

ME:5114 Nonlinear Control in Robotic Systems Spring 2024

Catalog Description: Linearization of Nonlinear Systems, Nonlinear Autonomous and Nonautonomous Systems, Lyapunov Stability, State Feedback, Output Feedback, Feedback Linearization, Backstepping, Robust and Adaptive Control, Robot Manipulator, and Wheeled Mobile Robots.

Prerequisites: Any of ME:3600, ME:4120, CBE:4150, ECE:3600 or equivalent

Instructor: Professor Shaoping Xiao, 2416B SC, shaoping-xiao@uiowa.edu

Student Hours: MWF 2:30 PM – 3:20 PM @ 2416B SC
Please email me if you need to make an appointment outside of these hours.

Lecture time: MWF 10:30 – 11:20 AM @ 3026 SC

Textbook: Lecture notes and reading materials provided by the instructor @ ICON

References: *Nonlinear Systems*: Third Edition by H. Khalil, 2002
Applied Nonlinear Control by Jean-Jacques Slotine, Weiping Li, Pearson Education, 1990

Course Goals: This course will expose students to nonlinear analysis and control systems theory. The course is focused on nonlinear autonomous and nonautonomous systems, as well as the applications of nonlinear control design tools on robotics systems. Lyapunov-based analysis methods and associated design techniques are emphasized. The first segment of the course introduces definitions of stability for autonomous and nonautonomous systems, leading to a Lyapunov framework. Then, based on the developed Lyapunov-based stability analysis tools, basic and advanced design tools for contemporary engineering problems are presented, including state-of-the-art techniques. Python programming will be utilized in this course. Also, some complementary topics are introduced, including advanced control techniques (LQR, MPC, Kalman filter) and reinforcement learning.

Homework Weekly homework will be assigned. Late homework is accepted by the next lecture after the due date. Only partial credits will be given for late homework. Detailed steps are needed for full credits if homework assignments are required via hand calculation.

Project Students will conduct team projects (2-3 students per team) to apply the control design tools to robotic systems. A final report is required.

Attendance: Attendance is mandatory and will be counted towards your final grade. Students are allowed to make up examinations that have been missed due to illness, religious holy days, other unavoidable circumstances, or sponsored University activities.

Grading Homework 40%; Midterms 30%; Project 20%; Attendance 10%

Free Speech and Expression: The University of Iowa supports and upholds the First Amendment protection of freedom of speech and the principles of academic and artistic freedom (<https://freespeech.uiowa.edu>). We are committed to open inquiry, vigorous debate, and creative expression inside and outside the classroom.

Classroom expectations: The learning activities in this course benefit from you coming to class prepared and participating. I have found this is the best way to engage with the material, and it allows all of us to learn from one another. The expected classroom behaviors are outlined in the Code of Student Life (<https://dos.uiowa.edu/policies/code-of-student-life>). Please be aware that failure to follow behavior expectations may be addressed by me and may also result in discipline under the Code of Student Life policies governing E.5 Disruptive Behavior or E.6 Failure to Comply with University Directive.

Attendance: Please plan to attend every class. However, I recognize that illness or other extenuating circumstances can arise to make this difficult. If you cannot participate in a class, please let me know, and I can work with you regarding making up missed work such as assignments, quizzes, and classroom attendance. If you know you will miss an examination due to illness, religious holy days, military service obligations, or other unavoidable circumstances or other sponsored University activities (<https://opsmanual.uiowa.edu/students/absences-class>), please let me know as soon as possible. We can work together to have you make up the examination. I may require documentation in the case of a brief illness. Some specific instructions are described below.

Illness, Unavoidable Circumstances, and University Sponsored Activities: Please communicate with me at your earliest convenience.

Holy Days: You may notify me in writing of any such religious Holy Day conflicts within the first days of the semester and no later than the third week.

Military Service Obligations: Please discuss the expected possibility of missing class with me as soon as possible.

