Theoretical Foundations of Deep Learning: Course Overview

CS 839@UW-Madison

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Teaching team

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- More Information on course website:
    https://pages.cs.wisc.edu/~yliang/cs839_spring23/index.html

Where to find content

- Canvas – private materials that should not be shared
    - Assignments
    - Grades

- Course website – public materials
    - Slides
    - Schedule
    - Policies

Major goals

1. Learn about open questions/challenges in theoretical analysis of deep learning
2. Learn about existing techniques/results
3. Try to propose new questions/techniques and get new results

Emphasize on open discussion

May not fit: if just interested in **using** deep learning or the empirical aspects, but not about its theoretical analysis

Discussions

1. What is Deep Learning?

2. What is the meaning of Theoretical Foundations?

3. Why care about theoretical analysis?

Course requirements

- ~5 homework assignments: 50%
  - Math analysis
  - **post on Canvas; submit your solutions on Canvas**

- Paper presentation: 10%

- Project: 40%

# Expected background

- (CS760 or CS761 or CS861)

- AND strong math background in
  - machine learning
  - probability/statistics
  - optimization

Standard Tools

- Understanding machine learning: From theory to algorithms. Shai Shalev-Shwartz, and Shai Ben-David. Cambridge University Press, 2014.

- Foundations of machine learning. Mehryar Mohri, Afshin Rostamizadeh, and Ameet Talwalkar. MIT Press, 2018.

- High-Dimensional Probability: An Introduction with Applications in Data Science. Roman Vershynin. Cambridge University Press, 2018

- Introductory Lectures on Convex Optimization: A Basic Course. Yurii Nesterov. Springer, 2004.
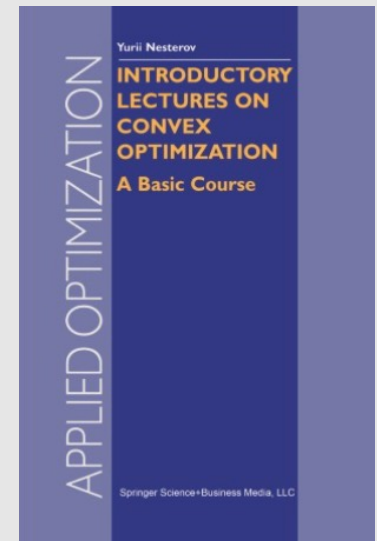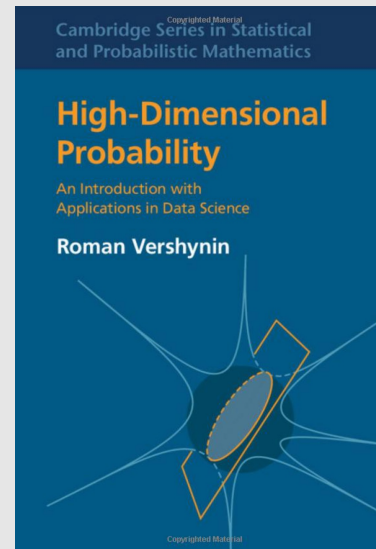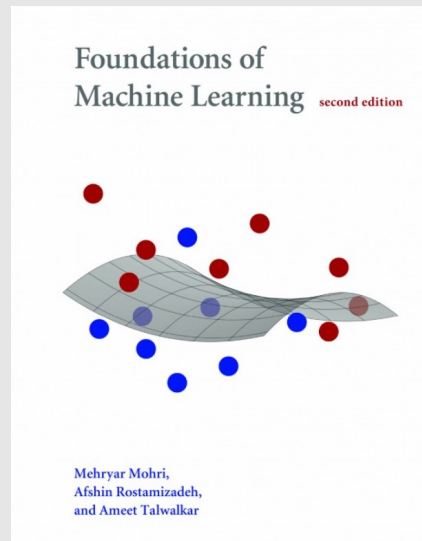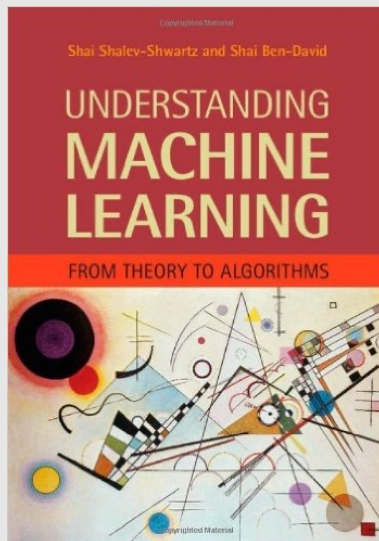
Topics

- Challenges in theoretical analysis of deep learning

- Approximation/representation power of neural networks

- Neural Tangent Kernel (NTK)
- Mean-field analysis

- Optimization: landscape, Implicit regularization

- May consider: complexity, representation learning, GAN, …

Assignments

Review reading

- Understanding machine learning: From theory to algorithms. First 4 chapters.

- High-Dimensional Probability: An Introduction with Applications in Data Science. Chapter 1, 2, 8

- Links can be found on course website: https://pages.cs.wisc.edu/~yliang/cs839_spring23/index.html

HW1: Background test

- Will post on Canvas
- Will set up how to submit the solutions on Canvas

- If you find many questions intimidating, we suggest you drop the course and take it again in the future when you are more prepared

Topics:

- ML theory basics
- probability
- Optimization basics

THANK YOU