Seminar course: **Algorithms with Predictions**
Course number: **COMPSCI 692K**
Organizer: **Mohammad Hajiesmaili**

Note that the syllabus is tentative and subject to change.

Seminar Description:
This seminar course will cover the recent topics in the emerging field of *Algorithms with predictions*, also known as learning-augmented algorithms or algorithms with ML advice.

This is an emerging topic at the intersection of theoretical computer science and machine learning. Here are some foundational questions that the research aims to answer:

- How to parameterize algorithms so that they can adapt their behavior to the properties of the input distribution and consequently improve their practical performance while still satisfying the theoretical worst-case guarantees.
- How to use imperfect (untrusted) predictions robustly – retaining worst-case guarantees of classic algorithms – yet achieve satisfactory performance when the predictions are accurate?
- How to determine the right time to use advice for online problems when it comes with an additional cost?

Generally speaking, a result in this area takes a problem with strong information-theoretic lower bounds (for instance, on the competitive ratio), identifies a compact prediction that can be learned from real data, and proves the performance of the algorithm to the quality of the underlying prediction. The field has blossomed with applications to a broad range of classic domains in theoretical computer science, such as classical streaming algorithms, online scheduling, clustering, filtering data structures, and many others. The focus of this seminar, however, will be on online algorithms with predictions.

This seminar is inspired by the following recent workshops/seminars:

- Workshop on Algorithms with Predictions, at EPFL, 2022
- Workshop on Algorithms with Predictions, STOC, 2022
- Machine Learning for Algorithms, FODSI, 2021
- Workshop on Algorithms with Predictions, STOC 2020
- Reading Group on Learning Augmented Algorithms, at CWI, 2022
- Data-driven Decision Processes, Simon Institute, Fall 2022

Time: Fall 2022: Tue (11:30-12:45) Fri 1-2:15 pm ET
Location: ~~Hasbrouck Laboratory room 228~~ -> **LGRC A311**, Zoom: https://umass-amherst.zoom.us/j/94052012757
How the seminar is organized:

- Tue slots will be devoted to an introduction and background on the core topic, mainly presented by a subset of students. We have reserved Thu 11:30-12:45 pm ET just in case the background needs more time.
- Fri slots will be dedicated to the prediction version of the topic of the week. We will have invited speakers for Friday slots, and participation in the Friday session is expected.

Tentative Topics:
The topic of weeks 1-8 is mainly focused on online algorithms with ML advice. The topics of weeks 9-13 are other broader approaches for integrating machine learning into algorithm design.

Week	Topic	Invited speaker	Main resource	Presenter	Scribe	Zoom recordings
1. Sep 9	Caching with advice	Thodoris Lykouris, MIT	Competitive caching with machine-learned advice, ICML'18, JACM'21	Rajarshi Bhattacharjee		September 6, 2022 September 9, 2022 (talk, slides)
2. Sep 16	K-server, MTS, algorithms with switching costs	Antonios Antoniadis, The University of Twente (meetings)	Online Metric Algorithms with Untrusted Predictions, ICML'20	Russell Lee		Sep 13, 2022 September 16, 2022 (slides, talk)
3. Sep 23	Ski-rental and job scheduling with advice	Ravi Kumar, Google (meetings)	Improving Online Algorithms via ML Predictions, NeurIPS'18	Ali Zeynali		Sep 20, 2022 September 19, 2022 (slides, talk)
4. Sep 30	The primal-dual method for online algorithms with ML advice	Andreas Maggiori, EPFL (meetings)	The Primal-Dual method for Learning Augmented Algorithms, NeurIPS'20	Rik Sengupta		September 27, 2022 September 30, 2022 (slides, talk)
5. Oct 7	Online search with advice	Bo Sun, CUHK	Pareto-optimal algorithms for online conversion problems, NeurIPS'21	Cuong Than		Oct 4, 2022 (part 1, part 2) October 7, 2022 (slides, talk)
6. Oct 14	Bin packing with advice	Shahin Kamali, York University	Online Computation with Untrusted Advice, ITCS'20, IJCAI'22	An La		October 9, 2022 October 14, 2022 (slides, talk)
7. Oct 21	Chasing Convex Bodies and Functions with Black-Box Advice	Nico Christianson, Caltech	Chasing Convex Bodies and Functions with Black-Box Advice, COLT'22	Kevin Chen and Adam Lechowicz		October 18, 2022 October 21, 2022 (slides, talk)

