CS 4501 Introduction to Algorithmic Economics
Spring 2022

1 Basic Information

Pandemic Related Information:

- First, all lectures will be in person. Physical participation of the class is strongly encouraged though not mandatory. Additionally, the course is also live-streamed via zoom and the recorded videos will be uploaded to Teams afterwards.
- To minimize contact, all office hour are set to be virtual on zoom, but in person office hours are available by request. The course calendar on Microsoft Teams for OH and all zoom links.

Lecture: Mon/Wed, 2:00 pm to 3:15 pm, Olsson Hall 011.

Instructor 1: Denis Nekipelov (from Econ)

- **Email**: dn4w AT virginia.edu
- **Office** : Monroe Hall, Room 254
- **Office hours**: Mon 12:00 pm - 1:00 pm

Instructor 2: Haifeng Xu (from CS)

- **Email**: hx4ad AT virginia.edu
- **Office** : Rice Hall 522
- **Office hours**: Thur 4:00 am - 5:00 pm

TAs:

- Shuze Liu, Email: sl5nw AT virginia.edu; Office Hour: Tue 10 - 11 am.
- Zirou Qiu, Email: zq5au AT virginia.edu; Office Hour: Thur 2 - 3 pm.
- Kyeongtak Do, Email: kd5tt AT virginia.edu; Office Hour: Kyeongtak is assigned as a grader, so does not have responsibility for hosting office hours, but feel free to email him if you may have any econometrics-related questions.

Course Material: This is a complete new course, so no official textbooks. The contents are entirely written by the instructors. Some references include the linked papers/notes from slides.

Prerequistes: This course has substantial elements of discrete math and probabilities (and additionally, coding for CS students). Formally,

- For CS students: require CS 2120 and CS 2150

- For Econ students: require Econ 3010 and Econ 3720

Please review basic probability and mathematics on your own if it is not fresh in your head.

Communication: We will pretty much only use Microsoft Teams, which has almost all functionalities needed — schedule zoom meetings, discussions, posting messages, start separate/private channels with your group members, etc.

As a UVA student, you should have be able to access all functionalities of Teams for free, using your UVA email account.

2 Overview

Welcome! This is an undergraduate topic course covering basics of **economic and algorithmic theory for decision making**. Today, algorithms (or AI) are increasingly used in many economic applications to assist decision making, and the examples are ubiquitous: pricing mechanisms designed by Amazon sellers, recommendation algorithms by Yelp, routing algorithms to optimize your driving routes, etc. Underlying all these applications is the increasingly common of phenomenon of using algorithms to assist or interact with acts of agents with economic incentives. This prominent trend gives rise to the current new course.

The central theme of this brand new course is to study rational decisions from both economic and algorithmic perspective and, more importantly, try to understand how they interact with each other to lead to more realistic decision making. Therefore, the evaluation of the course will primarily be testing how you can use the learned knowledge to solve real problems. The course has three major parts.

Three Main Parts and Corresponding Topics

- Part 1: Single-Agent Decision Making
  - (week 1-2) Preferences, utilities, and information; Economic behavior with private information; Bayesian updating and Bayesian learning
  - (week 3-4) Introduction to machine learning, and PAC learnability; Convex learning problems and gradient methods
- Part 2: Multi-Agent Decision Making in Single-Shot Interactions
  - (week 5-6) Online learning; The concept of regret; Online learning under full information feedback and *bandit* information feedback;
  - (week 7-8) Stability of environments with online learning agents; Nash equilibrium and Correlated equilibrium; Learning algorithms and implementation of an equilibrium;
- Part 3: Multi-Agent Decision Making in Sequential Dynamic Environments
  - (week 9-10) System with long-run feedback; Dynamic optimization and dynamic Markov games with incomplete information;

- (week 11-12) Reinforcement learning; Model-based and model-free algorithms for reinforcement learning; Reinforcement learning algorithms as strategies in dynamic Markov games.

Note: after removing spring recess, there will be roughly 25 lectures. The remaining two or three lectures are reserved for course project presentations.

3 Course Requirements

The course has 4 projects: 3 mini projects and 1 final project (no exams, but mini projects will contain HW-style exercise and an open-ended problem solving task):

- **3 Mini Projects**: each corresponds to one part in the above course topics (20% each)
  - Team up: 2 – 3 people per team; must have **at least one CS and one Econ student (a minor in CS or Econ also counts)**
  - Unless rare special cases, the team must remain the same during all these three projects
- **The Final Project**: fully open-ended so long as being related to the course
  - Team up: 2 – 5 people per team; again, must have **at least one CS and one Econ student**
  - Can form a different team for this final (bigger) project (grading will factor the number of team members into account)
  - Evaluated by a project presentation and the final paper writeup.
  - More instructions will come after 3 weeks when Part I almost completes.

We would like to specially note that the course evaluation is designed to be open-ended.

Note: All group members will receive the *same score* for a project. Thus it is your responsibility to find collaborative partners to work together on the project. In the past, we have received complaints about some group members not doing the work. You should try to **figure out this as early as possible and, if necessary, re-form the group**. For such situations, we cannot do much from our side unfortunately, especially when it comes close to the end of the deadline.

4 Covid Policies FAQ

While it is really exciting to be in person, we also know that this is a quite uncertain period and will try our best to create a good learning experience for everyone. This certainly requires the effort and cooperation among all of us. Towards this end, we will diligently follow all University regulations in effect at that time. The instructor will be wearing mask while lecturing. We also respecfully ask that, if feasible, you follow some additional safety precautions with regard to COVID-19.

