Nonlinear Control

EML 6350
Class Periods: MWF Period 3, 9:35-10:25 am
Location: NEB 100
Academic Term: Fall 2022

Instructor:
Warren E. Dixon
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352-846-1463
Office Hours: Wednesday 2-3 PM and Friday 10:30-11:30 AM or by appointment. **For appointments contact Stephanie Warrren** @ swarren@mae.ufl.edu

*To minimize class interruption due to occasional travel, some classes may be prerecorded. The time and location of the pre-recording will be posted so you will have an opportunity to attend the live lecture.

Grader:
Please contact through the Canvas website

- Lee, Angela <chialinglee@ufl.edu>

Course Description
Introduction to nonlinear analysis and control systems theory. Lyapunov-based analysis and design techniques.

This course is intended to introduce students to nonlinear analysis and control systems theory. The course is focused on Lyapunov-based analysis methods and associated design techniques. The first segment of the course introduces definitions of stability for autonomous and nonautonomous systems leading to a Lyapunov framework. Based on the developed Lyapunov-based analysis tools, basic and advanced design tools for contemporary engineering problems are presented including state-of-the-art techniques. Topics include: Solution Concepts for Nonlinear Differential Equations, Autonomous and Nonautonomous Systems, Integrator Backstepping, Observers and Filters, Switched and Hybrid Systems, and Robust and Adaptive Control. The content will be mathematical with illustrative examples taken from general engineering systems.

Course Pre-Requisites / Co-Requisites
The course is designed as an introductory course with no prerequisites, yet a general understanding of feedback systems, linear algebra, and exposure to differential equations will be beneficial. The student will also be expected to be able to use some simulation software (e.g., Matlab) to complete class projects.

Course Objectives
At the completion of the course, students should be able to use Lyapunov-based analysis tool to design controllers and to analyze the stability of continuous time nonlinear differential equations.

Materials and Supply Fees
None.

Required Textbooks and Software
None.

Strongly Recommended Textbook
Nonlinear Systems: Third Edition by H. Khalil, 2002.
Nonlinear Control: First Edition by H. Khalil, 2015.

Supplemental Textbooks

1. **Nonlinear Control of Engineering Systems: A Lyapunov-Based Approach** by W. E. Dixon, A. Behal, D. M. Dawson, and S. Nagarkatti, Birkhäuser Boston, 2003.
2. **Applied Nonlinear Control** by Jean-Jacques Slotine, Weiping Li, Pearson Education, 1990.
3. **Nonlinear Dynamical Systems and Control: A Lyapunov-Based Approach** by Wassim Haddad and VijaySekhar Chellaboina, Princeton Press, 2008.
4. **Switching in Systems and Control** by Daniel Liberzon, Springer Science, 2003.
5. **Hybrid Dynamical Systems: Modeling, Stability, and Robustness** by R. Goebel, R. Sanfelice, and A. Teel, 2012.

Course Content

1. Motivation for Nonlinear Control (Chapter 1 - Dixon)
2. Behavior of Nonlinear Dynamic Systems (Chapter 1,2 Khalil)
3. Lyapunov Stability (Chapters 3, 4 - Khalil)
4. Sliding Mode Control (Chapter 14- Khalil)
5. Integrator Backstepping (Chapter 14- Khalil)
6. Robust and Adaptive Control Applications (Chapter 2-6 - Dixon and Supplemental)
7. Switched and Hybrid Systems (Chapter 1,3 – Liberzon and Supplemental)

Attendance Policy, Class Expectations, and Make-Up Policy

Attendance is not required but highly encouraged. All students are responsible for all material presented in class. Office hours will not be used to compensate for class absence. Excused absences must be consistent with university policies in the Graduate Catalog (https://catalog.ufl.edu/graduate/regulations) and require appropriate documentation. Additional information can be found here: https://gradcatalog.ufl.edu/graduate/regulations/

Evaluation of Grades

Assignment	Total Points	Percentage of Final Grade
Exam 1	100	30%
Exam 2	100	30%
Exam 3	100	30%
Final Project	100	10%
		100%

Exams: There will be three exams and a final project. The exams will be administered as a mix of in-class (at normal meeting times) and take-home components. All exams will be cumulative but will emphasize the most recently covered material. There is no final exam. The final project will be assigned early in the semester, with an option to replace it with a research-based result.

