USC Viterbi
School of Engineering

Course 599 Model Predictive Control and Reinforcement Learning
Units: 4
Term—Day—Time: [Spring 2025] — [TuTh 10–11:50am <u>OR</u> 110mins twice weekly]

Location: [THH115]

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Teaching Assistant:
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Catalogue Description
Model predictive control, optimal control, system identification, state estimation, reinforcement learning, and optimization tools for engineers, and skills to apply them for advanced control of multivariable processes

Course Description
Covers linear operators, linear systems, system identification, state estimation (Kalman filtering), linear quadratic optimal control, linear model predictive control, nonlinear model predictive control, reinforcement learning, and applications in industrial processes, manufacturing, and engineering, emphasizing data-driven control of constrained multivariable systems.

Learning Objectives
Model-based optimal control is a crucial tool for industrial control, and knowledge of related optimization and machine learning tools is essential for all engineers. This course will provide students with a fundamental understanding of model-based optimal control, enabling them to build models and controllers for a wide array of systems, including chemical, petroleum, food, pharmaceutical, minerals, and pulp and paper industries. Additionally, the course will cover related topics such as state estimation, system identification, optimization, and reinforcement learning, which can be applied to various decision problems in process and business environments.

In the topics of Model Predictive Control and Reinforcement Learning, students are expected to demonstrate the following capabilities:

1. **Understand the Basics:** Demonstrate understanding of the basics of linear systems and optimal control.
2. **System Identification:** Construct a linear system model from noise-corrupted input-output data and sparse data using system identification methods.
3. **Formulate and Implement:** Demonstrate the ability to formulate industrial control problems as optimal control problems and implement them as a model predictive controller.
4. **Synergy between Methods:** Understand the relationships between state estimation, system identification, model predictive control and reinforcement learning methods and their synergy.

Prerequisite(s): None
Co-Requisite(s): None
Concurrent Enrollment: None

Recommended Preparation: The basics of linear algebra (on the level of MATH 225) and probability theory /statistics (on the level of MATH 114 or MATH 307). Additionally, students are expected to be able to perform linear algebra operation using MATLAB and Python.

Course Notes

Course **information is distributed** via Brightspace and via email. Assignments will be completed and submitted on Brightspace. Students are also expected to access e-lessons/videos available on the internet as assigned by the instructor to prepare for in-lecture activities.

Technological Proficiency and Hardware/Software Required

The course will be taught via in-person lecturing. Students will need to be able to access materials from Brightspace and use materials available on-line through the USC Library. Brightspace will be used to communicate, post materials to be used by students in the course, and for the Instructor to communicate to the class.

Students will need to use MATLAB/Python to solve problems and perform projects.

Required Readings and Supplementary Materials

The required course textbook (tentative) is
   Model Predictive Control
   Authors: Jay H. Lee and Niket S. Kaisare, to be published by Wiley. The PDF preprint of the book will be provided.

Optional Readings and Supplementary Materials

   Reinforcement Learning: An Introduction
   Authors: Sutton, R. S. and Barto, A. G., 2nd Edition, MIT Press, 2017

Description of Assignments and How They Will Be Assessed

The course will include a mid-term exam, and students will complete three projects, one for each of the broad topics: system identification, model predictive control, and reinforcement learning. Additionally, short homework problems will be assigned to encourage students to learn the covered topics.

While the instructor reserves the right to change the format of the mid-term exam mid-semester, it will be conducted in a closed-book setting with a calculator (not a phone or computer/laptop).

The course projects provide an opportunity to integrate many of the course topics to study system identification, model predictive control, and reinforcement learning methods applied to realistic problems. Students will perform tasks in the projects using linear regression tools and model predictive control/reinforcement learning methods. During these exercises, students will experience the impact of various decisions (such as choice of model structure, data, optimization formulation, and hyperparameters) on the results obtained.

Before the commencement of project assignments, some homework will be assigned for completion outside of lecture time. Homework must be neatly presented and prepared individually, even though group discussions on how to solve the problems are encouraged. Homework must be submitted via Brightspace. Homework problems will be graded with an emphasis on effort and will be scored on a scale of 0, 1, or 2 per question: 2 = substantially correct, 1 = reasonable attempt, and 0 = not much effort. Solutions to the homework will be posted on the class website soon after the due date, and late homework will not be accepted (resulting in a score of 0 for that assignment) without prior permission from the instructor and TA.

