Course Syllabus

INDENG 290: Applications of machine learning to electronic markets

Instructor

Dr. Svitlana Vyetrenko **svitlana@berkeley.edu (mailto:svitlana.s.vyetrenko@jpmchase.com)**

Office Hours

Virtual office hours, https://berkeley.zoom.us/j/8014977561

Mon 1:30 - 2:30 pm PST

Tue 1:30 - 2:30 pm PST

Teaching Assistant and Office Hours (theoretical assignments + project proposal discussions)

Dr. Jiacheng Zhang **jiachengz@berkeley.edu (mailto:jiachengz@berkeley.edu)**

Office hours: Thu 2 - 4 pm PST, 4175 Etcheverry Hall

Reader

Siqi Wang **siw119@berkeley.edu (mailto:siw119@berkeley.edu)**

Class Info

This class will be offered in-person. Class location: 3 Physics, 3-5 pm on Fridays.

https://berkeley.zoom.us/j/8014977561

Prerequisites

Ability to code in Python + basic understanding of statistics and optimization

Homework

Homework will be a mix of theoretical exercises and programming assignments. Homework will be due 3 pm on Friday before the class starts. No late homework will be accepted.

Data

Useful data and some supporting code will be shared **here. (https://bcourses.berkeley.edu/courses/1518016/files/folder/LOB%20data) (https://bcourses.berkeley.edu/courses/1518016/files/83920339?wrap=1)**

Final Exam

Take home final exam will be given during the final week. The exam will be a mix of theoretical and programming assignments.

Capstone project proposal and proposal presentation

Part of the goal of this class is to prepare students for the Capstone project in the spring. During the course, students will be exposed to the current research on applications of machine learning in electronic markets and, as a result, will be asked to work in groups to submit and present a 5-page proposal for their Capstone project (which will be due on December 2, 2022). More details and important deadlines about the Capstone student group formation and the proposal content can be found on the **Fintech 2022 project site. (https://bcourses.berkeley.edu/courses/1516411)** Possible student projects include but are not limited to:

- Implementation of reinforcement learning agents for market making and algorithmic execution
- Market simulator calibration
- Implementation of a synthetic time series generator for market data
- Improving forecast of a time series model with synthetic time series augmentation

Grade

Assignment	%
Homework 1	20
Homework 2	20
Homework 3	20
Capstone project proposal and presentation	20
Final Exam	20
Total	**100**

We will be using gradescope.com for homework/final/proposal submission.

Books

1. Z. Bodie, A. Kane, A. J. Markus. Investments (12th edition).
2. **A. Rao, T. Jelvis. Foundations of reinforcement learning with applications to finance. (https://stanford.edu/~ashlearn/RLForFinanceBook/book.pdf)**

Lecture Outline

Date	Description	Suggested Reading	Special
Aug 26	Introduction - electronic markets, order book, order types, return distributions, market impact	Lecture 1 Notes (https://bcourses.berkeley.edu/courses/1518016/files/83940566?wrap=1) Book 1, Ch. 2, 3, 5 R. Almgren et al. Direct estimation of equity market impact. (https://www.cis.upenn.edu/~mkearns/finread/costestim.pdf) S. Vyetrenko et al. Get Real: Realism Metrics for Robust Limit Order Book Market Simulations. (https://arxiv.org/abs/1912.04941)	
Sep 2	Market Impact; historical limit order book data; stylized facts	Lecture 2 Notes (https://bcourses.berkeley.edu/courses/1518016/files/83980253?wrap=1) R. Cont. Empirical properties of asset returns: stylized facts and statistical issues. (http://rama.cont.perso.math.cnrs.fr/pdf/empirical.pdf) (https://arxiv.org/abs/1912.04941)	
Sep 9	Order book trading algorithms: market making and algorithmic execution	Lecture 3 Notes (https://bcourses.berkeley.edu/courses/1518016/files/84035153?wrap=1) R. Almgren, N. Chriss. Optimal execution of portfolio transactions. (https://www.smallake.kr/wp-content/uploads/2016/03/optliq.pdf) M. Avellanida, S. Stoikov. High-frequency trading in a limit order book. (https://www.math.nyu.edu/~avellane/HighFrequencyTrading.pdf) Book 2, Ch. 8	
Sep 16	Markov decision processes and foundations of reinforcement learning	Lecture 4 Notes (https://bcourses.berkeley.edu/courses/1518016/files/84111406?wrap=1) Book 2, Ch. 2, 9, 11	Homework 1 due
Sep 23	Q-learning; RL for optimal	Lecture 5 Notes (https://bcourses.berkeley.edu/courses/1518016/files/84260258?wrap=1)	

