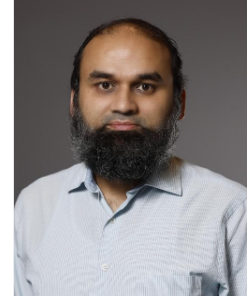




## MECHENG 7194: ADVANCED LEARNING BASED CONTROLS

**INSTRUCTOR: Dr. Qadeer Ahmed** ([ahmed.358@osu.edu](mailto:ahmed.358@osu.edu))

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Department of Mechanical and Aerospace Engineering  
Department of Electrical and Computer Engineering  
Department of Integrated Systems Engineering  
Affiliated Faculty: Center for Automotive Research, Smart Vehicle Concepts Center,  
Sustainability Institute and Institute of Cybersecurity and Digital Trust.



OFFICE HOURS (In person): TBD

### COURSE DESCRIPTION

This advanced course bridges control theory and machine learning, focusing on model-free, model-based, offline vs online, transformer-based, MPC-integrated, and meta-reinforcement learning (RL). It includes the concept of ISO/PAS 8800 to ensure the safety of learning-based control solutions. The course also includes RL for cost function learning, controller gain tuning, and safe MPC. It covers advanced neural architectures like liquid neural networks (LNNs), graph models (Graph NN, Graph attention network (GAT)), Foundation models and World models. Generative Adversarial Networks (GANs) and its advanced variants, physics-informed techniques, and Koopman operator are used for system identification. Control theories such as contraction theory and region of attraction (ROA) are also covered that ensure NN stability or safety. Explainability, Interpretability, and Trustworthiness of black-box ML/RL models is also considered for dynamical systems and controls. Through theory and project-based learning, students solve real-world problems, enhancing adaptability in autonomous systems.

#### Course Objectives:

1. Develop the motivation for bridging the gap between conventional control theory and learning techniques.
2. Understand the concept of ISO/PAS 8800 to ensure the safety of learning-based control solutions.
3. Understand and apply advanced RL methods, including model-free and model-based, online versus offline, policy vs knowledge distillation, Transformer-based, MPC-integrated, and meta-RL. (e.g. TD3, DDPG, SAC, PPO, TADPO ...)
4. Explore RL for learning cost functions and constraints in MPC, gain tuning for controllers (PID, LQR), and safe RL with MPC.
5. Explore and implement advanced neural architectures including Spiking NN (SNN), Liquid NN (LNNs), graph NNs (GNNs), etc. for control tasks.
6. Develop the understanding of Foundation models and World models including Artificial General intelligence (AGI) for dynamical system and controls.
7. Utilize GANs, physics-informed methods, and Koopman operator for accurate system identification and dynamics modeling.
8. Apply control theories like contraction theory and region of attraction (ROA) to ensure stability, robustness, or safety in learning-based systems.



9. Develop the learning-based controller and perform its stability analysis using quadratic constraints and ROA.
10. Develop understanding of Explainability, Interpretability, and Trustworthiness of black-box ML/RL models used for dynamical systems and controls.
11. Emerging topics in Learning-based controls.
12. Enhance programming and mathematical analysis skills.

## PREREQUISITES

- ECE5551, ME5372, ECE 5307, ME5775
- ME 6xxx course on LBC
- Graduate standing or instructor permission.
- Intermediate knowledge of Matlab/Simulink is required. The course will use Matlab/Python to build and run models, with more advanced tools explained in class.

## COURSE FORMAT

- **Mode of Delivery:** 100% in-person.
- **Lecture Schedule:** Tu/Th 09:35am – 10:55am (Caldwell Lab 119)

## CREDIT HOURS AND WORK EXPECTATIONS

- **Credit Hours:** 3
- **Direct instruction:** ~5 hours/week
- **Outside work:** ~10 hours/week (homework, project assignments, review lecture material)

## ATTENDANCE AND PARTICIPATION REQUIREMENTS

- **Engagement:** Consistent engagement is expected. Participation in class discussions, group work, and sharing experiences is encouraged.
- **Missed Lectures:** Review missed material before the next lecture. Obtain notes from classmates and attend office hours if needed. If you require further clarification or assistance, please make use of the instructor's office hours.

