Course Syllabus

MEC 549: Robot Dynamics and Control

Fall 2022

Instructor	Amin Fakhari, Ph.D., Department of Mechanical Engineering
Office	165 Light Engineering, Stony Brook University
Office Hours	Wed 5:45 – 7:00 PM, Thu 1:30 – 3:00 PM (and, any other time by appointment*)
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* I will respond to your emails as soon as possible, however, please allow 24-48 hours for a response. Please use your SBU email for all your communications.

Course Detail

Title	MEC 549: Robot Dynamics and Control
Credit	3
Lecture	Wed 2:40 – 5:30 PM, Melville Library N3063
Prerequisites	Students are expected to have taken MEC 529 (Introduction to Robotics: Theory and Applications) or an equivalent course that covers the kinematics of rigid bodies and robotic manipulators. Students should be comfortable with programming in either MATLAB or Python.

References

- Kevin M. Lynch and Frank C. Park, *Modern Robotics: Mechanics, Planning, and Control*, Cambridge University Press, 2017 [Publisher, Amazon, PDF (freely available by its publisher)].
- Bruno Siciliano, Lorenzo Sciavicco, Luigi Villani, Giuseppe Oriolo, *Robotics: Modelling, Planning and Control*, Springer, 2009 [Publisher, Amazon].
- Rafael Kelly, Victor Santibáñez Davila, and Julio Antonio Loría Perez, *Control of Robot Manipulators in Joint Space*, Springer, 2005 [Publisher, Amazon].
- Frank L. Lewis, Darren M. Dawson, and Chaouki T. Abdallah, *Robot Manipulator Control: Theory and Practice*, 2nd Edition, CRC Press, 2003 [Publisher, Amazon, PDF (freely available by its authors)].

Course Description

This course will cover the fundamentals of dynamic modeling and control techniques for robots, focusing mainly on robot manipulators. The **dynamic modeling** part includes Lagrange formulation, Newton–Euler formulation, properties of the dynamic equations, and trajectory planning with dynamic constraints, and the **control** part includes nonlinear systems, state-space representation, Lyapunov stability theorems, feedback linearization, linear controller design, position control, motion control, inverse dynamics control, robust control, adaptive control, force control, impedance control, hybrid motion–force control, and implementation of controllers.

Course Learning Objectives

Upon completion of this course, students will be able to

- Derive the dynamic equations of motion of a robot manipulator.
- Plan trajectories subject to the robot's actuator limits.
- Understand the concepts of stability and the basis of feedback controller design for manipulators.
- Understand and implement the different position, motion, and force control algorithms.

Tools

Blackboard: It is required that you use the Blackboard for this course. Blackboard is used for facilitation of communications between faculty and students, submission of assignments, posting of the course materials, important announcements, and grades.

MATLAB: It is a programming and numeric/symbolic computing environment developed by MathWorks. MATLAB allows matrix manipulations, plotting of functions and data, implementation of algorithms, creation of user interfaces, and interfacing with programs written in other languages. An additional package, Simulink, adds graphical multi-domain simulation and model-based design for dynamical systems and embedded systems. You can Download and Install MATLAB Software using your SBU email address. Make sure to install Robotics System Toolbox while installing MATLAB.

Homework Assignments, Paper Review, and Final Project

- Homework assignments will be assigned in the class or posted on Blackboard.
- You are allowed and encouraged to discuss and work with your classmates, however, you have to submit your own homework. Any discussion or help that you have taken from your classmates should be acknowledged explicitly by writing their names and the kind of help you have received. Note that your homework should not be a copy of your classmate's homework.
- You have up to 15 late days for use on any homework assignment throughout the semester, but no homework may be more than 5 days late. Once you used your budget of 15 late days for the semester, each late day will be assessed a 25% penalty on your grade for that assignment(s).
- Each student will select an academic paper to review, present, and discuss with the class. Each presentation should follow the following format:
  - (a) Title Slide: Including authors names and institutions, the presenter's name, and date,
  - (b) Summary Slide: Summary of the main contributions of the paper,
  - (c) Background Slide(s): Summary of the relevant background of the problem to be solved,
  - (d) Method Slide(s): Summary of the methods used,
  - (e) Results Slide(s): Details of the paper's main results including supporting figures,
  - (f) Strengths Slide(s): Discussion of at least one major strength of the paper,
  - (g) Weakness Slide(s): Discussion of at least one major weakness and how it might be improved.
- There will be one final project that will be done in groups of at most 2 students. You have to submit a final project report and present it in the class (more information will be provided during the semester).
- No late submission is allowed for the final project report.
- All students are expected to attend all paper review and final project presentations.

