University of California, Davis
Department of Chemical Engineering
ECH 267
Advanced Process Control

M. Ellis **COURSE SYLLABUS** **Winter 2021**

Course Information

Lectures: MWF 2:10PM-3:00PM

Zoom Link: Meeting ID: 972 6233 4095; Passcode: 672565

Prerequisites: ECH 157 (or equivalent undergraduate control course)

This course is an introduction to advanced process control with the main focus being nonlinear systems theory and nonlinear control. Even though the context of the course is process control, no extensive knowledge of process control is required. The only prerequisite for the course is an undergraduate control course. Topics covered include a) Lyapunov stability for nonlinear systems including converse theorems, b) design of nonlinear controllers for various classes of nonlinear systems, c) nonlinear tracking and economic model predictive control.

Instructional Team

Professor Matt Ellis, mjellis@ucdavis.edu

Office Hours

Wednesdays 1-2PM or by appointment

Recommended Texts

- **(Khalil) *Nonlinear Systems*, Khalil, H. K., Prentice Hall, Upper Saddle River, New Jersey, 3rd edition, 2002.**
- (Rawlings) *Model Predictive Control: Theory, Computation, and Design*, Rawlings, J. B., Mayne, D. Q., Diehl, M. M, Nob Hill Publishing, Madison, WI, 2nd Edition, 2017.

Lectures

Students are expected to attend lectures and participate in the lectures.

Homework

A few homework assignments will be given throughout the course, which will require computational tools to complete (e.g., Matlab, R, Python). Students may complete the computational part via the programming language of their choice. For each assignment, one problem of the assignment will be randomly selected and rigorously graded. The problem will be graded based on correctness and the supporting work. Points may be deducted if the solution is difficult to follow or illegible. The remaining problems will be graded based on completion. The homework grading policy is subject to change depending on participation in lectures. Homework solutions should be uploaded to Canvas by the due date and time indicated on the assignment problem set. The code to reproduce the solutions for any computational problem must also be uploaded to Canvas or a repository (e.g., Github) with the repository link provided on the homework solution. Failure to submit the code/repository link will be considered an incomplete. No late homework submissions will be accepted.

Midterm Exam

There will be one midterm exam. The exam will cover the lecture materials and reading assignments from the beginning of the course until the exam date. Students will have 24 hours to complete the exam, and submit the solutions to Canvas. Detailed instructions will be provided on the exam problem statement. Students are expected to complete the exam individually and may not consult anyone. The course will not have a final exam.

Course Project

In lieu of a final exam, each student will be required to complete a course project on any topic that is related to the course content. The project is meant to simulate a real-world project, and only has a few formal requirements. The requirements are:

1. Students must submit an abstract describing the project topic, the problem statement, and how the project relates to the course. Students will receive feedback on the abstract and an overall rating of “Accept”, “Minor Revisions”, “Major Revisions”, or “Reject”. Students receiving a rating of “Major Revisions” or “Reject” are required to submit a revised abstract that addresses the instructor’s feedback to receive credit for the abstract. Students receiving a rating of “Minor Revision” should account for the feedback in their final report. The due date for the abstracts is Wednesday, March 3 at 6PM PST, but students are encouraged to submit their abstracts much earlier for feedback.
2. The project must include a computational component with the final code posted to a repository (e.g., Github). Direction on reproducing the final results from the code must be provided, so the results may be reproduced by others.
3. Students should submit a final report and presentation that discusses the project methodology, results, and conclusions. The final report is due March 10 at 6PM PST. Final presentations will take place during finals week and may not exceed 10 minutes. A question and answer session will take place after the presentation (does not count towards the maximum 10 minutes).
4. Students will be required to peer review 2 other students’ final reports, and submit their feedback and comments to the instructor via email (due date for feedback is March 18 6PM PST). The student’s peer review is expected to cover the technical content, organization, and presentation of the report.

The abstract accounts for 10% of the total project grade. The report, presentation, and project code accounts for 80% of the total project grade. Specifically, this portion will be graded based on (1) the ability to deliver a solution to the problem statement with appropriate justification, (2) the effectiveness of the report and presentation to highlight the main project results and conclusions, and (3) reproducibility of the results by running the code. Completion of the peer review accounts for the remaining 10% of the total project grade.

Grading

The course grading structure is as follows:

Homework	30%
Midterm	30%
Project	40%
Abstract	10%
Peer report evaluations	10%
Final report and presentation	80%

Tentative Lecture Schedule

Date	Topic	Reading
1/4	Introduction and mathmatical modeling	Khalil: Chapter 1
1/6	Differences between linear and nonlinear systems	Khalil: Chapter 2
1/8	Local analysis of nonlinear systems and phase portraits	Khalil: Chapter 2
1/11	Fundamental properties of nonlinear ordinary differential equations	Khalil: Chapter 3
1/13	Fundamental properites of nonlinear oridinary differential equations	Khalil: Chapter 3
1/15	Lyapunov stability for nonlinear systems	Khalil: Chapter 4
1/18	No class - Martin Luther King Jr. Holiday	
1/20	Lyapunov stability for nonlinear systems, assessing stability, and Lyapunov functions	Khalil: Chapter 3
1/22	Lyapunov direct method	Khalil: Chapter 3
1/25	Lyapunov direct method and domain of attraction	Khalil: Chapter 3
1/27	Invariance theory and LaSalle's theorem	Khalil: Chapter 3
1/29	Introduction to nonlinear control and feedback linearization	Khalil: Chapter 12 & 13
2/1	Feedback linearization (input/state)	Khalil: Chapter 13
2/3	Feedback linearization (input/output)	Khalil: Chapter 13
2/5	Lyapunov-based control	
2/8	Nonautonomous systems	Khalil: Chapter 3
2/10	Nonautonomous systems	Khalil: Chapter 3
2/12	Converse theorem and perturbed systems	Khalil: Chapter 3
2/15	No class - Presidents' day	
2/17	No class - **midterm exam**	
2/19	Input-to-state stability	Khalil: Chapter 3
2/22	Input-to-state stability	Khalil: Chapter 3
2/24	Introduction to optimal control and model predictive control	Rawlings: Chapter 1
2/26	Introduction to discrete-time systems	Rawlings: Appendix B
3/1	Linear model predictive control	Rawlings: Chapter 2
3/3	Nonlinear model predictive control	Rawlings: Chapter 2
3/5	Nonlinear model predictive control	Rawlings: Chapter 2
3/8	Nonlinear model predictive control	Rawlings: Chapter 2
3/10	Economic model predictive control	Rawlings: Chapter 2
3/12	Economic model predictive control	Rawlings: Chapter 2
3/15	Finals week - **project presentations**	