EEE 598 AI-based Decision-making in Dynamic Systems

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Office Hours: 8:30 am – 9:30 am Mondays/Wednesdays/Fridays or you can contact me anytime over email!

Lectures: Mondays, Wednesdays, Fridays 10:10 am – 11:00 am, Location: TEMPE SCOB 101

School of Electrical and Computer Engineering / University of New Mexico

Course Description

The course focuses on the intersection of artificial intelligence (AI) and dynamic system modeling, with emphasis on how AI techniques can be leveraged to make optimal decisions in uncertain and evolving environments. It covers essential theoretical frameworks such as non-cooperative game theory, which examines competitive scenarios where independent agents' decisions influence each other, often leading to equilibrium strategies. Prospect theory is explored to provide insights into decision-making under risk and uncertainty, reflecting real-world behaviors that may deviate from rational models, such as risk-aversion or irrational preferences. Additionally, contract theory is introduced to address how optimal incentive structures can be designed in dynamic systems, with applications in scenarios where agreements between different entities, such as cloud service providers and users, are essential for efficient resource allocation. Reinforcement learning serves as a core AI technique within the course, guiding students through the process of optimizing decision-making strategies in complex systems via continuous interaction and feedback from the environment. Through a combination of theory and practical application, the course emphasizes the relevance of these decision-making frameworks to various real-world engineering challenges. In electrical and computer engineering, for instance, these concepts can be applied to optimize resource allocation in communication networks, manage energy in smart grid systems, and improve the performance of autonomous vehicles and robotics. Students will engage with research projects that enable them to apply these theoretical models to dynamic system scenarios. The course provides a comprehensive approach to mastering decision-making in dynamic systems, blending theoretical rigor with practical engineering applications. The audience of this course can be undergraduate and graduate students from any engineering department.

Course Objectives

At the completion of the course, students will be able to

- **Understand and apply** AI techniques such as reinforcement learning and game theory to optimize decision-making in uncertain and dynamic environments.
- **Explore and utilize** decision-making frameworks like prospect theory and contract theory to model real-world behaviors and design optimal incentive structures.
- **Apply** theoretical models to engineering challenges, including resource allocation in communication networks, energy management in smart grids, and autonomous system optimization.

Credits: 3

Prerequisites and Co-requisites

There are no prerequisite requirements for this course.

Textbook and Supplemental Materials

Required Textbooks:

1. *Reinforcement Learning: An Introduction (second edition). R. Sutton and A. Barto. MIT Press, 2018*

2. *Lecture Notes*

Recommended and/or Optional Textbooks:

If you would like to talk more about the recommend and/or optional textbooks for this course, please send me an email or meet with me during office hours.

1. *Algorithms for Reinforcement Learning. C. Szepesvari. Morgan and Claypool Publishers, 2010*
2. *Reinforcement Learning: State-of-the-Art. M. Wiering and M. van Otterlo. Springer, 2012*
3. *Game Theory, by Drew Fudenberg and Jean Tirole, The MIT Press, 1991.*
4. *Prospect theory: For risk and ambiguity, by Petter Wakker, Cambridge University Press. 2010.*
5. *Convex optimization, by Stephen Boyd and Lieven Vandenberghe Cambridge university press, 2004.*
6. *WNP: Wireless Network Pricing, by J. Huang and L. Gao, Morgan Claypool Publishers, 2013.*
7. *Foundations of Modern Networking: SDN, NFV, QoE, IoT, and Cloud, by William Stallings, Pearson, 2016.*

Coursework, Participation, and Grading Procedures

Project (60%): There will be one research project that the students should complete during the semester. Each student should **deliver a report (30%) and a presentation (30%)** based on a selected research journal paper in topics related to the course. The structure of the projects will be announced on Canvas at the beginning of the semester. The project report and presentation should be uploaded to Canvas by the announced deadline. Delayed reports will not be graded, and no grade will be assigned to the specific delayed reports. **Deadline: TBA**

Final Exam (40%): The final exam is open book and lecture notes. No additional material will be used. If a student must miss the exam, and if that student has a written, verifiable, legitimate (health-related issues) excuse for the absence, then the student must contact the instructors prior to the Exam Date and provide necessary written evidence for the absence (evidence for health-related problems may be presented later in consultation with the instructor). The instructors reserve sole discretion in this matter of providing the opportunity for a makeup Exam. This opportunity is available only once during the semester. **Deadline: TBA**

Attendance (0%): Each student is responsible for all of the information (**including announcements and handouts**) presented in class. Traditionally, poor performance in this class has been closely related to poor attendance. Your participation is voluntary. Students are

encouraged to contact the instructors and the teaching assistant during the office hours at instructor's office.