Exam 1: Friday September 23.
Exam 2: Friday October 28.
Exam 3: Friday December 2.
Final Project Due Wednesday December 6.

Grading Policy

Percent	Grade	Grade Points
90.0- 100	A	4.00
86.7 - 89.9	B+	3.33
83.4 - 86.6	B	3.00

80.0 - 83.3	B-	2.67
76.7 - 79.9	C+	2.33
73.4 - 76.6	C	2.00
70.0 - 73.3	C-	1.67
66.7 - 69.9	D+	1.33
63.4 - 66.6	D	1.00
60.0 - 63.3	D-	0.67
0 - 59.9	E	0.00

More information on UF grading policy may be found at:
UF Graduate Catalog
Grades and Grading Policies

Students Requiring Accommodations
Students with disabilities who experience learning barriers and would like to request academic accommodations should connect with the disability Resource Center by visiting https://disability.ufl.edu/students/get-started/. It is important for students to share their accommodation letter with their instructor and discuss their access needs, as early as possible in the semester.

Course Evaluation
Students are expected to provide professional and respectful feedback on the quality of instruction in this course by completing course evaluations online via GatorEvals. Guidance on how to give feedback in a professional and respectful manner is available at https://gatorevals.aa.ufl.edu/students/. Students will be notified when the evaluation period opens, and can complete evaluations through the email they receive from GatorEvals, in their Canvas course menu under GatorEvals, or via https://ufl.bluera.com/ufl/. Summaries of course evaluation results are available to students at https://gatorevals.aa.ufl.edu/public-results/.

In-Class Recording
Students are allowed to record video or audio of class lectures. However, the purposes for which these recordings may be used are strictly controlled. The only allowable purposes are (1) for personal educational use, (2) in connection with a complaint to the university, or (3) as evidence in, or in preparation for, a criminal or civil proceeding. All other purposes are prohibited. Specifically, students may not publish recorded lectures without the written consent of the instructor.

A "class lecture" is an educational presentation intended to inform or teach enrolled students about a particular subject, including any instructor-led discussions that form part of the presentation, and delivered by any instructor hired or appointed by the University, or by a guest instructor, as part of a University of Florida course. A class lecture does not include lab sessions, student presentations, clinical presentations such as patient history, academic exercises involving solely student participation, assessments (quizzes, tests, exams), field trips, private conversations between students in the class or between a student and the faculty or lecturer during a class session.

Publication without permission of the instructor is prohibited. To "publish" means to share, transmit, circulate, distribute, or provide access to a recording, regardless of format or medium, to another person (or persons), including but not limited to another student within the same class section. Additionally, a recording, or transcript of a recording, is considered published if it is posted on or uploaded to, in whole or in part, any media platform, including but not limited to social media, book, magazine, newspaper, leaflet, or third party note/tutoring services. A student who publishes a recording without written consent may be subject to a civil cause of action instituted by a person injured by the publication and/or discipline under UF Regulation 4.040 Student Honor Code and Student Conduct Code.

University Honesty Policy

UF students are bound by The Honor Pledge which states, "We, the members of the University of Florida community, pledge to hold ourselves and our peers to the highest standards of honor and integrity by abiding by the Honor Code. On all work submitted for credit by students at the University of Florida, the following pledge is either required or implied: "On my honor, I have neither given nor received unauthorized aid in doing this assignment." The Honor Code (https://sccr.dso.ufl.edu/process/student-conduct-code/) specifies a number of behaviors that are in violation of this code and the possible sanctions. Furthermore, you are obligated to report any condition that facilitates academic misconduct to appropriate personnel. If you have any questions or concerns, please consult with the instructor or TAs in this class.

