THE UNIVERSITY OF TEXAS AT AUSTIN

ASE 389: Modeling Multi-Agent Systems

Syllabus, Fall 2021 (Prepared: August 16, 2021)

Administrative

Unique course number: 14500
Instructor: David Fridovich-Keil
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Classroom: ETC 2.102
Class time: MWF 11am - 12pm
Office hours: ASE 3.232 (TBA or by appointment)

Course description

In recent years, autonomous systems have become more and more integrated with society, from the gig economy to smart grids to autonomous cars. This course will introduce the mathematics which characterize groups of agents interacting rationally over time: dynamic game theory. While the tools we develop are generally applicable, we will use self-driving vehicles as an ongoing case study, where we shall see the importance of game-theoretic ideas as well as some of their shortcomings. Instruction will follow three related themes: (1) dynamic game theory for motion planning, (2) numerical optimization techniques pertaining to multi-agent problems, and (3) special topics in decentralized control. There will be a small number of hands-on programming assignments in the first two-thirds of the course, followed by a group project in which teams are encouraged to find new and interesting applications of course material in physical robotic scenarios.

Course objectives

This course is intended for graduate students with a strong interest in control theory and multi-agent robotic systems. Overall, the course aims to:

- introduce students to game-theoretic models of multi-agent interaction
- build both mathematical and programming expertise
- probe various robotic applications of game-theoretic planning

- expose students to recent advances in the literature of game-theoretic control and robotics

Prerequisites

There are *no strict prerequisites* for this class. However, successful students should be fluent in linear algebra and vector calculus. Students are also expected to be familiar with programming in a high-level language such as MATLAB, Python, or Julia. No background in game theory or optimization is assumed.

If you have any questions about these expectations, please do not hesitate to consult the instructor. Undergraduates must obtain the instructor's explicit approval before enrollment.

Grading

Grades will be computed according to these proportions:

- Final project: 50%
- Programming assignments: 30%
- Paper reviews and presentations: 10%
- Participation: 10%

Note that part of the participation grade will be based upon scribing lecture notes. See below.

Assignments

This course will have four types of assignments in addition to a final project. There will be no exam.

1. *Programming assignments:* There will be ~5 hands-on programming assignments which will give students hands-on experience in game theory and optimization. Assignments will use the language Julia and be distributed and graded using GitHub.
2. *Paper reviews:* Students will be asked to read and write mock reviews (as for a conference or journal) for several papers throughout the course.
3. *Paper presentations:* Students will present at least one paper to the class during the semester.
4. *Scribe notes:* Students will transcribe their notes from lecture into LaTeX several times throughout the semester. As lectures are transcribed and edited, the typeset notes will be made available.

The final project will consist of four components: (1) brief written/oral proposal, (2) brief mid-way update, (3) final presentation, and (4) final writeup. The final writeup will be in the form of a website.

Late policy

Programming/written assignments may be turned in late, however each late day will result in a 10% penalty and the lowest programming assignment grade will be dropped. Class presentations must occur on schedule, except with the prior permission of the instructor.

Collaboration

Students are encouraged to answer one anothers' questions on course forums, consult online resources and recommended textbooks as needed, and to attend office hours with remaining questions.While collaboration is encouraged, students should complete all programming assignments, paper reviews, and paper presentations on their own.

Attendance

Regular attendance is expected and will be recorded at the beginning of each class. If you need to miss a class, please notify the instructor at least one day in advance. Acceptable reasons to miss class include religious holidays, family emergencies, and health concerns. In particular, if you feel ill, *please do not attend class in person and notify the instructor.*

Schedule

- Week 0: introduction to multi-agent modeling and traffic games
- Week 1: static games
- Week 2: finite dynamic games
- Weeks 3-6: smooth dynamical systems and dynamic games
- End of week 6: project proposals due
- Weeks 7-10: numerical optimization in optimal control and smooth games
- End of week 10: project updates
- Weeks 11-14: special topics in decentralized control
- Week 14-end: project presentations

All programming assignments will be due before week 11 and are intended to provide useful starting points for potential course projects.

Textbooks

We will cover material in both dynamic game theory, control theory more broadly, and nonlinear programming. The course will draw heavily from two texts:

- Dynamic Noncooperative Game Theory, 2nd Edition (Başar and Olsder)

- Numerical Optimization (Nocedal and Wright)

Several other relevant background textbooks are:

- Differential Games: A Mathematical Theory with Applications to Warfare and Pursuit, Control and Optimization (Isaacs)
- Linear System Theory (Callier and Desoer)
- Nonlinear Systems: Analysis, Stability, and Control (Sastry)
- Nonlinear Programming (Bertsekas)
- Dynamic Programming and Optimal Control (Bertsekas)

While *none of these textbooks are required* and all course material will be self-contained, these references are highly recommended. Copies of some of these books may be consulted in office hours.

Class format and COVID

Per the registrar's listing, this course will meet face-to-face. To help preserve our in person learning environment, the university recommends the following:

- **Adhere to university mask guidance.** Masks are strongly recommended indoors regardless of vaccination status.
- **Vaccinations are widely available,** free, and not billed to health insurance. The vaccine will help protect against the transmission of the virus to others and reduce serious symptoms in those who are vaccinated. More information is available here.
- **Proactive Community Testing** remains an important part of the university's efforts to protect our community. Tests are fast and free. More information is available here.
- Updated information and announcements from the university can be found here.

Class recordings

Class recordings are reserved only for students in this class for educational purposes and are protected under FERPA. The recordings should not be shared outside the class in any form. Violation of this restriction by a student could lead to Student Misconduct proceedings. Guidance on public access to class recordings can be found here.