BUS41918: Data, Learning, and Algorithms

The University of Chicago
Booth School of Business

Syllabus, Winter 2024

Contact Information
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Course Description

This Ph.D. level course will provide an overview of machine learning and its algorithmic paradigms, and explore recent topics on learning, inference, and decision-making with large data sets. Emphasis will be made on theoretical insights and algorithmic principles.

Prerequisite

This is a Ph.D.-level course for students with strong quantitative and mathematical backgrounds. Basic graduate-level probability and statistics classes as prerequisites are recommended. Students should be comfortable with probability theory, statistics, numerical linear algebra, and basic knowledge of continuous optimization.

Tentative Topics

Here is a list of some critical ideas that we plan to cover:

- Randomized linear algebra, dimension reduction, and data visualization
  Lecture 1: Randomize
- Computer age inference, simulation-based and resampling method
  Lecture 2: Resample
- Causal inference in practice: design and inference
  Lecture 3: What If
- Online algorithms and optimization;
  Lecture 4: No Regret
- Sequential decision making, dynamic programming, and reinforcement learning
  Lecture 5: Explore vs. Exploit I

- Bandits, exploration and exploitation
  Lecture 6: Explore vs. Exploit II
- Kernel trick: from parametric to non-parametric
- Concentration of measure, uniform LLN, empirical processes

Textbooks and Readings

- Prediction, Learning, and Games, by Nicolò Cesa-Bianchi and Gabor Lugosi.
- Patterns, Predictions, and Actions, by Moritz Hardt and Benjamin Recht.
- Computer Age Statistical Inference, by Bradley Efron and Trevor Hastie.
- Foundations of Data Science, by Avrim Blum, John Hopcroft and Ravindran Kannan.
- Understanding Machine Learning, by Shai Shalev-Shwartz and Shai Ben-David.
- Elements of Causal Inference, by Jonas Peters, Dominik Janzing and Bernhard Schölkopf.

Non-technical Writings:

- Data Science at the Singularity, by David Donoho.
- The Unreasonable Effectiveness of Data, by Alon Halevy, Peter Norvig, and Fernando Pereira.

Course Website

TBD

Honor Code

Students in this course, as with all Chicago Booth courses, are required to adhere to the standards of conduct in the Chicago Booth Honor Code and the Chicago Booth Standards of Scholarship. The Chicago Booth Honor Code requires students to sign the following Chicago Booth Honor Code pledge, "I pledge my honor that I have not violated the Honor Code during this examination" on the midterm and final exams. I consider your printed name on an assignment or exam submission a signature of the honor code. As a result, you do not have to physically sign the assignment.

References

Avrim Blum, John E. Hopcroft, and Ravindran Kannan. *Foundations of Data Science*. Cambridge University Press, 2020.

Nicolò Cesa-Bianchi and Gábor Lugosi. *Prediction, Learning, and Games*. Cambridge University Press, 2006.

Bradley Efron and Trevor Hastie. *Computer Age Statistical Inference: Algorithms, Evidence, and Data Science*. Cambridge University Press, 2016.

Nathan Halko, Per-Gunnar Martinsson, and Joel A. Tropp. Finding structure with randomness: Probabilistic algorithms for constructing approximate matrix decompositions, December 2010.

Moritz Hardt and Benjamin Recht. *Patterns, Predictions, and Actions: A Story about Machine Learning*. Princeton University Press, 2022.

John L Kelly. A new interpretation of information rate. *the bell system technical journal*, 35(4):917–926, 1956.

Tor Lattimore and Csaba Szepesvári. *Bandit algorithms*. Cambridge University Press, 2020.

Judea Pearl. *Causality*. Cambridge university press, 2009.

Jonas Peters, Dominik Janzing, and Bernhard Schölkopf. *Elements of Causal Inference: Foundations and Learning Algorithms*. The MIT Press, 2017.

Shai Shalev-Shwartz and Shai Ben-David. *Understanding Machine Learning: From Theory to Algorithms*. Cambridge University Press, 2014.

Herbert A Simon. Dynamic programming under uncertainty with a quadratic criterion function. *Econometrica, Journal of the Econometric Society*, pages 74–81, 1956.

Henri Theil. A note on certainty equivalence in dynamic planning. *Econometrica: Journal of the Econometric Society*, pages 346–349, 1957.