Grading Breakdown

Homework:	20%
Mid-Term Exam	20%
Projects	60% (20% each)

We will work many more "workshops" in class than will be considered in grading since working problems (workshops) has been demonstrated to be an effective learning tool. While not announced ahead of time, it will be clear in lecture which in-class activities will need to be submitted for credit.

Assignment Submission Policy
Late submissions will not be accepted because solutions will be posted after the submission time. Students are **encouraged** to contact the instructor or TAs with reasonable requests for changes to the due date. These requests will not be acceptable last minute or after the due date. The instructor or TAs will decide whether a modified due date will be accepted and with what penalty.

All student submissions must be professionally prepared with the author(s) clearly identified, answers clearly and completely presented, and final results and conclusions clearly identified. Points will be deducted for unprofessional preparation.

Additional Policies

Grading Timeline
Every effort is made to provide feedback within 10 days of when the assignment is submitted.

Classroom Norms
As course instructor

- I will come prepared to present the material for the course and work problems in lecture to assist students in learning.

- I will make the effort to learn everyone's name – this is a challenge and will be more so with remote lectures/office hours.
- I will respect all questions asked by students, but I may reserve the right to ask to answer questions later. I recognize that you have many competing priorities and will not hold it against you if you are not able to attend class upon occasions with good reasons.
- If I don't know the answer, I will not try to pretend that I do, and I will get back with you with a thoughtful answer.
- I will attempt to provide a diverse learning environment so that student with different learning styles can be successful in the course.
- I do set high standards because I want to see each student succeed in the course and as an engineer.

As students,

- I expect that you will make a solid effort in the course. This means attending lectures, coming to prepared for lecture having watched/read the preparation materials, participating in lecture discussions, and attempting to do the workshops, submitting your own work product.
- I do not judge students based on their questions so you should ask questions to clarify your understanding of the material.
- While I understand grades are important, understand the material and being able to use the material should be every student's goal. This understanding means more than just knowing the formula/math to solve problems.
- I also expect you to respect your fellow students, contributing equally to group work (don't hitchhike on assignments, workshops, or laboratories).
- If other students are waiting to ask questions when you are having significant problems understanding the material, try to be respectful of their time and consider asking for different time to ask more extensive questions.

Finally, if you think I don't know your name or am pronouncing it wrong, help me by letting know what you want to be called and how to pronounce it. Also, if you have a concern, I ask that you approach me and we will work through and attempt to mutually resolve your concern.

Bottom line, my goals is to see each of you be successful students and, in the future, engineers. I would like is a course to provide a respectful and open environment for learning.

Attendance
The students are expected to make their own choices about attending lectures. Missed in-lecture workshops/exercises cannot be made-up.

Academic integrity and Professional Ethics
Professional behavior will be an essential aspect of your engineering career. You have been observing an important standard for ethical behavior since joining USC. We will continue to observe the academic integrity policies in this course.

> *The School of Engineering and the Department of Chemical Engineering and Materials Science adhere to the University's policies and procedures governing academic integrity as described in SCampus. Students are expected to be **aware** of and **observe** the academic integrity standards described in SCampus.*

As engineers you will be professionals expected uphold the profession behavior set out by the National Society of Professional Engineers and AIChE. You can find the ethical code of conduct statements at the NSPE and AIChE websites – you should consider reading them.

Course Content Distribution and Synchronous Session Recordings Policies
USC has policies that prohibit recording and distribution of any synchronous and asynchronous course content outside of the learning environment.

Recording a university class without the express permission of the instructor and announcement to the class, or unless conducted pursuant to an Office of Student Accessibility Services (OSAS) accommodation. Recording can inhibit free discussion in the future, and thus infringe on the academic freedom of other students as well as the instructor. ([Living our Unifying Values: The USC Student Handbook](), page 13).