If you're not feeling well, for all our safety and health, we strongly encourage you to watch the virtual lecture (whether you might think it's actually a cold or just seasonal allergies). Certainly, we will ensure that staying home does not impact your grade compared to being in person, so that you can take the time you need to get better, quarantine, or isolate.

Q: I am worried about the virus: will I know if there is an unvaccinated students in the class?

The University announced that all students who live, learn, or work in person at the University during the next academic year must be fully vaccinated with booster shot before returning to Grounds unless they have obtained a medical or religious exemption from the University. Therefore, you can expect that most students (if not all) in your class are vaccinated. A very small number of students have received vaccination exemptions, so the likelihood that an unvaccinated student is in your class is slight. Note that you may not ask a student if they have been vaccinated as that is private health information.

Q: Do I have to wear a mask?

We encourage so. Our class will diligently follow all University regulations in effect at that time. If masks are required during a certain period, then they are absolutely required for class. If policy has changed, then we will adjust accordingly. Failure to mask if a regulation is in effect will result in reporting to UJC and a professionalism penalty for the class.

Note that some members of the staff and class will continue to mask for the entire semester. They also may request that you remain distant (or wear a mask as a courtesy) as well. Please be kind to each other!

Q: How will you accommodate a student who needs to isolate/quarantine?

If a student informs us that they cannot attend class in-person because they have been requested to isolate or quarantine due to possible exposure to COVID-19, we will treat you as we would any other student absent due to illness. You will have access to the recordings of the lecture, either synchronously or asynchronously. You can also continue to interact with your partner and access other online tools.

Q: Can I just not come to the classroom and just watch the lecture over Zoom or watch the recordings?

This is allowed, but we strongly encourage you to attend lectures in person if possible. Based on our previous experience and surveys, attending physical lectures is much more efficient and significantly helps you to engage in the class and with your fellow peers, especially that the materials we cover are new and may not be easily found anywhere else.

5 Other Related Statements

Diversity and Inclusion In an ideal world, science would be objective. However, much of science is subjective and is historically built on a small subset of privileged voices. We acknowledge that it is possible that there may be both overt and covert biases in the material due to the lens with which it was written, even though the material is primarily of a scientific nature. Since integrating a diverse set of experiences is important for a more comprehensive understanding of science please contact the course staff (in person or electronically) or submit anonymous feedback if you have any suggestions to improve the quality of the course materials.

We would like to create a learning environment that supports diversity of thoughts, perspectives, and experiences, and honors your identities. If you have a name and/or set of pronouns that

differ from those that appear in your official records, please let us know! If you feel like your performance in the class is being impacted by your experiences outside of class, please don't hesitate to contact us.

Honor code (Adapted from Honor Syllabus Example Statement of UVa) I trust every student in this course to fully comply with all of the provisions of the University's Honor Code. By enrolling in this course, you have agreed to abide by and uphold the Honor System of the University of Virginia, as well as the policies specific to this course. All suspected violations will be forwarded to the Honor Committee, and you may, at my discretion, receive an immediate zero on that assignment regardless of any action taken by the Honor Committee.

Please let me know if you have any questions regarding the course honor policy. If you believe you may have committed an Honor Offense, you may wish to file a Conscientious Retraction by calling the Honor Offices at (434) 924-7602. For your retraction to be considered valid, it must, among other things, be filed with the Honor Committee before you are aware that the act in question has come under suspicion by anyone. More information can be found at here.

Students with disabilities or learning needs We thrive to create a learning experience that is as accessible as possible. If you anticipate any issues related to the format, materials, or requirements of this course, please meet with me outside of class so we can explore potential options. Students with disabilities may also wish to work with the Student Disability Access Center to discuss a range of options to removing barriers in this course, including official accommodations. Please visit their website for information on this process and to apply for services online: sdac.studenthealth.virginia.edu. If you have already been approved for accommodations through SDAC, please send me your accommodation letter and meet with me so we can develop an implementation plan together.

Discrimination and power-based violence The University of Virginia is dedicated to providing a safe and equitable learning environment for all students. To that end, it is vital that you know two values that I and the University hold as critically important:

- Power-based personal violence will not be tolerated.
- Everyone has a responsibility to do their part to maintain a safe community on Grounds.

If you or someone you know has been affected by power-based personal violence, more information can be found on the UVA Sexual Violence website that describes reporting options and resources available - https://eocr.virginia.edu/

As your professor and as a human, I care about you and your well-being and stand ready to provide support and resources as I can. As a faculty member, I am required by University policy and federal law to report what you tell me to the University's Title IX Coordinator. The Title IX Coordinator's job is to ensure that the reporting student receives the resources and support that they need, while also reviewing the information presented to determine whether further action is necessary to ensure survivor safety and the safety of the University community. If you wish to report something that you have seen, you can do so at the Just Report It portal. The worst possible situation would be for you or your friend to remain silent when there are so many here willing and able to help.

Religious accommodations It is the University's long-standing policy and practice to reasonably accommodate students so that they do not experience an adverse academic consequence when sincerely held religious beliefs or observances conflict with academic requirements.

Students who wish to request academic accommodation for a religious observance should submit their request in writing directly to me via Email as far in advance as possible. Students who have questions or concerns about academic accommodations for religious observance or religious beliefs may contact the University's Office for Equal Opportunity and Civil Rights (EOCR) at UVAEOCR@virginia.edu or 434-924-3200.