## TEXTBOOKS/REFERENCES

- Albrecht, Stefano V., Filippos Christianos, and Lukas Schäfer. *Multi-agent reinforcement learning: Foundations and modern approaches*. MIT Press, 2024.
- Sutton, Richard S., and Andrew G. Barto. *Reinforcement learning: An introduction*. MIT press, 2018.
- Bertsekas, Dimitri. *Reinforcement learning and optimal control*. Vol. 1. Athena Scientific, 2019.
- Jiang, Zhong-Ping, Tao Bian, and Weinan Gao. "Learning-based control: A tutorial and some recent results." *Foundations and Trends® in Systems and Control* 8, no. 3 (2020): 176-284.
- Course materials (notes, required readings, software) will be available on Carmen.
- Additional readings (books, technical papers) will be posted on Carmen.

## COURSE TECHNOLOGY

For technical support, contact the Ohio State IT Service Desk:

- **Self-Service and Chat support:** [ocio.osu.edu/help](https://ocio.osu.edu/help)



- **Phone:** 614-688-4357(HELP)
- **Email:** [servicedesk@osu.edu](mailto:servicedesk@osu.edu)

## REQUIRED EQUIPMENT

- **Computer:** Access to a computer in the MAE computer lab or any other computer that can connect to Carmen (<https://carmen.osu.edu/>) for accessing course materials, submitting assignments, and running Matlab for solving assignments. Use Microsoft Office 365 or another editing tool like Overleaf for preparing reports. A personal device is not necessary.
- **Other:** a mobile device (smartphone or tablet) or landline to use for BuckeyePass authentication

## REQUIRED SOFTWARE

- **A text editor for writing reports** (e.g., LaTeX or Microsoft Word). Note that Microsoft Office 365 is free for OSU Students.
- **Matlab R2022a or Higher:** Free for OSU Students <https://osuitsm.service-now.com/selfservice/>.

## CARMEN ACCESS

You will need to use [BuckeyePass](#) multi-factor authentication to access your courses in Carmen.

## GRADING POLICY:

### HOMEWORK ASSIGNMENTS (50% OF FINAL GRADE):

1. **Project Assignments:** There will be three or four project assignments that will constitute 30% of the grade including literature survey, problem statement, proposed solution, technical depth, and the simulations.
2. **Homework Assignments:** There will be some homework (reading/discussion) assignments as well that will constitute 20% of the grade.
3. **Submission:** Reports should be submitted electronically on CarmenCanvas. MATLAB files should accompany the report.
4. **Late Submission:** Not permitted without documented medical reasons or family emergencies. Extensions require 48-hour notice. Reports not submitted by the due date will result in a grade of 0 for that assignment.
5. **Preparation:** Individual reports must be typed and submitted in .pdf format; handwritten parts will NOT be graded.

### FINAL PROJECT (50% OF FINAL GRADE):

**Scope:** The project will apply advanced concepts such as learning-based control design, system identification, uncertainty modeling using ML, advanced neural networks including liquid neural networks (LNNs), and contrastive learning. It may involve model-free, model-based, offline RL, or physics-informed methods. Students will simulate and verify performance, stability, or safety on dynamic systems. Projects must align with course topics and target real-world control applications like robotics, autonomous systems, chemical, manufacturing systems, etc.

#### Submission:

1. **Project Proposal:** An electronic submission of a one-page proposal including motivation, method, expected results, and references (not counted towards any page limit).
2. **Final Report (IEEE format):** The final report will be part of the grade, assessing the problem statement, proposed solution, technical depth, and ability to provide simulations results effectively, including conclusion, and references.

**Grading:** The final grading will be done based on:



1. **Presentation:** The project presentation will be part of the grade, assessing clarity, technical depth, and ability to communicate results effectively.
2. **Final Report (IEEE format):** The final report will be part of the grade, assessing the problem statement, proposed solution, technical depth, and ability to provide simulations results effectively, including conclusion, and references.

## GRADING SCALE:

The course will be grading using the **absolute** grading scale below. Therefore, the final grade you receive will not depend on the performance of your fellow classmates.

|                |                 |                 |
|----------------|-----------------|-----------------|
| Above 93%: A   | 88% - 92.9%: A- | 85% - 87.9%: B+ |
| 82% - 84.9%: B | 79% - 81.9%: B- | 75% - 78.9%: C+ |
| 70% - 74.9%: C | 60% - 69.9%: D  | Below 59.9%: E  |

## INSTRUCTOR FEEDBACK AND RESPONSE TIME

- **Grading Feedback:** Within 14 days for homework assignments.
- **Email:** Use [ME COURSE NUMBER] in the subject. Expect a response within one business day.