8. Oct 28	Linear quadratic control with advice	Tongxin Li, Caltech, CUHK	Robustness and Consistency in LQR with Predictions, Sigmetrics'22	Janice Chen		October 25, 2022 October 28, 2022 (slides, talk)
9. Nov 4	Data-driven algorithms	Ellen Vitercik, Stanford	Dispersion for Data-Driven Algorithm Design, FOCS'18, STOC'21	Will Schwarzer		November 1, 2022 November 4, 2022 (slides, talk)
10. Nov 9 (Wed)	DLS: Algorithm Analysis Beyond the Worst-Case	Anupam Gupta, CMU (DLS)	Learning from a Sample in Online Algorithms NeurIPS'22	Akhil Ayyanki		November 8, 2022 November 9, 2022 (slides, talk)
11. Nov 18	Online learning with hints	Ashok Cutkosky, Boston University (in-person)	Online Learning with Imperfect Hints, ICML'20	Cooper Sigrist		November 15, 2022 November 18, 2022 (slides, talk)
Nov 25	No class - Thanksgiving					
12. Dec 2	Learning-augmented mechanism design	Eric Balkanski Columbia (remote)	Learning-Augmented Mechanism Design, EC'22	Amirmahdi Mirfakhar and Kyle Doney		November 29, 2022 December 2, 2022 (slides, talk)
13. Dec 8 (Thu)	Online algorithms with multiple advice	Debmalya Panigrahi, Duke (in-person)	Online Algorithms with Multiple Predictions, ICML'22	Weronika Nguyen		December 6, 2022 December 8, 2022 (slides, talk)

Grading Policy:

1 credit:

- Class participation (20%: 10% Tue slot with student presentations; 10% Fri slot with invited speaker presentation, and meet the speaker)
- Class presentation (60%: either class presentation or scribing the lecture note)
- Lecture review (20%; 4 out of 13 is required, 5% each)

3 credit:

- Class participation (20%: 5% Tue slot with student presentations; 5% Fri slot with invited speaker presentation, and meet the speaker)
- Class presentation (30%: either class presentation or scribing the lecture notes)
- Lecture review (20%; 5 out of 13 is required)
- Class project: 30% (either individually or in a group of two)

Deadlines:

- **Class presentation**

    - Preparation for the in-class lecture: one week before the presentation (Thu, 3-4 pm ET, LGRC A323)
    - Scribe notes: two weeks after the presentation (Tue, 11:59 pm ET)
- **Lecture review**
    - One week after the seminar talk (Fri, 11:59 pm ET)
- **Project (3 credits)**
    - **Proposal deadline:** Oct 28, 2022
    - **Final project deadline**: December 16, 2022

A description of the class project (3 credits)

- The project is a research-based project. The topic selection is flexible. The only requirement is to show how "prediction" can improve the performance of an algorithm provably. If you are a Ph.D. student, a topic closely related to your current research focus is preferred. We can brainstorm for the selection of the project.
- Almost all the invited speakers are available for individual meetings, which might give you some ideas for a promising project and even collaborate with them.
- Final deliverable is a technical report, which may or may not lead to a publication.

Class website: piazza.com/umass/fall2022/compsci692k

Prerequisites: There are no undergraduate prerequisites for this seminar course. This is a theoretical seminar course emphasizing algorithm design, correctness proofs, and analysis. And a general background in algorithms and a strong mathematical background are required.

Accommodation Statement: The University of Massachusetts Amherst is committed to providing equal educational opportunities for all students. If you have a documented physical, psychological, or learning disability on file with Disability Services (DS), you may be eligible for reasonable academic accommodations to help you succeed in this course. If you have a documented disability that requires accommodation, please notify me within the first two weeks of the semester so we can make appropriate arrangements. For further information, please visit Disability Services (https://www.umass.edu/disability/)

Academic Honesty Statement: Since the integrity of the academic enterprise of any institution of higher education requires honesty in scholarship and research, academic honesty is required of all students at the University of Massachusetts Amherst. Academic dishonesty is prohibited in all programs of the University. Academic dishonesty includes but is not limited to: cheating, fabrication, plagiarism, and facilitating dishonesty. Appropriate sanctions may be imposed on any student who has committed an act of academic dishonesty. Instructors should take reasonable steps to address academic misconduct. Any person who has reason to believe that a student has committed academic dishonesty should bring such information to the attention of the appropriate course instructor as soon as possible. Instances of academic dishonesty not related to a specific course should be brought to the attention of the appropriate department Head or Chair. Since students are expected to be familiar with this policy and the commonly

accepted standards of academic integrity, ignorance of such standards is not normally sufficient evidence of lack of intent (http://www.umass.edu/dean_students/codeofconduct/acadhonesty/).