ME 403

Introduction to Robotics

Spring 2023

Course Information

Lecture:	Tuesday	12:40am – 2:30pm @ FENS L055 and synchronous Zoom session
	Wednesday	12:40pm – 1:30pm @ FASS G056 and synchronous Zoom session
Recitation:	Tuesday	5:40pm – 7:30pm @ FENS L035 and synchronous Zoom session
Laboratory:	Thursday	5:40pm – 7:30pm @ FENS G029 and synchronous Zoom session
Credit:	3 credit hours	

Instructor

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Resources

Web Site:	Available through SUCourse. Please check regularly for announcements and updates.
Textbook:	Mark W. Spong, Seth Hutchinson, M. Vidyasagar, Robot Modeling and Control, John Wiley & Sons, Inc., 2006. Several copies of the book are available at the library.

Prerequisites and Co-requisites

A minimum grade of "D" from ENS206 or equivalent is a strictly enforced prerequisite. ME403R and ME403L are the co-requisites for the course. Attendance to ME403L is mandatory, while attendance to lectures and recitations are highly encouraged. Students are also expected to have a working knowledge of differential equations, linear systems, statics, kinematics and dynamics. Familiarity with programming is recommended.

Purpose

This course is designed to equip students with fundamental theories and computational methodologies that are used in design and analysis of robotic systems. Students will learn how to analytically formulate kinematic and dynamic equations for robot manipulators, how to synthesize trajectory and force tracking controllers, as well as how to utilize numerical algorithms to simulate and real-time hardware-in-the-loop controllers to implement such closed-loop control systems.

During the first part of the course, students will be introduced to rigid motions in space and homogeneous transformations, forward and inverse kinematics at configuration and velocity levels, and Lagrange's equations. Computer-aided dynamic simulations with numerical time integration methods will be exercised.

During the second part of the course, students will be introduced to path and trajectory planning methods, as well as fundamental techniques for robot control. In particular, independent joint control, multi-variable control, force and impedance control approaches will be introduced and implemented on the hardware.

The emphasis in this course is an integrated understanding of the kinematic/dynamic modeling and control concepts for robotic manipulators. Real-time hardware-in-the-loop implementation of the controllers is also emphasized such that students can experience the control challenges of the real world, such as sensor noise and unmodeled system dynamics.

This course involves a hands-on laboratory component (ME 403L) and a team project where the students are expected to implement their algorithms on sample robotic platforms.

Homework

Homework will be assigned regularly and posted on the course web site. Hard copies will generally not be made available in class, so you will have to produce your own printout.

Exams

There will be one mid-term and one final exam. Since the course continually builds upon previous material, all exams will be comprehensive. In class exams are closed book, with one page of formulas supplied by the instructor.

Lecture

The lecture format will be loose. There may be a short break during the two hour lecture period. Extra lectures and problem solving sessions may be scheduled if necessary. Class participation and cooperation among students are highly encouraged. Student feedback will be collected throughout the semester and adaptation will be undertaken accordingly.

Project/Take-Home Exam

Students will be assigned a course project that will be graded as a take-home exam. The project topic will address a real life problem and aims to let students demonstrate their proficiency at a technical level.

Tentative Grading Policy

Your course grade is determined from the total points you receive from attendance, homework, midterm, project/take-home exam, laboratory assignments, and the final exam. Borderline grades are determined by class participation.

Homework must be submitted to the assigned teaching assistants by the end of the due date (5:00pm). **No late problem sets will be accepted.** (Extensions may be granted for special circumstances and only when requested **at least one day in advance**.)

You are responsible for all information given in class verbally and/or in writing. Any information about the course on the web may be replaced by the information given in the class.

Cooperative efforts at understanding the material and the assignments of the course are encouraged. You may also use the assignments of the previous years as exercises. However, you may only submit work that **you** have completed **individually**. For example, you may communicate verbally about methods for solving the assigned problems, but **sharing written work is not permitted**. Copying solutions from the assignments of the previous years or from internet resources is also **strictly forbidden**. Submitting any work that is not the result of a student's own effort is considered cheating and will result in **disciplinary action**.

Homework Sets:	20%
Midterm Exam:	20%
Laboratory Assignments:	20%
Take-Home Exam:	20%
Final Exam:	20%
	100%

Other Notes

Any student with a disability requiring accommodation in this course is encouraged to contact the instructor during the first two weeks of the semester.
Students whose attendance to exams is less than 50% will be assigned an "NA" grade.

We may have to revise the course plan according to the countrywide reassessment to be made regarding higher education. This is expected to happen at the beginning of April. The content to be delivered is certain but the method of course delivery, the number and dates of exams, and some other details are subject to change.

Tentative Schedule and Topics

	<u>Introduction</u>
Week 1	History Highlights and Future Terminology
	<u>Mathematics of Rigid Body Motion</u>
Week 2 and 3	Vectors, Bases, Frames Coordinate Vectors Similarity Transformations Rotations in Space and Topology of SO(3) Representing Rotations Homogeneous Transformations
	<u>Kinematics</u>
Weeks 4 – 7	Kinematic Chains Denavit-Hartenberg Convention Forward Kinematics Inverse Kinematics Angular Velocity Kinematic and Analytic Jacobian Singularities Static Force/Torque Relationship
	<u>Dynamics</u>
Week 8 – 10	Holonomic Constraints and Virtual Work Kinetic and Potential Energy Inertia Euler-Lagrange Equations Properties of Robot Dynamic Equations Numerical Integration of Equations of Motion
	<u>Robot Control</u>
Weeks 11 – 14	Actuator and Drive Train Dynamics Feed-forward Compensation Independent Joint Control Inverse Dynamics and Computed Torque Control Passivity Based Control Force and Impedance Control