## COMMUNICATION GUIDELINES

- **Writing Style:** Use good grammar, spelling, and punctuation.
- **Tone and Civility:** Maintain a supportive learning community.
- **Citing Sources:** Include author, title, and page numbers for textbooks, journal articles, and other course materials.

## ACADEMIC INTEGRITY POLICY

### OHIO STATE'S ACADEMIC INTEGRITY POLICY

Academic integrity is essential to maintaining an environment that fosters excellence in teaching, research, and other educational and scholarly activities. Thus, The Ohio State University and the Committee on Academic Misconduct (COAM) expect that all students have read and understand the university's [Code of Student Conduct](#), and that all students will complete all academic and scholarly assignments with fairness and honesty. Students must recognize that failure to follow the rules and guidelines established in the university's *Code of Student Conduct* and this syllabus may constitute "Academic Misconduct."

The Ohio State University's *Code of Student Conduct* (Section 3335-23-04) defines academic misconduct as: "Any activity that tends to compromise the academic integrity of the university or subvert the educational process." Examples of academic misconduct include (but are not limited to) plagiarism, collusion (unauthorized collaboration), copying the work of another student, and possession of unauthorized materials during an examination. Ignorance of the university's *Code of Student Conduct* is never considered an excuse for academic misconduct, so I recommend that you review the *Code of Student Conduct* and, specifically, the sections dealing with academic misconduct. **If I suspect that a student has committed academic misconduct in this course, I am obligated by university rules to report my suspicions to the Committee on Academic Misconduct.** If COAM determines that you have violated the university's *Code of Student Conduct* (i.e., committed academic misconduct), the sanctions for the misconduct could include a failing grade in this course and suspension or dismissal from the university.



If you have any questions about the above policy or what constitutes academic misconduct in this course, please contact me. Other sources of information on academic misconduct (integrity) to which you can refer include:

- The Committee on Academic Misconduct web pages ([COAM Home](#))
- *Ten Suggestions for Preserving Academic Integrity* ([Ten Suggestions](#))
- *Eight Cardinal Rules of Academic Integrity* ([www.northwestern.edu/uacc/8cards.htm](http://www.northwestern.edu/uacc/8cards.htm))

## ARTIFICIAL INTELLIGENCE AND ACADEMIC INTEGRITY

There has been a significant increase in the popularity and availability of a variety of generative artificial intelligence (AI) tools, including ChatGPT, Sudowrite, and others. These tools will help shape the future of work, research and technology, but when used in the wrong way, they can stand in conflict with academic integrity at Ohio State. All students have important obligations under the Code of Student Conduct to complete all academic and scholarly activities with fairness and honesty. Our professional students also have the responsibility to uphold the professional and ethical standards found in their respective academic honor codes. Specifically, students are not to use unauthorized assistance in the laboratory, on field work, in scholarship, or on a course assignment unless such assistance has been authorized specifically by the course instructor. In addition, students are not to submit their work without acknowledging any word-for-word use and/or paraphrasing of writing, ideas or other work that is not your own. These requirements apply to all students undergraduate, graduate, and professional. You can use any generative AI tool for completing the HW and assignments in this class, but you are required to clearly stating how you used such tools, what software you used, what you did to verify the correctness of the output from such software.

## COPYRIGHT DISCLAIMER

The materials used in connection with this course may be subject to copyright protection and are only for the use of students officially enrolled in the course for the educational purposes associated with the course. Copyright law must be considered before copying, retaining, or disseminating materials outside of the course.

## STUDENT RESOURCES AND SUPPORT SERVICES

### STATEMENT ON TITLE IX

All students and employees at Ohio State have the right to work and learn in an environment free from harassment and discrimination based on sex or gender, and the university can arrange interim measures, provide support resources, and explain investigation options, including referral to confidential resources.

If you or someone you know has been harassed or discriminated against based on your sex or gender, including sexual harassment, sexual assault, relationship violence, stalking, or sexual exploitation, you may find information about your rights and options at [titleix.osu.edu](http://titleix.osu.edu) or by contacting the Ohio State Title IX Coordinator at [titleix@osu.edu](mailto:titleix@osu.edu). Title IX is part of the Office of Institutional Equity (OIE) at Ohio State, which responds to all bias-motivated incidents of harassment and discrimination, such as race, religion, national origin and disability. For more information on OIE, visit [equity.osu.edu](http://equity.osu.edu) or email [equity@osu.edu](mailto:equity@osu.edu).

