

Oxford University, Hilary term 2021, Syllabus for: Advanced Econometrics

Foundations of machine learning

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class time	Tue 11:00-12:30 and Th 15:30-17:00
webpage	https://maxkasy.github.io/home/ML-Oxford-2021/
location	Online

<https://zoom.us/j/94522927229?pwd=OUNKZC9FcWFQdUN6Y05FUzBCejFpdz09>

Overview and Objectives

This class will cover some of the theoretical foundations of machine learning. The class starts with a review of statistical decision theory, which provides the conceptual framework for the rest of the course. We then consider regularization and data-driven choice of tuning parameters. We will discuss the canonical normal means model. In this model, we will motivate shrinkage estimators in different ways, and will prove the famous result that shrinkage estimators can uniformly dominate conventional estimators. As an example of a supervised learning method that builds on these ideas, we will discuss (deep) neural nets, including some numerical methods used for training them, such as stochastic gradient descent.

After that, we will discuss methods for active learning in the context of multi-armed bandit settings. We will review some theoretical results providing performance guarantees (regret bounds) for algorithms used for learning in bandit settings. We will then turn to a generalization of bandit problems, Markov decision problems, and will discuss reinforcement learning approaches for solving these.

Online lectures Classes will take place online, via Zoom. The link to the Zoom room can be found at the beginning of this page. Classes are live and attendance is required, but I might share recordings of classes at a later point. You are asked to turn your webcams on throughout, but keep your microphone muted unless you have a question. Classes take place during the regular class time.

The teaching format will deviate minimally from standard lectures. I will lecture using the slides posted on my webpage. I will also use an online whiteboard.¹ You should keep this whiteboard open during lectures, and can also return to it later.

You should feel free to ask questions at any point during lectures, by just unmuting yourself. I will also take regular breaks to see if there are any questions. I will not monitor questions in the chat while teaching.

Practice problems I have posted example exam question on my course homepage. Additionally, the slides contain a lot of practice problems, which you will have to solve in class. The idea is to have you complete most of the proofs, after I pointed you in the right direction. After a few minutes, we will discuss the solutions to these problems. These problems provide good guidance for what you might expect from the exam.

If you need any special accommodations for physical or medical reasons, please send me an email.

¹Available at <https://jamboard.google.com/d/1az6HER_tQk4jCcNzOXPkjvXw8Cfyyj17NlqgLfkeNk>.

Outline of the course

Decision theory

- Basic definitions
- Optimality criteria
- Relationships between optimality criteria
- Analogies to microeconomics
- Two justifications of the Bayesian approach

Shrinkage in the normal means model

- Setup: the normal means model $\mathbf{X} \sim N(\boldsymbol{\theta}, I_k)$ and the canonical estimation problem with loss $\|\hat{\boldsymbol{\theta}} - \boldsymbol{\theta}\|^2$.
- The James-Stein (JS) shrinkage estimator.
- Three ways to arrive at the JS estimator (almost):
 1. Reverse regression of θ_i on X_i .
 2. Empirical Bayes: random effects model for θ_i .
 3. Shrinkage factor minimizing Stein's Unbiased Risk Estimate.
- Proof that JS uniformly dominates \mathbf{X} as estimator of $\boldsymbol{\theta}$.
- The normal means model as asymptotic approximation.

Deep neural nets

- What are neural nets?
- Network design:
Activation functions, network architecture, output layers.
- Calculating gradients for optimization:
Backpropagation, stochastic gradient descent.
- Regularization using early stopping.

Bandit problems

- Setup: The multi-armed bandit problem.
Adaptive experiment with exploration / exploitation trade-off.
- Two popular approximate algorithms:
 1. Thompson sampling
 2. Upper Confidence Bound algorithm
- Characterizing regret.
- Characterizing an exact solution: Gittins Index.
- Extension to settings with covariates (contextual bandits).

Reinforcement learning

- Markov decision problems.
- Expected updates – dynamic programming.
- Sample updates:
 - On policy: Sarsa.
 - Off policy: Q-learning.
- Approximation:
 - On policy: Semi-gradient Sarsa.
 - Off policy: Semi-gradient Q-learning.
 - Deep reinforcement learning.

References

Review of decision theory

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Shrinkage in the normal means model

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Bandit problems

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- Kasy, M. and Sautmann, A. (2020). Adaptive treatment assignment in experiments for policy choice. *Econometrica*, forthcoming.

Reinforcement learning

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