Appropriate curving will be performed based on the performance of the whole class.

This is a 3 credit course, and outside of our regular class meetings, students can expect to complete approximately 5 hours of coursework per week (on readings, assignments, etc.).

Grading Scale

Points (%)	Grade	Points (%)	Grade	Points (%)	Grade
[98,100]	A+	[80,83)	B-	[63,68)	D
[93,98)	A	[78,80)	C+	[60,63)	D-
[90,93)	A-	[73,78)	C	[0,60)	F
[88,90)	B+	[70,73)	C-		
[83,88)	B	[68,70)	D+		

Permitted Collaboration

The following items are encouraged and allowed at all times for all students in this class:

- Discussion of material covered during lecture or in handouts
- Discussion of the requirements of an assignment
- Discussion of the use of tools
- Discussion of general approaches to solving problems
- Discussion between a student and the instructor for the course

Unpermitted Collaboration

All submissions must represent original, independent work. Some examples of activities that do not represent original work include:

- Copying solutions from others. In particular, do not ask anyone to provide a copy of his or her solution or, conversely, give a solution to another student who requests it.
- Studying another student's solution. Do not read another solution submission whether in electronic or printed form, even to "check answers."

Course Schedule

Revisit the course schedule during the semester as timing changes will be made on the fly based on your performance.

Class Modules	Tentative Topics
Module 1	• Reinforcement Learning • Examples • Elements of Reinforcement Learning • Limitations and Scope • An Extended Example: Tic-Tac-Toe • Summary • Early History of Reinforcement Learning
Module 2	• Multi-armed bandits • Action-value methods • Tracking a non-stationary problem • Optimistic Initial Values
Module 3	• Upper-confidence-bound action selection • Gradient bandit algorithms • Contextual bandits
Module 4	• Finite Markov Decision Processes (MDP) • Agent-environment interface • Goals and rewards • Returns and Episodes
Module 5	• Unified notation for episodic and continuing tasks • Policies and value functions • Optimal policies and optimal value functions • Optimality and approximation
Module 6	• Dynamic programming • Policy evaluation • Policy improvement • Policy iteration
Module 7	• Value iteration • Asynchronous dynamic programming • Generalized policy iteration • Efficiency of dynamic programming
Module 8	• Monte Carlo methods • Monte Carlo prediction • Monte Carlo estimation of action values • Monte Carlo control
Module 9	• Off-policy prediction via importance sampling • Incremental implementation • Off-policy Monte Carlo control • Discounting-aware Importance Sampling • Per-decision Importance Sampling
Module 10	• Contract Design Adverse Selection • Contract Design Moral Hazard • Contract Theory vs Other Theories • Application Examples of Contract Theory
Module 11	• Application Examples of Contract Theory • Incentives towards multi layer delay tolerant computing • Computing resource trading in collaborative Mobile Edge Computing networks

Module 12	• What is Game Theory? • Basic Concepts of Game Theory • Distributed Resource Management • Nash Equilibrium • Satisfaction Equilibria
Module 13	• Efficient Satisfaction Equilibrium • Optimal Efficient Satisfaction Equilibrium • Optimal Satisfaction Equilibrium (OSE) • Common Pool Resource (CPR) games • The Tragedy of the Commons
Module 14	• The Standard CPR Game • Prospect Theory: Risk Aware Resource Management • A Fragile CPR Game • An Application in Computing Networks
Module 15	• Oligopoly • Cournot model • Bertrand model • Hotelling model
Module 16	Questions & Answers – Final Exam

Course Access

Your ASU courses can be accessed by both my.asu.edu (http://my.asu.edu) and myasucourses.asu.edu (http://myasucourses.asu.edu); bookmark both in the event that one site is down.

Communicating With the Instructor

Email

ASU email is an official means of communication (http://www.asu.edu/aad/manuals/ssm/ssm107-03.html) among students, faculty, and staff. Students are expected to read and act upon email in a timely fashion. Students bear the responsibility of missed messages and should check their ASU-assigned email regularly.

Absence policies

Excused absences for classes will be given without penalty to the grade in the case of (1) a university-sanctioned event [ACD 304-02]; (2) religious holidays [ACD 304-04]; a list of religious holidays can be found here https://eoss.asu.edu/cora/holidays]; (3) work performed in the line-of-duty according [SSM 201-18]. Students who request an excused absences must follow the policy/procedure guidelines. Excused absences do not relieve students of responsibility for any part of the course work required during the period of absence.

Recording Lectures

Note that class sessions may be recorded, and recordings provided to enrolled students, instructors or instructional support personnel. If you have concerns about being recorded, please contact the course instructor.

Recordings may be used to accommodate student absences. Recordings of all class sessions will be posted in Canvas for all students to access for reviewing course materials.

