ASEN 5014 LINEAR CONTROL DESIGN

Course Description: Modeling, analysis, and design of continuous-time control systems using the state space approach. Vector spaces, linear operators, and linear equation solution theory are used to describe system solutions and their stability, controllability, and observability properties. State observers and state feedback control are developed, along with an introduction to linear-quadratic optimal control. Robustness to model uncertainty is addressed.

Instructor:

Dale Lawrence.

Prerequisite:

Undergraduate course in signals, systems, or control (e.g. ASEN 2003, ASEN 3200, ASEN 3128, or equivalent)

Textbook:

Modern Control Theory, W. L. Brogan, 3rd ed. Prentice-Hall, 1991.
ISBN 0-13-589763-7

Class Web Page:

Teaching Assistant:

Karan Muvvala

Syllabus Outline

Topics	**Weeks**
Introduction: Guiding Questions	1
State Space Model Construction	1
Linear Spaces	2
Midterm Exam 1	
Linear Mappings	3
Midterm Exam 2	
State Space System Solutions	3
Lyapunov Stability	1
Project 1	
Controllability and Observability	2
State Observation and Feedback Control	2
Optimization and Robustness	1
Project 2 (in lieu of final exam)	

Course Policies and Grading

Lectures: Simultaneous in-person and distance section (via Zoom). Lectures will be recorded and slides from class will be posted. Attendance in lecture will not be taken, but attendance is strongly encouraged.
Grading: Two exams and two projects---20% each., homework---20%.
Homework: Group work is encouraged, although individual understanding will be necessary to do well on exams and on the projects. Homework will be partially graded, solutions posted, and questions about homework are encouraged in office hours.
Exams: Take home, individual, involving both analysis and computation. Questions are designed to measure grasp of concepts, rather than memorization or repetition of homework problems. Honor system applies.
Projects: Worked in small teams, with individual contributions explicitly described. Distance students my work the projects individually, if teaming is problematic.
Office hours: To be arranged outside scheduled class meeting time, held on Zoom.
Missed Assignments: No make ups will be given for missed assignments (exams, projects, homework). Instead, course credit will be shifted to completed assignments in that category. Extended absences should be discussed with the instructor.
Late Assignments: Maximum credit decreases by 10% of nominal per day.

Course Purpose and Learning Objectives

Linear systems are models for physical processes having dynamics. Although physical systems are usually non-linear, linear models are simpler, and can often provide reasonable approximations. They have the added benefit of a very complete theoretical understanding of their behavior and of how control can change behavior, leading to great insight into the complexities of these dynamics and useful design tools to achieve desired behavior objectives.

The purpose of this course is to provide an understanding of the theory of linear systems from the state space perspective, with specific application toward feedback control design. Although mathematics (particularly linear algebra) is the language by which the theory is described, this is not a mathematics course. A formal theorem/proof format is avoided in favor of an exposition of the main ideas and use of these ideas to demonstrate key theoretical results. The geometry and insight behind matrix algebra, in particular, is stressed. However, expect to learn a little math in the process, including mathematical reasoning for demonstrating results. Careful use of terminology is necessary to understand the ideas, and to do well on exams and projects. Students will select an example application for the two projects to apply the ideas developed in class.

The understanding sought in this course is a foundation for further graduate work in various fields, particularly nonlinear dynamical systems, estimation and data analysis, and advanced control systems. It introduces standard viewpoints, methods, and terminology used in the applied and research literature. It also provides the basis for understanding how many computational analysis and design tools work.

The main learning objectives of Linear Control Design are

- Develop some expertise with the state space modeling/analysis/design approach, learning to see dynamical systems in a new way with new concepts, vocabulary, tools, and insights.
- See linear algebra in a new light, where matrices are representations of linear operators, and these operators have simple geometry and corresponding insights. This understanding is used widely (both within control and many other applications).
- Glimpse how optimization can be used to design control systems ``automatically".
- Understand how applications of this theory can be limited by inaccuracy in system models.