### YOUR MENTAL HEALTH

As a student you may experience a range of issues that can cause barriers to learning, such as strained relationships, increased anxiety, alcohol/drug problems, feeling down, difficulty concentrating and/or lack of motivation. These mental health concerns or stressful events may lead to diminished academic performance or reduce a student's ability to participate in daily activities. The Ohio State University offers services to assist you with addressing these and other concerns you may be experiencing. If you find yourself feeling isolated, anxious or overwhelmed, please know that there are resources to help: [ccs.osu.edu](http://ccs.osu.edu). You can reach an on-call counselor when CCS is closed at (614) 292-5766 and 24 hour emergency help is also available through the 24/7 National Prevention Hotline at 1-(800)-273TALK or at



[suicidepreventionlifeline.org](https://suicidepreventionlifeline.org). The Ohio State Wellness app is also a great resource available at [go.osu.edu/wellnessapp](https://go.osu.edu/wellnessapp).

## STUDENT EMERGENCY FINANCIAL SUPPORT

The **Student Advocacy Center** staff members are continuing to serve students during normal business hours and are accepting online appointments.

The **Student Emergency Fund** is available to students who may otherwise be at risk of dropping out of college due to an unexpected financial emergency. If you, or a student you know, are experiencing an unplanned expense, the Student Emergency Fund may be an option. Their office is accepting applications and may be able to award up to \$1,000 to eligible students. [Learn more and apply](#).

The Together As Buckeyes emergency grants program, funded primarily by the federal Coronavirus Aid, Relief and Economic Security (CARES) Act, is available to all students — undergraduate, graduate and professional — through the Student Financial Aid office. To apply for a grant, students need to complete a one-page [Emergency Request form](#) and provide any supporting documentation. The Office of Student Financial Aid will process applications after determining eligibility based on each student's circumstances and guidance from the U.S. Department of Education. Franklin County Department of Job and Family Services has amended its Prevention, Retention and Contingency Program to provide targeted relief for families impacted by the COVID-19 pandemic. The Franklin County COVID-19 Response PRC Program provides eligible families with \$500 in one-time cash assistance to help address emergent needs and expenses brought about by the public health emergency. Families can [apply online](#) today.

The **Student Wellness Center** offers financial coaching through the Scarlet and Gray Financial nationally recognized peer financial coaching program. Through the program, students will learn about financial goal setting, banking basics, budgeting, credit education, debt repayment education and saving and retirement education. [Learn more](#).

## FOOD ASSISTANCE

It's a common idea that pervades American culture: when you're in college, it's simply a rite of passage to sustain yourself on cheap, unhealthy food. We disagree. We highly recommend OSU's **Buckeye Food Alliance** Lincoln Tower 150 food pantry (<https://www.buckeyefoodalliance.org>) and the MidOhio Foodbank (<https://www.midohiofoodbank.org>). The **Buckeye Food Alliance** will remain open to support students in need. Starting Monday, March 23 the pantry will be open Monday/Thursday 10 a.m. – 2 p.m.; Tuesday/Wednesday 4 – 8 p.m. and Friday 11 a.m. – 3 p.m. If these times do not work for your schedule, you can schedule a special appointment by contacting Nick Fowler at [fowler.318@osu.edu](mailto:fowler.318@osu.edu).

## CREATING AN ENVIRONMENT FREE FROM HARASSMENT, DISCRIMINATION, AND SEXUAL MISCONDUCT

The Ohio State University is committed to building and maintaining a welcoming community. All Buckeyes have the right to be free from harassment, discrimination, and sexual misconduct. Ohio State does not discriminate on the basis of age, ancestry, color, disability, ethnicity, gender, gender identity or expression, genetic information, HIV/AIDS status, military status, national origin, pregnancy (childbirth, false pregnancy, termination of pregnancy, or recovery therefrom), race, religion, sex, sexual orientation, or protected veteran status, or any other bases under the law, in its activities, academic programs, admission, and employment. Members of the university community also have the right to be free from all forms of sexual misconduct: sexual harassment, sexual assault, relationship violence, stalking, and sexual exploitation. To report harassment, discrimination, sexual misconduct, or retaliation and/or seek confidential and non-confidential resources and supportive measures, contact the Civil Rights Compliance Office (CRCO): Online reporting form: <http://civilrights.osu.edu/>. Call 614-247-5838 or TTY 614-688-8605. [civilrights@osu.edu](mailto:civilrights@osu.edu). The university is committed to stopping sexual misconduct, preventing its recurrence, eliminating any hostile



environment, and remedying its discriminatory effects. All university employees have reporting responsibilities to the Civil Rights Compliance Office to ensure the university can take appropriate action:

- All university employees, except those exempted by legal privilege of confidentiality or expressly identified as a confidential reporter, have an obligation to report incidents of sexual assault immediately.
- The following employees have an obligation to report all other forms of sexual misconduct as soon as practicable but at most within five workdays of becoming aware of such information: 1. Any human resource professional (HRP); 2. Anyone who supervises faculty, staff, students, or volunteers; 3. Chair/director; and 4. Faculty member.

