SIE 550 (Linear) Systems Theory: Spring 2019

Course Instructor, Lectures and Course Website

Instructor: Dr. Roberto Furfaro, robertof@email.arizona.edu
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Office Hours: Tue-Th 3pm-4pm or by appointment.
Teaching Assistant: Mr. Enrico Schiassi, eschiassi@email.arizona.edu (OH: for TA will be announced later)
Lectures: Tue-Th, 4:00pm - 5:15pm
Course content on D2L: www.d2l.arizona.edu

Course Description

This course is a core course for graduate students at the SIE department. Although the title is "Linear Systems Theory", the course will cover both linear and non-linear systems under a unified framework. The goal of the course is to give the students a deep understanding of the behavior of dynamical systems as well as means to analyze autonomous and non-autonomous systems employing basic and advanced mathematical techniques. The material covered in this course spans from representation and analysis of dynamical systems, Lyapunov stability theory, controllability and observability of linear systems as well as design techniques for dynamical system stabilization.

Schedule and Topics

Week 0: Jan 10
Topic: Introduction

Week 1: Jan 15 -17
Topic: Mathematical Background: Fundamentals of linear algebra

1. Vector spaces
2. Linear Operators
3. Eigenvalues and Eigenvectors
4. Diagonal Forms and Jordan Forms
5. Special Linear Operators: Symmetric and Normal/Orthogonal Operators

Week 2: Jan 22 -24
Topic: Linear and Non-Linear Dynamical Systems

1. General Dynamical Models
2. Examples of linear and non-linear models
3. Linear and non-linear phenomena

Week 3: Jan 29 – Jan 31

Topic: Solutions of Linear Differential Equations

1. Solution of Systems of linear differential Equations
2. Laplace transform and the concept of transfer function
3. Duality

Wed Jan 30 *- HW#1 due*

Week 4: Feb 5 – 7

Topic: Stability Concepts I

1. Stability of Equilibrium Points and Linearization
2. Lyapunov Stability: General Concepts
3. Lyapunov Stability for Linear Systems

Week 5: Feb 12-14

Topic: Stability Concepts II

1. Lyapunov Stability for Non-linear Systems and Linearization
2. Exponential Stability and Region of Attraction
3. Converse Lyapunov Functions and Non-Autonomous Systems

Wed Feb 13 *– HW#2 Due*

Week 6: Feb 19 – 21

Topic: Stability Concepts III

1. Perturbed Systems
2. BIBO Stability

Week 7: Feb 26-Feb 28

Topic: Finite Time Stability

1. Finite Time Stability: Basic Concept and Definitions
2. Finite Time Stability Conditions for Autonomous and Non-Autonomous Systems

Wed Feb 27 *– HW#3 Due*

Week SB (Mar 2- Mar 10): Spring Recess

Week 8: Mar 12-14

Topic: Controllability

1. General Conditions
2. Controllability Canonical Forms
3. Time Invariant Systems
4. Output and Trajectory Controllability
5. Controllability and Stability for General Systems

Week RW (Review): Mar 19-21

Topic: Review and Mid-Term Exam

Wed Mar 20 *- HW#4 Due*

Tue Mar 19 *- Midterm Review*

Th Mar 21 *- Midterm Exam*

Week 9: Mar 26- Mar 28

Topic: Observability

1. General Conditions
2. Observability Canonical Forms
3. Time Invariant Systems

Wed Mar 27 *- HW# 5 due*

Week 10: Apr 2-4

Topic: Canonical Forms

1. Controllability Canonical Forms
2. Observability Canonical Forms
3. Examples

Week 11: Apr 9-11

Topic: Systems Design and Estimation I: Linear Methods

1. Stabilization: Basic Concepts and Linearization
2. Linear Systems Design: Eigenvalues placements
3. Linear Systems Observers
4. Controller Observer Separation Theorem
5. Examples

Wed Apr 12 – HW#6 due

Week 12: Apr 16-18

Topic: Systems Design and Estimation II: Linear Methods

1. Design and Estimation examples via MATLAB
2. Linear Quadratic Regulator

Week 1: Apr 23-25

Topic: Systems Design and Estimation III: non-linear methods

1. Lyapunov-based stabilization
2. Robust stabilization and sliding control

Wed Apr 24 *– HW#7 due*

Week 16: Apr 30

Topic: Systems Design and Estimation IV: Finite time controllers

1. Sliding control and finite-time stability

Wed May 1 *– HW#8 due*

Final Exam: TBD

Grading

A regular grade (A, B, C, D, E) will assigned. The grade will be established as function of the class performance (curve). Each student will receive a numerical value according to his/her performance on the following items:

Midterm Exam	30%
Final Exam	40%
Homework/Quizzes	30%

Course Objectives

At the end of the course, the students are expected to be able to:

1. Analyzing of Linear and Non-Linear Dynamical Systems
2. Applying of the Lyapunov Stability Theory to Dynamical Systems
3. Understanding if a System is Controllable and Observable
4. Applying a Variety of Design Methodologies to Stabilize Dynamical Systems

Semester Assignments, Midterm and Final Examination

During the semester, students will be required to submit approximately 8 (eight) homeworks with bi-weekly frequency. Homeworks will be a combination of theoretical analysis and limited computer simulation via MATLAB. There will be one mid-term exam and one comprehensive final exam. Make-up exams for a valid excuse must be arranged at least 1 week before the scheduled exam date. Emergency situation should be communicated to the instructor as soon as possible to arrange for an alternative schedule. Without prior consent, there will be no make-up exams.

Class Attendance, Participation and General Ethical Guidelines

The students are expected to regularly attend the lectures. If lectures are missed, the student should make sure you get up-to-date with the course material by reviewing the schedule and the material posted on the D2L course website. Students and faculty each have a responsibility for maintaining an appropriate learning environment. Those who fail to adhere to such behavioral standards may be subject to discipline. Active participation during classes (e.g. answering questions when asked by the instructor, show interest and motivation for the subject) is encouraged and it may be taken into account when establishing the final grade. While collaboration and discussion between students during homework is encouraged, plagiarism is not tolerated and may be subjected to disciplinary actions.

Textbooks

Szidarovszky and Bahill, Linear Systems Theory, Second Edition (Systems Engineering) Hardcover – November 25, 1997 (Required).

Instructor class notes and relevant material (the instructor will make them available through the D2L course website at d2l.arizona.edu)

Software

MATLAB (full version available for download to UA students)