General Policies and Resources

Classroom Behavior

Students and faculty are responsible for maintaining an appropriate learning environment in all instructional settings, whether in person, remote, or online. Failure to adhere to such behavioral standards may be subject to discipline. Professional courtesy and sensitivity are especially important with respect to individuals and topics dealing with race, color, national origin, sex, pregnancy, age, disability, creed, religion, sexual orientation, gender identity, gender expression, veteran status, marital status, political affiliation, or political philosophy.

For more information, see the classroom behavior policy, the Student Code of Conduct, and the Office of Institutional Equity and Compliance.

Accommodation for Disabilities, Temporary Medical Conditions, and Medical Isolation

If you qualify for accommodations because of a disability, please submit your accommodation letter from Disability Services to your faculty member in a timely manner so that your needs can be addressed. Disability Services determines accommodations based on documented disabilities in the academic environment. Information on requesting accommodations is located on the Disability Services website. Contact Disability Services at 303-492-8671 or DSinfo@colorado.edu for further assistance. If you have a temporary medical condition, see Temporary Medical Conditions on the Disability Services website.

If you have a temporary illness, injury or required medical isolation for which you require adjustment, please contact the instructor as soon as possible.

Preferred Student Names and Pronouns

CU Boulder recognizes that students' legal information doesn't always align with how they identify. Students may update their preferred names and pronouns via the student portal; those preferred names and pronouns are listed on instructors' class rosters. In the absence of such updates, the name that appears on the class roster is the student's legal name.

HONOR CODE

All students enrolled in a University of Colorado Boulder course are responsible for knowing and adhering to the Honor Code. Violations of the Honor Code may include but are not limited to: plagiarism (including use of paper writing services or technology [such as essay bots]), cheating, fabrication, lying, bribery, threat, unauthorized access to academic materials, clicker fraud, submitting the same or similar work in more than one course without permission from all course instructors involved, and aiding academic dishonesty. Understanding the course's syllabus is a vital part in adhering to the Honor Code.
All incidents of academic misconduct will be reported to Student Conduct & Conflict Resolution: StudentConduct@colorado.edu. Students found responsible for violating the Honor Code will be assigned resolution outcomes from the Student Conduct & Conflict Resolution as well as be subject to academic sanctions from the faculty member. Visit Honor Code for more information on the academic integrity policy.

SEXUAL MISCONDUCT, DISCRIMINATION, HARASSMENT AND/OR RELATED RETALIATION

CU Boulder is committed to fostering an inclusive and welcoming learning, working, and living environment. University policy prohibits protected-class discrimination and harassment, sexual misconduct (harassment, exploitation, and assault), intimate partner abuse (dating or domestic violence), stalking, and related retaliation by or against members of our community on- and off-campus. The Office of Institutional Equity and Compliance (OIEC) addresses these concerns, and individuals who have been subjected to misconduct can contact OIEC at 303-492-2127 or email CUreport@colorado.edu. Information about university policies, reporting options, and support resources including confidential services can be found on the OIEC website.

Please know that faculty and graduate instructors must inform OIEC when they are made aware of incidents related to these policies regardless of when or where something occurred. This is to ensure that individuals impacted receive outreach from OIEC about resolution options and support resources. To learn more about reporting and support for a variety of concerns, visit the Don’t Ignore It page.

RELIGIOUS ACCOMMODATIONS

Campus policy requires faculty to provide reasonable accommodations for students who, because of religious obligations, have conflicts with scheduled exams, assignments or required attendance. Please communicate the need for a religious accommodation in a timely manner.

In this class, students who miss class can view the missed lectures on-line. Exams and homework assignments are 1-week take home format; students are expected to plan their work around religious holidays accordingly.

See the campus policy regarding religious observances for full details.

MENTAL HEALTH AND WELLNESS

The University of Colorado Boulder is committed to the well-being of all students. If you are struggling with personal stressors, mental health or substance use concerns that are impacting academic or daily life, please contact Counseling and Psychiatric Services (CAPS) located in C4C or call (303) 492-2277, 24/7.

Free and unlimited telehealth is also available through Academic Live Care.
The Academic Live Care site also provides information about additional wellness services on campus that are available to students.