RUTGERS

Syllabus for 16:332:505
Control Systems Theory
Spring, 2024

Time: Monday and Wednesday 3:50 am - 5:10 am (1 hour and 20 min)
Instruction mode: In-person
Location: Science & Engineering Resource Center – Room 212
Instructor: Dr. Daniel A. Burbano-L.
Email: daniel.burbano@rutgers.edu
Website: https://sites.rutgers.edu/swarm-intelligence-lab/
Office hours: TBD

Learning objectives: This course presents the theory of feedback control systems, with a focus on traditional topics in classical control theory, and application to electrical systems.
Topics include state-space representation and analysis, Internal stability, Lyapunov stability, nonlinear systems and linearization, control system design, controllability and observability, Optimal and Robust Control Design.

Pre-Requisite: Students should be familiar with differential equations and matrix/vector analysis.

Suggested Textbooks:

- **B1**: P. J. Antsaklis and A. N. Michel, A Linear Systems Primer by, Birkhauser Boston, 2007
- **B2**: W. J. Rugh, Linear Systems Theory, 2nd edition, Prentice-Hall, 1996
- **B3**: C.-T. Chen, Linear System Theory and Design, Oxford University Press, 2013

Homework: Three homework assignments will be given.

- Each homework assignment must be typed on a word-processor. Use of LaTeX is recommended, although other word processing platforms are acceptable.
- Students will be given extra points for clarity on the presentation of their HW.
- Students must upload their homework on Canvas.
- Students are permitted to discuss homework questions with other students, although they are not permitted to discuss solutions except in general terms.
- Solutions for all assigned problems will be provided
- Homework must be submitted by the deadline. Except for exceptional and documented circumstances, late homework are not accepted.

Project: Students should create small groups to work on a research project.
Each group will prepare and submit a written report and a 30 min presentation

The report/presentation should be organized as follows:

- Introduction (Broad overview of the problem under study, why it is important?, applications? Methods used to solve the problem, general conclusions from the study)
- Problem formulation/model: Clearly present the problem to be solved, derivation of the governing equations, the physical meaning of the state variables, and model parameters
- Analysis: Conduct a numerical analysis in MATLAB of the system under consideration
- Control design: Using the tools learned from class design controllers and implementing them in MATLAB
- Conclusions

Important Dates for the project:

- The topics of the projects will be defined in late February.
- Students will present a status update on the project on March 25/2024. The update consists of a 15-minute presentation to be done during class hours.
- Final presentation: Students will present their final projects in Late April during class hours.

Grading policy

The course final grade is determined as a sum of the following scores:
Homework: 25%
Midterm Exam: 20%
Project: 30%
Final Exam: 25%

Course grading will be based on the total score (TS) at the end of the semester according to $\mathrm{A}(TS \geq 90)$, $\mathrm{B}^+(TS \geq 82)$, $\mathrm{B}(TS \geq 75)$, $\mathrm{C}^+(TS \geq 67)$, $\mathrm{C}(TS \geq 60)$, $\mathrm{D}(TS \geq 50)$,

Tentative Lecture Schedule

* The course schedule can be changed by the instructor as needed

Lecture	Topic	Reading	Homework
1 Jan 17/2024	Review of feedback control systems and vector spaces	B2: Ch.1, B1: Ch.1 and Appendix A, B3: Ch.3	
2 Jan 22/2024	Review of Matrix Algebra, ODEs, Laplace Transform		
3 Jan 24/2024	State equation representation: Time Invariant Systems	B2: Ch.2, B1: Ch.2, and B3: Ch.2	
4 Jan 29/2024	State equation representation: Time Varying Systems		
5 Jan 31/2024	Nonlinear systems and linearization around equilibrium points	B2: Ch.2, B1: Ch.2, and B3: Ch.2	

6 Feb 05/2024	linearization around time varying trajectories		HW1
7 Feb 07/2024	The transition matrix: General analytical computation	B2: Ch.4-5, B1: Ch.3, and B3: Ch.4	
8 Feb 12/2024			
9 Feb 14/2024	The transition matrix: Properties and special cases		
10 Feb 19/2024	Internal Stability: General concept and examples of time-invariant systems	B2: Ch.6, B1: Ch.4, and B3: Ch.5	HW2
11 Feb 21/2024	Internal stability: general treatment for time-varying systems and examples of linearized systems		
12 Feb 26/2024	Lyapunov Stability and input-output stability: General concepts and Quadratic forms	B2: Ch.7, B1: Ch.4, and B3: Ch.5	
13 Feb 28/2024	Lyapunov Stability and input-output stability: General treatment for time-varying systems and examples of linearized systems		
14 Mar 04/2024			
15 Mar 06/2024	Mid-term exam		
Mar 09/2024 to Mar 17/2024	Spring Break		
16 Mar 18/2024	Controllability & Observability	B2: Ch.9, B1: Ch.5, and B3: Ch.6	
17 Mar 20/2024			
Mar 25/2024	Presentation: Project status update		
18 Mar 27/2024	State feedback: General Time varying systems and Pole Placement	B2: Ch.14-15, B1: Ch.9, and B3: Ch.8-9	
19 April 01/2024	Performance Specifications (Dominant Poles) and Feedforward action	Notes	HW3
20 April 03/2024	Observer design and Output feedback control	B2: Ch.14-15, B1: Ch.9, and B3: Ch.8-9	
21 April 08/2024	Optimal and Robust Control	Notes	
22 April 10/2024	Feedback Control for Tracking Problems	Notes	
23 April 15/2024	Model Predictive Control	Notes	
24 April 17/2024	Kalman Filter	Notes	
April 22/2024	Group Presentations I		
April 24/2024	Group presentations II		
May TBD/2024	Final Exam		