Accommodations for Students with Disabilities: The University is committed to providing an educational experience that is accessible to all students. If you have a diagnosed disability or other disabling condition that may impact your ability to complete the course requirements as stated in the syllabus, please seek accommodations through Student Disability Services (SDS <https://sds.studentlife.uiowa.edu/students>), which is responsible for making Letters of Accommodation (LOA) available to you. The LOA will specify what reasonable course accommodations you are eligible for and those I should provide. It would be very helpful if you could provide me an LOA as early in the semester as possible (at least two weeks prior to the scheduled activity for which an accommodation is sought). Additional information can be found on the SDS website (<https://sds.studentlife.uiowa.edu>).

Academic Integrity: As students enrolled in courses offered by the College of Engineering, you are expected to follow the College's Code of Academic Honesty (<https://engineering.uiowa.edu/current-students/advising-and-academic-information/academic-policies-and-procedures/academic-0>). Whether collaborations are allowed on assignments shall be specified on my syllabus. If you have questions about these boundaries or need clarification, please let me know.

Non-discrimination Statement: To make the campus a comfortable zone for your living and study, the University of Iowa prohibits discrimination and harassment on the basis of race, creed, color, religion, national origin, age, sex, pregnancy, disability, genetic information, status as a U.S. veteran, served in the U.S. military, sexual orientation, gender identity, associational preferences, or any other classification that deprives a person of consideration as an individual (<https://opsmanual.uiowa.edu/community-policies/human-rights>). For more information, you may contact the Office of Institutional Equity (<https://diversity.uiowa.edu/division/oie>). It would be helpful if you could share your pronouns and chosen/preferred names in [MyUI](#), which is accessible to instructors and advisors.

Sexual Harassment /Sexual Misconduct and Supportive Measures: The University of Iowa prohibits all forms of sexual harassment, sexual misconduct, and related retaliation. The Policy on Sexual Harassment and Sexual Misconduct (<https://opsmanual.uiowa.edu/community-policies/sexual-harassment-and-sexual-misconduct>) governs actions by students, faculty, staff, and visitors. Incidents of sexual harassment or sexual misconduct can be reported to the Title IX and Gender Equity Office (<https://osmrc.uiowa.edu/report-problem-0>) or to the Department of Public Safety (<https://police.uiowa.edu>). Please be aware that students impacted by sexual harassment or sexual misconduct may be eligible for academic supportive measures and can learn more by contacting the Title IX and Gender Equity Office. Information about confidential resources can be found at <https://osmrc.uiowa.edu/confidential-resources>. If needed, you can watch this video (https://www.youtube.com/watch?v=Jfjo6v6_b3Y) for an explanation of these resources.

Mental Health: It would be normal to feel overwhelmed and/or struggle to meet course expectations. I would like to encourage you to be mindful of your mental health and seek help as a preventive measure. You are welcome to talk to me for assistance with specific class-related concerns. For additional support and counseling, you may contact the University Counseling Service (UCS) <http://counseling.uiowa.edu>.

Basic Needs and Support for Students: We've all needed help in something at some point in our lives. Student Care & Assistance provides assistance to University of Iowa students experiencing a variety of crisis and emergency situations, including but not limited to medical issues, family emergencies, unexpected challenges, and basic sourcing needs such as food and shelter. You can find more information on the resources related to basic needs at this website: <https://basicneeds.uiowa.edu/resources/>. You also can contact Student Care & Assistance in the Office of the Dean of Students (Room 135 IMU, dos-assistance@uiowa.edu, or 319-335-1162) for support and assistance with resources.

DEI statement: It is my intention that all students, regardless of their diverse backgrounds and perspectives, are well-served by this course. We aim to address students' learning needs both in and out of the classroom, recognizing that the diversity students bring to this class is a valuable resource and strength. We reject all forms of prejudice and discrimination, including but not limited to those based on age, color, disability, gender, gender identity, gender expression, national origin, political affiliation, race, religion, sexual orientation, and veteran status. As a community, we prioritize respect for all. Both students and I are expected to commit to creating an environment that encourages inquiry and self-expression while understanding and respecting different viewpoints. Your suggestions for improving the course's effectiveness, whether for you, other students, or student groups, are encouraged and appreciated.

Please check more details @ <https://provost.uiowa.edu/student-course-policies>.