wednesday (January 15th) and sign up:

`https://docs.google.com/spreadsheets/d/1CGHLY1poKBFViDdi1BhJketap8p_bcxU0ZQrqFa9bsg/edit#gid=0`

5 Project

The project is relatively simple – you need to pick an interesting, recent, advanced paper (or papers) in the theoretical Statistics or Machine Learning literature. If you have trouble with this let me know and I can try to make some suggestions based on your interests. You will need to clear the paper with me (I will be looking for something technically substantive).

Your goal is to comprehensively study the paper of your choice.

- Prepare a report (for 70% of the project grade). This report should be roughly 8 pages in length, and should set-up, motivate, and state the main result of the paper. This should be followed by a digestible version of the proof. You can skip the proofs of more technical aspects but you should present the main ideas of the proof, important lemmas, and an understandable proof outline.

- For the remaining 30% of the project grade you will give a short (10 minute) presentation in class, during which you will have to tell us about the paper, why it is interesting, the main result, a high-level proof sketch and at least one really interesting idea you learned from the proof.

The goal of the project is to gain some practice in reading and digesting theoretical papers, and to practice clear exposition of theoretical ideas.

6 Homework

There will be roughly 5 HW assignments that will go out at various points. Homework problems will be assigned every 2 weeks. The problems will be mostly of theoretical nature.

There is a great value in discussing problems and sharing knowledge with your classmates, so you are encouraged to engage in group work. However, you should attempt to solve homework problems by yourself and only afterwards meet and compare with others.

In many cases, the HW will also involve reading exercises (reading and summarizing parts of some recent papers).

7 Attendance

It is important that you attend class, as the selection and organization of the topics will be on occasion different from the notes and textbooks. If you know you will be absent for few consecutive lectures, please let me know.

Come and see me any time you are confused or stuck and don?t be shy in class: the more questions you ask and the more feedback I receive from you, the better I will be able to tailor the lectures to your specific needs.

8 Very Tentative Lecture Schedule

Date	Lecture Topic	Reading
January 14th	Course overview, Introduction	Chapter 1, MJW
January 16th	Covering and Packing	Chapter 5.1, MJW
January 21st	Gaussian and Rademacher Complexity	Chapters 5.2, 5.3.1, 5.3.2 MJW
January 23rd	Chaining and Dudley's Bound	Chapter 5.3.3 MJW
January 28th	Comparison Inequalities, Lower Bounds	Chapter 5.4-end MJW
January 30th	Gaussian Covariance Matrix Estimation	Chapter 6.1, 6.2 MJW
February 4th	Instructor Travel	
February 6th	Instructor Travel	
February 11th	Random Matrix Theory and Matrix Concentration	Chapter 6.4 MJW, Tropp Survey
February 13th	Random Matrix Theory and Matrix Concentration	Chapter 6.4 MJW, Tropp Survey
February 18th	Estimating Structured Matrices	Chapter 6.5 MJW
February 20th	Singular Value Thresholding and Applications	Chatterjee paper
February 25th	Nuclear Norm Regularization, Matrix Completion	Chapter 10 MJW
February 27th	Sparse Linear Models, Basis Pursuit	Chapter 7.1 and 7.2, MJW
March 3rd	LASSO Prediction Error, Estimation Error	Chapter 7.3 and 7.4, MJW
March 5th	LASSO Support Recovery	Chapter 7.5, MJW
March 10th	**No classes: Spring Break**	
March 12th	**No classes: Spring Break**	
March 17th	High-dimensional inference, De-biasing	Recent papers
March 19th	Intro to non-parametric estimation	Chapter 1.1, 1.2, 1.5 Tsybakov Chapter 13.1, 13.2.0 MJW
March 24th	Non-parametric Least Squares	Chapter 13.2 MJW
March 26th	Non-parametric Least Squares	Chapter 13.3 MJW
March 31st	Minimax Lower Bounds	Chapter 15.1 and 15.2, MJW
April 2nd	Minimax Lower Bounds	Chapter 15.3, MJW
April 7th	Minimax Hypothesis Testing	Work of Ingster + Recent Papers
April 9th	Non-parametric Hypothesis Testing	Work of Ingster + Recent Papers
April 14th	Lower Bounds for Non-Parametric Testing	Work of Ingster + Recent Papers
April 16th	**No classes: Spring Carnival**	
April 21st	Distribution Functional Estimation	Bickel and Ritov, Chapter 2.7.5 Tsybakov
April 23rd	Robust Estimation	Paper by Yatracos + Recent Papers
April 28th	Project Presentations	
April 30th	Project Presentations	

9 Accommodations for Students with Disabilities

If you have a disability and have an accommodations letter from the Disability Resources office, I encourage you to discuss your accommodations and needs with me as early in the semester as possible. I will work with you to ensure that accommodations are provided as appropriate. If you suspect that you may have a disability and would benefit from accommodations but are not yet registered with the Office of Disability Resources, I encourage you to contact them at access@andrew.cmu.edu.

10 Statement of Support

Take care of yourself. Do your best to maintain a healthy lifestyle this semester by eating well, exercising, avoiding drugs and alcohol, getting enough sleep and taking some time to relax. This will help you achieve your goals and cope with stress.

All of us benefit from support during times of struggle. There are many helpful resources available on campus and an important part of the college experience is learning how to ask for help. Asking for support sooner rather than later is almost always helpful.

If you or anyone you know experiences any academic stress, difficult life events, or feelings like anxiety or depression, we strongly encourage you to seek support. Counseling and Psychological Services (CaPS) is here to help: call 412-268-2922 and visit their website at http://www.cmu.edu/counseling/. Consider reaching out to a friend, faculty or family member you trust for help getting connected to the support that can help.

If you or someone you know is feeling suicidal or in danger of self-harm, call someone immediately, day or night:

1. CaPS: 412-268-2922
2. Re:solve Crisis Network: 888-796-8226
3. If the situation is life threatening, call the police. On campus: CMU Police: 412-268-2323. Off campus: 911

If you have questions about this or your coursework, please let me know. Thank you, and have a great semester.