Syllabus for
Nonlinear Control 2
EML: 6351

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Office Hours: Zoom meeting Monday evening at 5pm ET or by virtual appointment but email anytime

Lecture Location and Hours:
Lectures will be recorded via Zoom Tuesday, Wednesday, and Thursday evening at 5pm ET; however, to minimize class interruption due to occasional travel, some lectures may be uploaded earlier.

Zoom link for office hours and lecture:
https://ufl.zoom.us/j/98700371853?pwd=YjUvdFZVa3VmS2t3RmhMemtHODlFZz09
Meet ID: 98700371853
Passcode: 008233

Course Overview: The objective of this course is to introduce students to advanced nonlinear adaptive control methods. Students will learn underlying theory derived from fundamental engineering science principles and will apply the theory to solve complex engineering problems using knowledge of mathematics. The objective will be achieved through:

- Uploaded lectures and examples
- Student completion of projects

Professional Component (ABET):
This course prepares graduates to have a knowledge of nonlinear Lyapunov-based control analysis and design methods and to have design competence that integrates covered topics.

Relation to Program Outcomes (ABET):

Outcome	Coverage*
1) An ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics.	High
2) an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors	
3) an ability to communicate effectively with a range of audiences	
4) an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgements, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts	
5) an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives	
6) an ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions	
7) an ability to acquire and apply new knowledge as needed, using appropriate learning strategies	Medium

Coverage is given as high, medium, or low. An empty box indicates that this outcome significantly addressed by this course.

Strongly Recommended Textbook:

Nonlinear Systems: Third Edition by H. Khalil, 2002.

Supplemental Textbooks on Deep Learning and Reinforcement Learning (not required but good references):

1. **Deep Learning** by Ian Goodfellow, Yoshua Bengio, and Aaron Courville, MIT Press, 2015.
2. **Reinforcement Learning: An Introduction Second Edition** by Richard S. Sutton and Andrew G. Barto, MIT Press, 2018
3. **Reinforcement Learning for Optimal Feedback Control: A Lyapunov-Based Approach** by Rushikesh Kamalapurkar, Patrick Walters, Joel Rosenfeld, and Warren Dixon, Springer, 2018

Supplemental Textbooks on Controls (not required but good references):

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.

Course Overview: This course is intended to expose students to nonlinear adaptive control analysis and theory. The course is focused on Lyapunov-based analysis methods and associated design techniques. The course will examine specific adaptive control methods, the stability of these methods using Lyapunov-based theory, and the implementation of these methods on nonlinear systems. There are numerous methods in this field but the topics we will focus on are: robust control methods, various data-based learning methods for generalized nonlinear systems, deep learning methods, and reinforcement learning methods. The content will be mathematical with illustrative examples taken from general engineering systems. The course is designed with the assumption of basic understanding of Lyapunov-based nonlinear control theory, but an understanding of linear algebra, and exposure to machine learning will be beneficial. The student will also be expected to be able to use simulation software (e.g., Python or Matlab) to complete class projects.

Course Content

1. Development and Simulation of Nonlinear Dynamics for Robotic Systems
2. Concurrent Learning Methods
3. Single Layer Neural Networks
4. Deep Neural Networks
5. RISE Methods
6. Reinforcement Learning

Projects: There will be a project analyzing and implementing each of the methods examined in the course. Depending on the pace of the course, some content may be removed; however, each project will be given 1-3 weeks to complete. During each project, we will primarily focus on material related to that project.

Projects	**Start Date**
Dynamics Simulation	January 7
Integral Concurrent Learning	January 14
Single Layer Networks	January 28
Deep Neural Networks	February 18
RISE	March 11
Reinforcement Learning	April 1

Exams: The course will not include any exams.

Attendance: Not required. All students are responsible for all material presented in class.

Late/Makeup Policy: Make-up will be given only for special circumstances that are pre-approved by the instructor.

Academic Honesty: All students admitted to the University of Florida have signed a statement of academic honesty committing themselves to be honest in all academic work and understanding that failure to comply with this commitment will result in disciplinary action. This statement is a reminder to uphold your obligation as a student at the University of Florida and to be honest in all work submitted and exams taken in this class and all others. All students should review the University's honor code policy you will be held to it.

For any project, sharing of code is considered a direct violation of the academic honesty policy.

Course Grading:
Projects (6) 16.67% each