THE UNIVERSITY OF TEXAS AT AUSTIN
Department of Aerospace Engineering and Engineering Mechanics

ASE 389: Game-Theoretic Modeling of Multi-Agent Systems
Fall 2022

SYLLABUS

Unique Number:	14890
Instructor:	David Fridovich-Keil ASE 3.232, dfk@utexas.edu
Time:	MW 11-12:30 CT
Location:	ETC 2.102
Teaching Assistant:	None
Web Page:	Canvas

Catalog 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) static games and complementarity programming, (2) dynamic game theory, and (3) special topics in game theory and multi-agent control. There will be several hands-on programming assignments in the first two-thirds of the course, followed by a group project in which students are encouraged to find new and interesting applications of course material in their own area of research.

Course Objectives:
This course is intended for graduate students with a strong interest in control theory and multi-agent 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 decision making

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.

Knowledge, Skills, and Abilities Students Should Have Before Entering This Course:
Students are expected to be mathematically mature, fluent in linear algebra and vector calculus, and comfortable programming in a high-level language.

Knowledge, Skills, and Abilities Students Gain from this Course (Learning Outcomes):
Students will build a broad background in both static and dynamic game theory, with a focus on connections to mathematical programming and optimal control theory.

Topics:
The course will cover static games (5 lectures), finite dynamic games (3 lectures), smooth dynamic games (8 lectures), and assorted special topics (7 lectures).

Professionalism Topics:
Teamwork, writing, and presentation

Design Assignments:
This course will include a group project, in which teams of 2-3 students explore a topic of their choice in depth. Students are encouraged to find new connections between the course material and their own areas of graduate research.

Computer:
Programming assignments will be completed in the Julia language, which is freely available and compatible with any major consumer-grade hardware and software stack.

Text:
We will cover material in both dynamic game theory, control theory more broadly, and nonlinear programming. While the course material will be largely self-contained, 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)
- Nonlinear Systems: Analysis, Stability, and Control (Sastry)
- Nonlinear Programming (Bertsekas)
- Dynamic Programming and Optimal Control (Bertsekas)

Class Format:
This class is listed as in-person by the registrar. Lectures and office hours will be held face-to-face, health permitting. Lectures will also be simulcast and recorded on Zoom, and will be made accessible on Canvas.

Class Schedule:
A tentative schedule is given in the table below. The content of each lecture and assignment due dates are subject to change. There will be no exams.

Date	Category	Topics	Assignment	Reading
8/22	Introduction			
8/24	Static games	Normal form, equilibrium concepts	Tutorial	BO 2.2, 3.2, 3.3
8/29	Static games	Smooth unconstrained static games		Papers 1 and 2
8/31	Static games	Mixed strategies, constrained static games		BO 2.3, 3.4, NW 12
9/5	HOLIDAY			
9/7	Static games	Complementarity programming		
9/12	Static games	Guest lecture: inverse static games		
9/14	Finite dynamic games	Extensive form, information patterns	Tag	BO 3.4, 3.5
9/19	Finite dynamic games	Tree search		Paper 3
9/21	Finite dynamic games	Perfect equilibria, informational inferiority		BO 3.5.5, 5.6
9/26	Smooth dynamic games	QPs, Minimum principle / HJB for LQR		BO 5.5

9/28	CANCELLED			
10/3	Smooth dynamic games	LQ feedback Nash + Stackelberg	Tic tac toe	BO 6.2.2, 7.3
10/5	Smooth dynamic games	LQ open-loop Nash		BO 6.2.1
10/10	Smooth dynamic games	Equality-constrained SQP, nonlinear open-loop Nash		NW 18.1, 18.2
10/12	Smooth dynamic games	Nonlinear feedback Nash		Paper 4
10/17	Project proposals		Proposal	
10/19	Smooth dynamic games	Inequality constraints in feedback games		NW 16.5
10/24	Smooth dynamic games	Reach-avoid and pursuit-evasion games		Paper 5
10/26	Smooth dynamic games	Continuous-time subtleties	LQ solvers	
10/31	Special topics			
11/2	Special topics		Trajectory games	
11/7	Special topics			
11/9	Special topics			
11/14	Project updates		Update	
11/16	Special topics			
11/21	HOLIDAY			
11/23	HOLIDAY			
11/28	Special topics			
11/30	Final presentations			
12/5	Final presentations			

The final project writeups will be due on 12/9.

Grading:
Grades will be computed according to the following proportions:
- Final project: 50%
- Programming assignments: 40%
- Class presentations: 10%

Grades will be assigned as letter grades with plus/minus modifiers as appropriate.

Homework Policy:
Programming assignments should be completed and submitted independently by each student. Grading is generally automated through GitHub. Assignments turned in late will incur a 10% penalty for each day that they are late. Exceptions may be granted at the instructor's discretion.

Examinations:
N/A

Attendance:
Regular attendance is expected, though not strictly required. In particular, if you feel ill, *please attend class on Zoom.*

Office Hours:
Tentatively, 9-10:45am on Mondays, in ASE 3.232.

Important Dates:
Please refer to the university academic calendar for important administrative dates.

Special Notes:
The University of Texas at Austin provides upon request appropriate academic adjustments for qualified students with disabilities. For more information, contact the Office of the Dean of Students at 471-6259, 471-4641 TDD or the Cockrell School of Engineering Director of Students with Disabilities at 471-4321.

Evaluation:
The Measurement and Evaluation Center forms for the Cockrell School of Engineering will be used during the last week of class to evaluate the course and the instructor. They will be conducted in an electronic format.

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.

Prepared by: David Fridovich-Keil Date: 8/12/2022