## INTELLECTUAL DIVERSITY

Ohio State is committed to fostering a culture of open inquiry and intellectual diversity within the classroom. This course will cover a range of information and may include discussions or debates about controversial issues, beliefs, or policies. Any such discussions and debates are intended to support understanding of the approved curriculum and relevant course objectives rather than promote any specific point of view. Students will be assessed on principles applicable to the field of study and the content covered in the course. Preparing students for citizenship includes helping them develop critical thinking skills that will allow them to reach their own conclusions regarding complex or controversial matters.

## RELIGIOUS ACCOMMODATIONS

Ohio State has had a longstanding practice of making reasonable academic accommodations for students' religious beliefs and practices in accordance with applicable law. In 2023, Ohio State updated its practice to align with new state legislation. Under this new provision, students must be in early communication with their instructors regarding any known accommodation requests for religious beliefs and practices, providing notice of specific dates for which they request alternative accommodations within 14 days after the first instructional day of the course. Instructors in turn shall not question the sincerity of a student's religious or spiritual belief system in reviewing such requests and shall keep requests for accommodations confidential. With sufficient notice, instructors will provide students with reasonable alternative accommodations with regard to examinations and other academic requirements with respect to students' sincerely held religious beliefs and practices by allowing up to three absences each semester for the student to attend or participate in religious activities. Examples of religious accommodations can include, but are not limited to, rescheduling an exam, altering the time of a student's presentation, allowing make-up assignments to substitute for missed class work, or flexibility in due dates or research responsibilities. If concerns arise about a requested accommodation, instructors are to consult their tenure initiating unit head for assistance. A student's request for time off shall be provided if the student's sincerely held religious belief or practice severely affects the student's ability to take an exam or meet an academic requirement **and** the student has notified their instructor, in writing during the first 14 days after the course begins, of the date of each absence. Although students are required to provide notice within the first 14 days after a course begins, instructors are strongly encouraged to work with the student to provide a reasonable accommodation if a request is made outside the notice period. A student may not be penalized for an absence approved under this policy. If students have questions or disputes related to academic accommodations, they should contact their course instructor, and then their department or college office. For questions or to report discrimination or harassment based on religion, individuals should contact the [Civil Rights Compliance Office](#).

## GRIEVANCES AND SOLVING PROBLEMS



According to University Policies, if you have a problem with this class, you should seek to resolve the grievance concerning a grade or academic practice by speaking first with the instructor or professor. Then, if necessary, take your case to the department chairperson, college dean or associate dean, and to the provost, in that order. Specific procedures are outlined in Faculty Rule 3335-8-23. Grievances against graduate, research, and teaching assistants should be submitted first to the supervising instructor, then to the chairperson of the assistant's department.

## ACCESSIBILITY ACCOMMODATIONS

### REQUESTING ACCOMMODATIONS

The university strives to make all learning experiences as accessible as possible. If you anticipate or experience academic barriers based on your disability including mental health, chronic or temporary medical conditions, please let me know immediately so that we can privately discuss options. To establish reasonable accommodations, I may request that you register with Student Life Disability Services. After registration, make arrangements with me as soon as possible to discuss your accommodations so that they may be implemented in a timely fashion. **SLDS contact information:** [slids@osu.edu](mailto:slids@osu.edu); 614-292-3307; 098 Baker Hall, 113 W. 12<sup>th</sup> Avenue.

### ACCESSIBILITY OF COURSE TECHNOLOGY

This online course requires use of Carmen (Ohio State's learning management system) and other online communication and multimedia tools. If you need additional services to use these technologies, please request accommodations with your instructor.