Distribution or use of notes, recordings, exams, or other intellectual property, based on university classes or lectures without the express permission of the instructor for purposes other than individual or group study. This includes but is not limited to providing materials for distribution by services publishing course materials. This restriction on unauthorized use also applies to all information, which had been distributed to students or in any way had been displayed for use in relationship to the class, whether obtained in class, via email, on the internet, or via any other media. ([Living our Unifying Values: The USC Student Handbook](), page 13).

Policy on the use of AI Generators
Since analyzing, writing and critical thinking are part of the learning outcomes of this course, the report should be prepared by the student working individually. Students may not have another person or entity complete any substantive portion of the report. Developing strong competencies in these areas will prepare you for a competitive workplace. Therefore, using AI-generated tools is prohibited in this course, will be identified as plagiarism, and will be reported to the Office of Academic Integrity.

However, the use of AI Generators such as ChatGPT is permissible under specific circumstances. Students are allowed to use these tools for proofreading and restructuring their text to enhance clarity. Such use can help to identify and correct grammatical errors, improve sentence structure, and enhance the overall readability of the text. The goal here is to facilitate better expression of your original thoughts and ideas, not to generate substantive content.

Therefore, while we discourage AI-generated content, we encourage and welcome the use of AI tools for proofreading and text restructuring to ensure the clarity and coherence of your report. This approach should serve to enhance, not replace, your individual creativity and critical thinking in the preparation of your report.

Course Evaluations
Course evaluation occurs at the end of the semester university-wide. It is an important review of students' experience in the class. The process and intent of the end-of-semester evaluation should be provided. In addition, a [mid-semester evaluation]() is recommended practice for early course correction.

Course Breakdown

This is an overall course plan for the semester. A detailed guide for student activities is provided separately on Brightspace. Assignment and due dates in this course plan are only a plan and the instructor will adjust the plan as needed during the semester. The detailed guidance document will be updated during the semester and weekly emails will be provided to remind students of the plan for the next week and to communicate any changes to the plan.

	Topics/Daily Activities	Readings/Preparation	Deliverables
Week 1	Introduction, Linear operators	Chapter 1, Appendix A (of textbook)	
Week 2	Linear operators	Appendix A	HW #1
Week 3	Linear systems	Chapter 4	
Week 4	Linear systems	Chapter 5	HW #2
Week 5	State Estimation	Chapter 6	
Week 6	Linear Quadratic Optimal Control	Chapter 7	HW #3
Week 7	Constrained Linear Quadratic Optimal Control	Chapter 8	
Week 8	Constrained Linear Quadratic Optimal Control	Chapter 8	HW #4
Week 9	System Identification	Chapter 9	
Week 10	System Identification	Chapter 9	Project #1
Week 11	State Space MPC	Chapter 10	
Week 12	Nonlinear MPC	Chapter 12	Project #2
Week 13	Dynamic Programming	Chapter 4 (supplementary text)	
Week 14	Temporal Difference Learning	Chapter 6 (supplementary text)	
Week 15	Other Reinforcement Learning Techniques	Supplementary notes	Project #3
FINAL	No Final Exam		Refer to the final exam schedule in the USC *Schedule of Classes* at classes.usc.edu.

Statement on Academic Conduct and Support Systems

Academic Integrity:
The University of Southern California is a learning community committed to developing successful scholars and researchers dedicated to the pursuit of knowledge and the dissemination of ideas. Academic misconduct, which includes any act of dishonesty in the production or submission of academic work, comprises the integrity of the person who commits the act and can impugn the perceived integrity of the entire university community. It stands in opposition to the university's mission to research, educate, and contribute productively to our community and the world.

All students are expected to submit assignments that represent their own original work, and that have been prepared specifically for the course or section for which they have been submitted. You may not submit work written by others or "recycle" work prepared for other courses without obtaining written permission from the instructor(s).

Other violations of academic integrity include, but are not limited to, cheating, plagiarism, fabrication (e.g., falsifying data), collusion, knowingly assisting others in acts of academic dishonesty, and any act that gains or is intended to gain an unfair academic advantage.

The impact of academic dishonesty is far-reaching and is considered a serious offense against the university. All incidences of academic misconduct will be reported to the Office of Academic Integrity and could result in outcomes such as failure on the assignment, failure in the course, suspension, or even expulsion from the university.

