ISYE 4601 ONLINE LEARNING AND DECISION MAKING

Concentration depth elective for Analytics and Data Sci.

Credit: 3-0-3

Coordinators: Prof. Muthukumar and Ziani

Prerequisite(s): ISYE 3133 Engineering Optimization

Catalog Description:
Fundamental theoretical tools for analyzing online methods, algorithmic techniques for developing computationally efficient methods, applications to real-world problems, and discussion around ethical and legal issues.

Text:
1. Course webpage/Canvas
2. Handwritten class notes by instructors

References:
1. Introduction to Online Convex Optimization by Elad Hazan, 2nd edition MIT Press, 2022.
2. Prediction, Learning, and Games by Nicolo Cesa-Bianchi and Gabor Lugosi, Cambridge University Press, 2006
3. Dynamic Programming and Optimal Control by Dimitri Bertsekas, Athena Scientific, 2012 (volumes 1 and 2).
4. Markov Decision Processes: Discrete Stochastic Dynamic Programming by Martin Puterman, Wiley-Interscience, 2005.

Course Description (please update)
At the heart of most machine learning applications today – like advertisement placement, movie recommendation, and node prediction in evolving networks – is an optimization engine trying to provide the best decision with the information observed thus far in time, i.e. the problem of online learning. To solve these problems, one must make online (meaning dynamic/real-time in machine learning lingo) decisions and continuously improve the performance with the arrival of data and feedback from previous decisions. The course aims to provide a foundation for the development of such online methods and for their analysis. We will discuss fundamental principles for learning from an unknown environment, limited feedback, and learning with dynamic, long-term consequences. Time permitting, the course will also discuss ethical and legal issues that arise due to unintended consequences of decision-making, and mathematical tools to formalize as well as mitigate such issues.

Topical Outline

Part	Topics	Weeks

		(approximate)
I	Principles for prediction from time-varying/adversarial data and learning with expert advice in the binary case	2
	Extensions to the non-binary case: multiplicative weights algorithm and applications in solving linear programming/zero-sum games	1
II	The exploration-vs-exploitation principle in stochastic bandits	1
	Foundational bandit algorithms: UCB and Thompson sampling	2
	Applications to recommendation systems	1
III	Dynamic programming and optimal control	1
	Basic principles of reinforcement learning and applications to operations management	1
	Discussion of ethical consequences of decision-making	1
Total		14

Course Outcomes and their relationships to ISyE Program Outcomes

At the end of this course, students will be able to:

1. Understand where online learning is applicable in many real-world scenarios,
2. Develop algorithms that combine partial information as best as possible to make online decisions,
3. Understand how exploration of decision space and exploitation from historic data must be prioritized to be able to reach optimal decisions,
4. Understand the consequences of automated decisions on different population groups and how to mitigate harm caused by online machine learning.

Course outcome \ Program Outcomes	1. identify, formulate solve engg prob by engg, sci & Math	2. produce solutions consider public health, safety, welfare, global, cultural, social, environ & economic	3 communicate with a range of audience	4. recognize ethical & professional responsibilities, make informed judgement consider resolutions in global, economic, environ and	5. effective on a team provide leadership, collaborative and inclusive envirn, plan tasks & meet objectives	6. develop and conduct experiment, analyze and interpret data & use engineering judgement to draw conclusions.	7. acquire and apply new knowledge using appropriate learning strategies
1. Understand where online learning is applicable	H	H					
2. Develop algorithms to make online	H	H					

decisions							
3. Understand how exploration of decision space and exploitation from historic data must be prioritized to be able to reach optimal decisions	H	H					
4. Understand the consequences of automated decisions on different population groups and how to mitigate harms caused by online machine learning.	M	M		M			

Evaluation of the important course outcomes

Please place H to indicate which one will be assessed. Others can be blank for not relevant, L for low and M for medium. Please also indicate how to assess. Questions on final or by project or assignment