- [CarmenCanvas accessibility](#)
- Streaming audio and video
- [CarmenZoom accessibility](#)

## COURSE TOPICS LIST

| Date                   | Units | Lecture    | Topic                                                                                        | HW                                                                    |
|------------------------|-------|------------|----------------------------------------------------------------------------------------------|-----------------------------------------------------------------------|
| 8/26/2025<br>8/28/2025 | 1     | Lecture 1a | Introduction to Learning Based Control (LBC)                                                 |                                                                       |
| 9/2/2025               | 2     | Lecture 2a | AI safety for Autonomous vehicles (ISO: PAS/8800)                                            |                                                                       |
| 9/4/2025               |       | Lecture 2b | AI safety for Autonomous vehicles (ISO: PAS/8800)+<br><a href="#">Final Project Overview</a> | <a href="#">Project Proposal Assigned</a>                             |
| 9/9/2025               |       | Lecture 2c | AI safety for Autonomous vehicles (ISO: PAS/8800)                                            |                                                                       |
| 9/11/2025              |       | Lecture 2d | AI safety for Autonomous vehicles (ISO: PAS/8800)                                            |                                                                       |
| 9/16/2025              | 3     | Lecture 3  | Recap of RL concepts, Q learning recap                                                       | <a href="#">Project Proposal Due/ Project Report (PR)- 1 Assigned</a> |
| 9/18/2025              |       | Lecture 4  | Recap of RL concepts, Q learning recap                                                       |                                                                       |
| 9/23/2025              |       | Lecture 5  | Double DQN, Implicit Q learning (IQL)                                                        |                                                                       |



|                          |              |                                    |                                                                                                          |                         |
|--------------------------|--------------|------------------------------------|----------------------------------------------------------------------------------------------------------|-------------------------|
| 9/25/2025                |              | Lecture 6                          | Recap of Transformers, Transformer Q-Learning (TQL)                                                      |                         |
| 9/30/2025                |              | Lecture 7                          | Actor Critic Review, Deep Deterministic Policy Gradient (DDPG), Twin Delayed DDPG (TD3)                  | PR-1 Due /PR-2 Assigned |
| 10/2/2025                |              | Lecture 8                          | Soft Actor Critic (SAC), Foundation Models, Decision Transformer (DT) with RL                            |                         |
| 10/7/2025                | 4            | Lecture 9                          | Policy Optimization- TRPO, Proximal Policy Optimization (PPO),                                           |                         |
| 10/9/2025                |              | Lecture 10                         | Proximal Policy Optimization (PPO), Group Relative Policy Optimization (GRPO)                            |                         |
| 10/14/2025               |              | Lecture 11                         | Model-Based Policy Optimization (MBPO), Teacher Action Distillation with Policy Optimization (TADPO)     | PR-2 Due /PR-3 Assigned |
| 10/16/2025               | Autumn Break |                                    |                                                                                                          |                         |
| 10/21/2025               | 5            | Lecture 12                         | Graph Neural Networks (GNNs, GAT)                                                                        |                         |
| 10/23/2025               |              | Lecture 13                         | Spiking Neural Networks (SNNs)                                                                           |                         |
| 10/28/2025<br>10/30/2025 |              | Mid semester project presentations |                                                                                                          |                         |
| 11/4/2025                |              | Lecture 14                         | Liquid Neural Network (LNN)                                                                              | PR-3 Due /PR-4 Assigned |
| 11/6/2025                |              | Lecture 15a                        | Knowledge Distillation with Teacher Student Model, Mixture of Experts (MoE) concept from Deep Seek Model |                         |
| 11/11/2025               |              | Veterans day                       |                                                                                                          |                         |



|                        |                  |                                    |                                                                                      |                 |
|------------------------|------------------|------------------------------------|--------------------------------------------------------------------------------------|-----------------|
| 11/13/2025             |                  | Lecture 15b                        | GANs, AGI (Artificial General Intelligence), Explainable AI (XAI)                    |                 |
| 11/18/2025             |                  | Lecture 16                         | PINNs (advanced topics)                                                              | PR-4 Due        |
| 11/20/2025             | 6                | Lecture 17                         | Koopman Operator for Learning Dynamics                                               |                 |
| 11/25/2025             | 7                | Lecture 18                         | RL for Gain tuning, learning the cost function, Safe Reinforcement Learning with CBF |                 |
| 11/27/2025             | Thanksgiving Day |                                    |                                                                                      |                 |
| 12/2/2025              | 8                | Lecture 19                         | Stability analysis of NN controller                                                  | Final paper due |
| 12/4/2025<br>12/9/2025 |                  | End semester project presentations |                                                                                      |                 |