For more information about academic integrity see [the student handbook](#) or the [Office of Academic Integrity's website](#), and university policies on [Research and Scholarship Misconduct](#).

Please ask your instructor if you are unsure what constitutes unauthorized assistance on an exam or assignment, or what information requires citation and/or attribution.

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Students and Disability Accommodations:

USC welcomes students with disabilities into all of the University's educational programs. [The Office of Student Accessibility Services](#) (OSAS) is responsible for the determination of appropriate accommodations for students who encounter disability-related barriers. Once a student has completed the OSAS process (registration, initial appointment, and submitted documentation) and accommodations are determined to be reasonable and appropriate, a Letter of Accommodation (LOA) will be available to generate for each course. The LOA must be given to each course instructor by the student and followed up with a discussion. This should be done as early in the semester as possible as accommodations are not retroactive. More information can be found at [osas.usc.edu](#). You may contact OSAS at (213) 740-0776 or via email at [osasfrontdesk@usc.edu](#).

Support Systems:

[*Counseling and Mental Health*](#) - *(213) 740-9355 – 24/7 on call*
Free and confidential mental health treatment for students, including short-term psychotherapy, group counseling, stress fitness workshops, and crisis intervention.

[*988 Suicide and Crisis Lifeline*](#) - *988 for both calls and text messages – 24/7 on call*
The 988 Suicide and Crisis Lifeline (formerly known as the National Suicide Prevention Lifeline) provides free and confidential emotional support to people in suicidal crisis or emotional distress 24 hours a day, 7 days a week, across the United States. The Lifeline is comprised of a national network of over 200 local crisis centers, combining custom local care and resources with national standards and best practices. The new, shorter phone number makes it easier for people to remember and access mental health crisis services (though the previous 1 (800) 273-8255 number will continue to function indefinitely) and represents a continued commitment to those in crisis.

[*Relationship and Sexual Violence Prevention Services (RSVP)*](#) - *(213) 740-9355(WELL) – 24/7 on call*
Free and confidential therapy services, workshops, and training for situations related to gender- and power-based harm (including sexual assault, intimate partner violence, and stalking).

[*Office for Equity, Equal Opportunity, and Title IX (EEO-TIX)*](#) - *(213) 740-5086*
Information about how to get help or help someone affected by harassment or discrimination, rights of protected classes, reporting options, and additional resources for students, faculty, staff, visitors, and applicants.

[*Reporting Incidents of Bias or Harassment*](#) - *(213) 740-5086 or (213) 821-8298*
Avenue to report incidents of bias, hate crimes, and microaggressions to the Office for Equity, Equal Opportunity, and Title for appropriate investigation, supportive measures, and response.

[*The Office of Student Accessibility Services (OSAS)*](#) - *(213) 740-0776*
OSAS ensures equal access for students with disabilities through providing academic accommodations and auxiliary aids in accordance with federal laws and university policy.

[*USC Campus Support and Intervention*](#) - *(213) 740-0411*
Assists students and families in resolving complex personal, financial, and academic issues adversely affecting their success as a student.

[*Diversity, Equity and Inclusion*](#) - *(213) 740-2101*

Information on events, programs and training, the Provost's Diversity and Inclusion Council, Diversity Liaisons for each academic school, chronology, participation, and various resources for students.

[USC Emergency](#) - *UPC: (213) 740-4321, HSC: (323) 442-1000 – 24/7 on call*
Emergency assistance and avenue to report a crime. Latest updates regarding safety, including ways in which instruction will be continued if an officially declared emergency makes travel to campus infeasible.

[USC Department of Public Safety](#) - *UPC: (213) 740-6000, HSC: (323) 442-1200 – 24/7 on call*
Non-emergency assistance or information.

[Office of the Ombuds](#) - *(213) 821-9556 (UPC) / (323-442-0382 (HSC)*
A safe and confidential place to share your USC-related issues with a University Ombuds who will work with you to explore options or paths to manage your concern.

[Occupational Therapy Faculty Practice](#) - *(323) 442-2850 or* otfp@med.usc.edu
Confidential Lifestyle Redesign services for USC students to support health promoting habits and