ME/AER 676 Robot Modeling And Control

Contact Information

Instructor:	Dr. Hasan A. Poonawala
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Office hours:	Wed 2pm - 3pm; Friday 11am - 12pm

Course Information

Time: Tue & Thurs 11:00 am - 12:15 pm
Location: In-person: Robotics & Manufacturing Bldg. Rm. 309.

Course Materials: Materials will be disseminated through the **Course Webpage**. Announcements will be made via `Canvas`. I recommend ensuring that announcements are sent to your email.

Course Description

This course covers the fundamentals of robot dynamics and motion control. We focus on two broad types of motion control problems: trajectory tracking in free space, and contact-rich manipulation. Students will see a broad range of approaches to solving these two problems, with a deeper study of state-of-the-art approaches through class discussions and project work. Throughout the course, we view these fundamentals in the context of applications such as quadrotor control, legged locomotion, and robot manipulation.
The course also introduces algorithms relevant to practical robotics: path planning (RRT*), Simultaneous Localization and Mapping (SLAM), and robot perception using Deep Learning.
Throughout the course, students will use simulations to apply the concepts they are learning. Students may use any language and simulation environment, which often include pre-existing packages for robotics. Examples include `Matlab`, `ROS`, `Gazebo`, `PyBullet`, `MuJoCo`, and `JuliaRobotics`.

Course Topics

Robot Configurations, Task Coordinates; Kinematics, Jacobians; Forward and Inverse Problems; Robot Dynamics Models; Trajectory Tracking; Trajectory Planning; Force and Impedance Control; Trajectory Optimization; Introduction to State Estimation; Introduction to Optimal Control, and Reinforcement Learning for robotics.

Prerequisites

No enforced course prerequisites. The course relies heavily on familiarity with linear and matrix algebra, intermediate dynamics (nonlinear ODE models, ME 644), and control systems (ME 340, 440, 645, 647). Assignments and projects require competency in software programming. Attempting to learn too many of these topics for the first time during the semester will be overwhelming.

Student Learning Outcomes

The goal of this course is to enable students to comprehend core methods for motion control of robots, and be able to implement these methods in simulation. Students will be able to critically examine robotics algorithms from a theoretical perspective. Through this course, students will

- understand what is meant by robot configuration and task coordinates,
- understand how to transform the robot configuration into task coordinates and *vice versa*, along with the challenges in these processes,
- learn approaches to planning motions in both task coordinates and robot configurations,

- learn approaches to executing planned motions using feedback control,
- understand the challenges of state estimation and perception,
- understand the dynamics and mechanics involved in robotic manipulation,
- understand the challenges introduced by robot-environment contact and how to manage them,
- understand the relationship between optimal control, motion planning, and reinforcement learning,
- simulate robotic systems and test control algorithms.

Source Materials: No required textbook.
Online Sources:
Notes on **Course Webpage**
Modern Robotics (pdf)
Course on `Julia`
Supplementary textbooks:
Robot Modeling and Control, M. W. Spong, S. Hutchinson, and M. Vidyasagar, John Wiley & Sons, 2006.
Robotics, Vision, and Control, Peter Corke, Springer International Publishing, 2017.
Introduction to Robotics: Mechanics and Control, J. J. Craig, Prentice Hall, 2004.
Robotics: Modelling, Planning and Control, B. Siciliano, L. Sciavicco, L. Villani, and G. Oriolo, Springer, 2011.

Office Policy

I encourage students to seek help if they have questions. I am available for technical questions during my office hours. For discussions related to other issues, please set up an appointment to meet with me.

Email Policy

I will respond to relevant emails within 48 hours, between 8am and 6pm. I welcome general questions through email; however, I prefer that you attend class or office hours for technical questions.

Course Assignments

	Weight	Due (Tentative)
Assignment 1	10%	Week 3
Assignment 2	10%	Week 6
Assignment 3	10%	Week 9
Paper Reviews	20%	-
Project Abstract	15%	Week 8
Project Midterm Paper	15%	Week 12
Project Paper	15%	Week 15
Project Presentation	5%	Week 15

Midterm and Final Exams

There are no exams for this course.

Git

Release (and submission) of some assignments (solutions) will involve use of the `git` version control system. Students will learn to use `git` largely through self-study. See this online course for an introduction to `git`.

Homework Assignments

Code assignments: Three assignments involve writing code for simulation of robot algorithms. Assignments may be attempted and submitted in groups of no more than three individuals.
Paper Reviews: Students will be assigned a collection of papers that they must read each week. The assignment involves submitting a summary of the papers.

Homework Grading
Code assignments are graded based on successful generation of a satisfactory solution. Paper reviews are graded based on satisfactory summary of papers.

Course Grading
The course is graded based on successful completion of assignments and the project (proposal; final paper).

Academic Integrity
Per University policy, students shall not plagiarize, cheat, or falsify or misuse academic records. Students are expected to adhere to University policy on cheating and plagiarism in all courses.

Attendance Policy
Students are responsible for all material covered during lectures. Attendance is strongly recommended; however, attendance will not be taken during lecture.

Classroom Conduct
Students are expected to conduct themselves in a professional and courteous manner. While this course consists primarily of lectures, students are encouraged to ask questions during lectures. There is no talking during class unless contributing to class discussion. There is no eating during class. Please ensure that cell phones do not ring during class.

Excused Absences
Students anticipating an absence for a major religious holiday are responsible for notifying the instructor in writing of anticipated absences due to their observance of such holidays no later than the last day in the semester to add a class. Two weeks prior to the absence is reasonable, but should not be given any later. Information regarding major religious holidays may be obtained through the Ombud ($859 - 257 - 3737$).
Per Senate Rule 5.2.4.2, students missing any graded work due to an excused absence are responsible for informing the Instructor of Record about their excused absence within one week following the period of the excused absence (except where prior notification is required).

Make-up Exams
None.

Accommodations due to disability
If you have a documented disability that requires academic accommodations, please arrange to meet with me as soon as possible during scheduled office hours. In order to receive accommodations in this course, you must provide me with a Letter of Accommodation from the Disability Resource Center (DRC).

Further Information
Please see this link for further information and details on policies regarding excused absences, verification of absences, academic integrity, Title IX and discrimination.