Commitment to a Safe and Inclusive Learning Environment

The Herbert Wertheim College of Engineering values broad diversity within our community and is committed to individual and group empowerment, inclusion, and the elimination of discrimination. It is expected that every person in this class will treat one another with dignity and respect regardless of gender, sexuality, disability, age, socioeconomic status, ethnicity, race, and culture.

If you feel like your performance in class is being impacted by discrimination or harassment of any kind, please contact your instructor or any of the following:

- Your academic advisor or Graduate Program Coordinator
- Jennifer Nappo, Director of Human Resources, 352-392-0904, jpennacc@ufl.edu
- Curtis Taylor, Associate Dean of Student Affairs, 352-392-2177, taylor@eng.ufl.edu
- Toshikazu Nishida, Associate Dean of Academic Affairs, 352-392-0943, nishida@eng.ufl.edu

Software Use

All faculty, staff, and students of the University are required and expected to obey the laws and legal agreements governing software use. Failure to do so can lead to monetary damages and/or criminal penalties for the individual violator. Because such violations are also against University policies and rules, disciplinary action will be taken as appropriate. We, the members of the University of Florida community, pledge to uphold ourselves and our peers to the highest standards of honesty and integrity.

Student Privacy

There are federal laws protecting your privacy with regards to grades earned in courses and on individual assignments. For more information, please see: https://registrar.ufl.edu/ferpa.html

Campus Resources:

Health and Wellness

U Matter, We Care:

Your well-being is important to the University of Florida. The U Matter, We Care initiative is committed to creating a culture of care on our campus by encouraging members of our community to look out for one another and to reach out for help if a member of our community is in need. If you or a friend is in distress, please contact umatter@ufl.edu so that the U Matter, We Care Team can reach out to the student in distress. A nighttime and weekend crisis counselor is available by phone at 352-392-1575. The U Matter, We Care Team can help connect students to the many other helping resources available including, but not limited to, Victim Advocates, Housing staff, and the Counseling and Wellness Center. Please remember that asking for help is a sign of strength. In case of emergency, call 9-1-1.

Counseling and Wellness Center: https://counseling.ufl.edu, and 392-1575; and the University Police Department: 392-1111 or 9-1-1 for emergencies.

Sexual Discrimination, Harassment, Assault, or Violence

If you or a friend has been subjected to sexual discrimination, sexual harassment, sexual assault, or violence contact the **Office of Title IX Compliance**, located at Yon Hall Room 427, 1908 Stadium Road, (352) 273-1094, title-ix@ufl.edu

Sexual Assault Recovery Services (SARS)
Student Health Care Center, 392-1161.

University Police Department at 392-1111 (or 9-1-1 for emergencies), or http://www.police.ufl.edu/.

Academic Resources

E-learning technical suppor*t*, 352-392-4357 (select option 2) or e-mail to Learning-support@ufl.edu. https://lss.at.ufl.edu/help.shtml.

Career Connections Center, Reitz Union, 392-1601. Career assistance and counseling; https://career.ufl.edu.

Library Support, http://cms.uflib.ufl.edu/ask. Various ways to receive assistance with respect to using the libraries or finding resources.

Teaching Center, Broward Hall, 392-2010 or 392-6420. General study skills and tutoring. https://teachingcenter.ufl.edu/.

Writing Studio, 302 Tigert Hall*,* 846-1138. Help brainstorming, formatting, and writing papers. https://writing.ufl.edu/writing-studio/.

Student Complaints Campus*:* https://sccr.dso.ufl.edu/policies/student-honor-code-student-conduct-code/;https://care.dso.ufl.edu.

On-Line Students Complaints*: https://distance.ufl.edu/state-authorization-status/#student-complaint.*