UNIVERSITY OF CALIFORNIA, SANTA CRUZ
BOARD OF STUDIES IN COMPUTER ENGINEERING

CMPE 240: INTRODUCTION TO LINEAR DYNAMICAL SYSTEMS

WINTER 2016
T-Th 12:00 – 1:45 PM
CLASS: Engineering 2 – Room 194

DEFINITION

Linear Dynamical Systems refers to a mathematical representation of a physical system that can be represented by a set of 1st order differential equations or 1st order difference (or recursion) equations for discrete time systems. Generally, these systems can be written in a very simple (and very overloaded form) of:

$$\dot{x} = Ax + Bu$$
$$y = Cx + Du$$

$$x_{k+1} = Ax_k + Bu_k$$
$$y_k = Cx_k + Du_k$$

The study of these linear systems started historically in the 1960's and required a Ph.D. in math as a necessary prerequisite. Most of the applications at the time were to aerospace control problems (such as rocket guidance). Today, these types of systems are studied extensively, and applications range from controls to economics. Frequently, these problems are cast as dual problems: *design* (where the input vector is altered to reach a desired output) and *estimation* (where a set a sensor measurements are processed to estimate the state of the system).

INSTRUCTOR:

GABRIEL HUGH ELKAIM
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Office: Engineering 2 (E2), 337B
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Phone: (831) 459-3054 (Office)
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SYLLABUS

LECTURE 0 – BASIC COURSE INFO
LECTURE 1 – OVERVIEW
LECTURE 2 – LINEAR FUNCTIONS
LECTURE 3 – LINEAR ALGEBRA REVIEW
LECTURE 4 – ORTHONORMAL VECTORS AND QR FACTORIZATION
LECTURE 5 – LEAST-SQUARES
LECTURE 6 – REGULARIZED LEAST-SQUARES AND MINIMUM-NORM METHODS
LECTURE 7 – AUTONOMOUS LINEAR DYNAMICAL SYSTEMS

LECTURE 8 – SOLUTIONS VIA LAPLACE TRANSFORM AND MATRIX EXPONENTIAL
LECTURE 9 – EIGENVECTORS AND DIAGONALIZATION
LECTURE 10 – JORDAN CANONICAL FORM
LECTURE 11 – LINEAR DYNAMICAL SYSTEMS WITH INPUTS AND OUTPUTS
LECTURE 12 – EXAMPLE: AIRCRAFT DYNAMICS
LECTURE 13 – SYMMETRIC MATRICES, QUADRATIC FORMS, MATRIX NORM, AND SVD
LECTURE 14 – SVD APPLICATIONS
LECTURE 15 – EXAMPLE: QUANTUM MECHANICS
LECTURE 16 – CONTROLLABILITY AND STATE TRANSFER
LECTURE 17 – OBSERVABILITY AND STATE ESTIMATION
LECTURE 18 – SOME FINAL COMMENTS

TAS AND HELPERS:

TA: Sharon Rabinovich <srabinov@ucsc.edu>.

TEXTBOOKS (ALSO IN THE LIBRARY ON RESERVE):

"Linear Algebra and its Applications, 3rd Ed.," by Gilbert Strang, Brooks Cole, 1988. ISBN: 0155510053. Available at Baytree Bookstore and on reserve in the Engineering and Science Library. (Note that any edition is fine).

GRADING

The grading is based on the following percentages. Late homeworks are NOT accepted*. Homeworks will be due, 6PM on Thursdays, in the box outside my office.

HOMEWORKS	15%	9 homeworks, due once per week
MIDTERM	35%	Take Home, date TBD
FINAL EXAM	50%	Take Home, date TBD

*Each student has two "free" late days that they can use for any homework in the class, at any time, without advanced permission. That is, you can twice turn in your homeworks one day late each, or turn in one homework 2 days late, once. After that, you get a 0 on the homework.

WWW SITE, VIDEOS, AND WEBFORUM

Website: http://classes.soe.ucsc.edu/cmpe240/Winter16/

Check this site often as this is where the homework assignments, lecture notes, labs, homework and test solutions, and lecture videos are posted. You are expected to read the material on the website.

Videos: As an experiment in teaching technology, the instructor will be capturing both the audio and screen from the course in real-time. This will later be posted to the website. While every attempt will be made to capture the classes, as this is a new technology, there are no guarantees. Also, while watching the video should be a great way to review course material, if you are not in class you cannot ask questions and/or clarifications. Further, if too few students show up for lectures, the instructor may restrict access to class videos.

Piazza: https://piazza.com/ucsc/winter2016/cmpe240/home

Use Piazza to post questions to the tutors and the TAs about lab and class work. Use it to ask questions of other students. Do not expect quick replies from the instructor, use e-mail for that. Do NOT post code onto Piazza.

COURSE WORK: CMPE 240

Attendance is highly recommended for the lectures as the material builds up quickly. Lecture material will be made available on the website, usually before covered in class. Annotated lecture notes and videos of the lecture will be posted after class in a timely fashion (see note on video above).

There will be weekly homework assignments that are both required and graded. Though they are worth only 15% of your overall grade, they are essential to mastering the material. There will one take-home midterm exam and one take-home final. The midterm and final material will be based on homework and lecture material.

ACADEMIC HONESTY

Academic honesty is a requirement for the course. All assignments must be your own independent work; this includes homework and exams.

What is cheating? It is presenting work that is not yours as your own. You can, and are encouraged to, discuss and strategize with your colleagues on homeworks, but your work should be your own I expect you to work together on the homeworks, however copying is NEVER acceptable.

If a student is caught cheating in either the class or the exam this will result in an immediate failure in the class and the lab. It will be reported to your college and your department. DO NOT CHEAT; it is not worth it.

ACKNOWLEDGEMENTS

This course is based on the Introduction to Linear Dynamical Systems sequence (EE263 and EE363), offered at Stanford by Professor Stephen Boyd. Lecture notes are taken from his published lecture notes, "EE263: Introduction to Linear Dynamical Systems," Fall 2004.

I would like to acknowledge the tremendous help and generosity of Prof. Stephen Boyd of Stanford University in teaching the subject matter to me, for all of his help with the slides, the homeworks, and the course materials. I would also like to thank Prof. Ed Carryer at Stanford University for pioneering this video capture technology, and helping me to set it up. Without their help and inspiration, this class would not be here.