Policy regarding expected student behavior

Students in this class are expected to acknowledge and embrace the FSE student professionalism expectation located at: https://engineering.asu.edu/professionalism/

Generative AI

Generative AI is a technology that can often be useful in helping students learn the theories and concepts in this course. The use of generative AI tools to complete any portion of a course assignment or exam will be considered academic dishonesty and a violation of the ASU Academic Integrity Policy. Students confirmed to be engaging in non-allowable use of generative AI will be sanctioned according to the academic integrity policy and FSE sanctioning guidelines.

Academic Integrity

All engineering students are expected to adhere to the ASU Student Honor Code and the ASU academic integrity policy, which can be found at https://provost.asu.edu/academic-integrity/policy). Students are responsible for reviewing this policy and understanding each of the areas in which academic dishonesty can occur. If you have taken this course before, you may not reuse or submit any part of your previous assignments without the express written permission from the instructor. All student academic integrity violations are reported to the Fulton Schools of Engineering Academic Integrity Office (AIO). Withdrawing from this course will not absolve you of responsibility for an academic integrity violation and any sanctions that are applied. The AIO maintains a record of all violations and has access to academic integrity violations committed in all other ASU college/schools.

Student Copyright Responsibilities

You must refrain from uploading to this course shell, discussion board, website used by the course instructor or any other course forum, material that is not your own original work, unless you first comply with all applicable copyright laws. Course instructors reserve the right to delete materials from the course shell on the grounds of suspected copyright infringement.

The contents of this course, including lectures and other instructional materials, are copyrighted materials. Students may not share outside the class, including uploading, selling or distributing course content or notes taken during the conduct of the course. Any recording of class sessions is authorized only for the use of students enrolled in this course during their enrollment in this course. Recordings and excerpts of recordings may not be distributed to others. (see ACD 304–06, "Commercial Note Taking Services" and ABOR Policy 5-308 F.14 for more information).

Policy against threatening behavior, per the Student Services Manual, SSM 104–02

Students, faculty, staff, and other individuals do not have an unqualified right of access to university grounds, property, or services (see SSM 104-02). Interfering with the peaceful conduct of university-related business or activities or remaining on campus grounds after a request to

leave may be considered a crime. All incidents and allegations of violent or threatening conduct by an ASU student (whether on- or off-campus) must be reported to the ASU Police Department (ASU PD) and the Office of the Dean of Students.

Disability Accommodations

Suitable accommodations are made for students having disabilities. Students needing accommodation must register with the ASU Student Accessibility and Inclusive Learning Services office and provide documentation of that registration to the instructor. Students should communicate the need for an accommodation in enough time for it to be properly arranged. See ACD 304-08 Classroom and Testing Accommodations for Students with Disabilities.

Harassment and Sexual Discrimination

Arizona State University is committed to providing an environment free of discrimination, harassment, or retaliation for the entire university community, including all students, faculty members, staff employees, and guests. ASU expressly prohibits discrimination, harassment, and retaliation by employees, students, contractors, or agents of the university based on any protected status: race, color, religion, sex, national origin, age, disability, veteran status, sexual orientation, gender identity, and genetic information.

Title IX is a federal law that provides that no person be excluded on the basis of sex from participation in, be denied benefits of, or be subjected to discrimination under any education program or activity. Both Title IX and university policy make clear that sexual violence and harassment based on sex is prohibited. An individual who believes they have been subjected to sexual violence or harassed on the basis of sex can seek support, including counseling and academic support, from the university. If you or someone you know has been harassed on the basis of sex or sexually assaulted, you can find information and resources at https://sexualviolenceprevention.asu.edu/faqs.

As a mandated reporter, I am obligated to report any information I become aware of regarding alleged acts of sexual discrimination, including sexual violence and dating violence. ASU Counseling Services, https://eoss.asu.edu/counseling is available if you wish to discuss any concerns confidentially and privately. ASU online students may access 360 Life Services, https://goto.asuonline.asu.edu/success/online-resources.html.

Photo requirement

Arizona State University requires each enrolled student and university employee to have on file with ASU a current photo that meets ASU's requirements (your "Photo"). ASU uses your Photo to identify you, as necessary, to provide you educational and related services as an enrolled student at ASU. If you do not have an acceptable Photo on file with ASU, or if you do not consent to the use of your photo, access to ASU resources, including access to course material or grades (online or in person) may be negatively affected, withheld or denied.

Syllabus Disclaimer

The syllabus is a statement of intent and serves as an implicit agreement between the instructor and the student. Every effort will be made to avoid changing the course schedule but the possibility exists that unforeseen events will make syllabus changes necessary. Remember to check your ASU email and the course site often.