	execution	Y. Nevmyvaka et. al. Reinforcement learning for optimized trade execution. (http://smallake.kr/wp-content/uploads/2019/01/rlexec.pdf) S. Vyetrenko, K. Xu "Risk-Sensitive Compact Decision Trees for Autonomous Execution in Presence of Simulated Market Response" (https://arxiv.org/abs/1906.02312) O. Mihatsch et. al. Risk sensitive reinforcement learning. (https://link.springer.com/content/pdf/10.1023/A:1017940631555.pdf)	
Sep 30	Functional approximation; RL for market making; simulation	Lecture 6 Notes - Part 1 (https://bcourses.berkeley.edu/courses/1518016/files/84264101?wrap=1) Lecture 6 Notes - Part 2 (https://bcourses.berkeley.edu/courses/1518016/files/84264108?wrap=1) T. Spooner et. al. Market making via reinforcement learning. (https://arxiv.org/pdf/1804.04216.pdf) D. Byrd et. al. ABIDES: Towards High-Fidelity Market Simulation for AI Research. (https://arxiv.org/abs/2110.14771) D. Byrd. Explaining Agent-Based Financial Market Simulation. (https://arxiv.org/abs/1909.11650) S. Amrouni et. al. ABIDES-Gym: Gym Environments for Multi-Agent Discrete Event Simulation and Application to Financial Markets. (https://arxiv.org/abs/2110.14771)	
Oct 7	Simulation; classic time series models	Lecture 7 Notes (https://bcourses.berkeley.edu/courses/1518016/files/84330137?wrap=1)	
Oct 14	Q-learning coding tutorial; neural networks; synthetic time series augmentation	Lecture 8 Notes (https://bcourses.berkeley.edu/courses/1518016/files/84399805?wrap=1) Neural Networks (https://bcourses.berkeley.edu/courses/1518016/files/84399825?wrap=1) qlearning_frog_updated.ipynb (https://bcourses.berkeley.edu/courses/1518016/files/84411729?wrap=1) (https://bcourses.berkeley.edu/courses/1518016/files/84411729/download?download_frd=1)	Homework 2 due

		Elizabeth Fons et al. Evaluating data augmentation for financial time series classification. (https://arxiv.org/abs/2010.15111)	
Oct 21	Generative adversarial networks. GANs for market simulation.	Lecture 9 Notes (https://bcourses.berkeley.edu/courses/1518016/files/84470413?wrap=1) (https://bcourses.berkeley.edu/courses/1518016/files/84470413/download?download_frd=1) Goodfellow et. al. Generative Adversarial Networks. (https://arxiv.org/abs/1406.2661) A. Coletta et. al. Learning to simulate realistic limit order book markets from data as a World Agent. (https://arxiv.org/abs/2210.09897)	
Oct 28	Topics in machine learning for markets.	P. Liu et al. Biased or Limited: Modeling Sub-Rational Human Investors in Financial Markets. (https://arxiv.org/abs/2210.08569) Y. El-Laham, S. Vyetrenko. StyleTime: Style Transfer for Synthetic Time Series Generation. (https://arxiv.org/abs/2209.11306) E. Fons et al. HyperTime: Implicit Neural Representation for Time Series. (https://arxiv.org/abs/2208.05836)	
Nov 4	Seminar to discuss potential Capstone projects, please submit your ideas by Nov 2.	Capstone seminar class notes (https://bcourses.berkeley.edu/courses/1518016/files/84608747?wrap=1)	
Nov 11	Veteran's Day		No class
Nov 18	Guest Lecture - speaker(s) and talk title to be announced		Homework 3 due
Nov 25	Thanksgiving Break		No class
Dec	Capstone		Capstone

2	project proposal presentations		project proposals due
Dec 9	Review session for the final exam - on student request		
Dec 16	Final Exam		