ME 599/699
Robot Modeling And Control
Spring 2021

Contact Information

Instructor:	Dr. Hasan A. Poonawala
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Office hours:	TBD

Course Information

Time: Tue & Thurs 12:30 pm - 1:45 pm
Location: In-person: RGAN 203; Online: Zoom link

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 teaches students about what it takes to make robots move the way we want them to move. There are three parts to the course. The first part discusses how to represent robot position and motion mathematically. The second part focuses on executing motion through feedback control. The third part focuses on planning and perception. Beyond these core topics, we will look at how machine learning is being applied to robotics.
Throughout the course, students will use simulations to apply the concepts they are learning. We will primarily use `Julia`, assignments will require it. Students must expect to spend time every week becoming familiar with `Julia`.

Course Topics

Robot Configurations; Task Coordinates, Kinematics, Jacobians; Trajectory Planning; Motion Models; Trajectory Tracking; Introduction to State Estimation; Introduction to Trajectory Optimization, Optimal Control, Reinforcement Learning.

Prerequisites

No enforced course prerequisites. The course relies heavily on familiarity with linear algebra, dynamics (nonlinear ODE models), and control systems. Coursework involves programming using Julia, MATLAB. Attempting to learn too many of these for the first time during the semester will be overwhelming.

Student Learning Outcomes

The goal of this course is to enable students to comprehend various methods for motion control of robots, and be able to implement core algorithms in simulation. For ME 699 students, students will be able to critically examine robotics algorithms from a theoretical perspective, and propose methods that overcome existing approaches. 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 relationship between optimal control, motion planning, and reinforcement learning.
- simulate robotic systems and test control algorithms.

Source Materials: No required textbook.
Online Sources:
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 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%	Weekly
Project Proposal	30%	Week 8
Project Paper	20%	Week 15

Midterm and Final Exams
There are no exams for this course.

Julia & Git
The assignments require use of the `Julia` programming environment. Dissemination (submission) of some assignments (solutions) will involve use of the `git` version control system. Students will learn to use `Julia` and `git` largely through self-study. A good resource for `Julia` is this online course. Similary, see this online course for `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.

Tentative Course Schedule
See next page.

Course Schedule

Week	Mode	Class	Date	Day	Topic
1	In-person	1	Jan 26	T	Course Overview: Robots as powered mechanisms; Motion Tasks
	Online	2	Jan 28	R	Simulation using `Julia`; Alternatives
2	Online	3	Feb 2	T	Vector Spaces; Reference Frames & Coordinates; Coordinate/Frame Transformations
	Online	4	Feb 4	R	Kinematic Chains; Rigid Body Transformations: Homogenous Transformations
3	Online	5	Feb 9	T	Forward Kinematics; Jacobians; Force-Torque Relationships; Singularities; Manipulability
	Online	6	Feb 11	R	Inverse Kinematics; Differential Algorithms
4	Online	7	Feb 16	T	Robot Dynamics; Properties of Robot Dynamics
	Online	8	Feb 18	R	Set-point regulation; Actuators; Geared Motors
5	Online	9	Feb 23	T	Trajectory Tracking; Independent Joint Control; Feedforward Compensation
	Online	10	Feb 25	R	Computed Torque Control; Flexible-Joint Robots
6	?	11	Mar 2	T	Passivity-Based Control; Adaptive Control
	?	12	Mar 4	R	Force Control; Contacts
7	?	13	Mar 9	T	Whole-Body Control; Operational Space Control
	?	14	Mar 11	R	Impedance Control; Passivity
8	?	15	Mar 16	T	Intro to Optimal Control
	?	16	Mar 18	R	Deep Reinforcement Learning & Robotics
9	?	17	Mar 23	T	Perception #1
	?	18	Mar 25	R	Perception #2
10	?	19	Mar 30	T	Path Planning & Motion Planning
	?	20	Apr 1	R	Sampling-Based Planning Methods: PRM; RRT
11	?	21	Apr 6	T	State Estimation; Kalman Filter
	?	22	Apr 8	R	SLAM
12	?	23	Apr 13	T	TBD
	?	24	Apr 15	R	TBD
13	?	25	Apr 20	T	TBD
	?	26	Apr 22	R	TBD
14	?	27	Apr 27	T	TBD
	?	28	Apr 29	R	TBD
15	In-person	29	May 4	T	Project Evaluations
	In-person	30	May 6	R	Project Evaluations
16	-	31	May 11	T	(Finals Week)
	-	32	May 13	R	(Finals Week)