Topics on Mathematical Analysis of Machine Learning Algorithms

Description of Course: This course introduces essential mathematical techniques that are commonly used to analyze machine learning algorithms in current literature. The course examines the statistical and computational properties of popular machine learning methods. Topics include probability inequalities, uniform convergence, covering numbers, model selection techniques, and the theoretical foundations of kernel methods, additive models, and neural networks. By blending theory with practical examples, the course aims to equip students with the analytical skills required to assess algorithm performance and generalization behavior in modern machine learning applications.

Instructor and Contact Information

Professor/Lecturer: Ning Hao **Email:** nhao@arizona.edu

Textbook: *Mathematical Analysis of Machine Learning Algorithms* by Tong Zhang (**Electronic copy available in author's web**)

ISBN 9781009093057; Cambridge University Press

Relevant books: *High-Dimensional Statistics: A Non-Asymptotic Viewpoint* by Martin J. Wainwright

High-Dimensional Probability -- An Introduction with Applications in Data Science by Roman Vershynin (**Electronic copy available in author's web**)

Learning Outcomes: By the end of the course, students will be able to:

- Apply key probabilistic and statistical tools to analyze the behavior and performance of learning methods.
- Evaluate how measures of model complexity (such as uniform convergence, covering numbers, and VC-dimension) influence generalization.
- Critically assess both theoretical and computational aspects of learning algorithms across different paradigms.
- Engage with contemporary research literature to discuss current challenges and advancements in the mathematical analysis of machine learning.

Prerequisite: 567AB or 574M or basic knowledge on machine learning methods. Feel free to talk to me if you plan to take it without prerequisite.

Tentative Schedule: The current plan is to cover the first 15 chapters of the book, roughly one chapter per week.

Homework: Biweekly.

Final Project: We will have a final project with a written report and in-class presentation. Students should talk to the instructor on the topics of their presentation by the first week of October.

Course grade: Homework (50%), project (50%). Final percentages above 90, 80, 70, or 60 guarantee letter grades of A, B, C, or D, respectively.