Examinations

Midterm Exam	Wed, Oct. 5, 2022 (in class)
Final Exam	Wed, Dec. 7, 2022, 5:30 – 8:00 PM (in class)

(a) There will be no make-up exams unless provided me an official proof of the reason before, or within three days following the exam.
(b) The exam dates are subject to change. Students will be notified in a timely manner of any changes in the exam dates.

Grading Policy

Homework	35%
Midterm Exam	20%
Paper Review & Presentation	10%
Final Project & Presentation	35%

Grading Scale

A	[100, 90]%	**A$^-$**	(90, 85]%		
B$^+$	(85, 80]%	**B**	(80, 75]%	**B$^-$**	(75, 70]%
C$^+$	(70, 65]%	**C**	(65, 60]%	**C$^-$**	(60, 55]%
F	(55, 0]%				

- Grading will not probably be on a curve.

Tentative Course Schedule

Week 1: Review of kinematics of robot manipulators, trajectory planning, and linear algebra
Week 2: Dynamic modeling using Lagrange formulation
Week 3: Dynamic modeling using Newton–Euler formulation
Week 4: Properties of the dynamic equations
Week 5: Trajectory planning with dynamic constraints
Week 6: Introduction to nonlinear systems and state-space representation
Week 7: Lyapunov stability theorems
Week 8: Feedback linearization and linear controller design
Week 9: Kinematic control techniques
Week 10: Position control techniques
Week 11: Motion control techniques (decentralized, centralized, and inverse dynamics control)
Week 12: Motion control techniques (robust control and adaptive control)
Week 13: Force control, impedance control, and hybrid motion–force control

Syllabus Disclaimer

The instructor views the course syllabus as an educational understanding between the instructor and students. Every effort will be made to avoid changing the course schedule, materials, assignments, and deadlines, but the possibility exists that unforeseen events will make syllabus changes necessary. The instructor reserves the right to make changes to the syllabus as deemed necessary. Students will be notified in a timely manner of any syllabus changes via email or in the Blackboard Announcements. Please remember to check your SBU email or Blackboard Announcements regularly.

University Policies and Statements

Academic Integrity Statement

Each student must pursue his or her academic goals honestly and be personally accountable for all submitted work. Representing another person's work as your own is always wrong. Faculty is required to report any suspected instances of academic dishonesty to the Academic Judiciary. Faculty in the Health Sciences Center (School of Health Technology & Management, Nursing, Social Welfare, Dental Medicine) and School of Medicine are required to follow their school-specific procedures. For more comprehensive information on academic integrity, including categories of academic dishonesty please refer to the academic judiciary website at http://www.stonybrook.edu/commcms/academic_integrity/index.html.

Student Accessibility Support Center (SASC) Statement

If you have a physical, psychological, medical, or learning disability that may impact your course work, please contact the Student Accessibility Support Center, Stony Brook Union Suite 107, (631) 632-6748, or at sasc@stonybrook.edu. They will determine with you what accommodations are necessary and appropriate. All information and documentation is confidential. Students who require assistance during emergency evacuation are encouraged to discuss their needs with their professors and the Student Accessibility Support Center (SASC). For procedures and information go to Evacuation Guide for People with Physical Disabilities and search Fire Safety and Evacuation and Disabilities.

Critical Incident Management Statement

Stony Brook University expects students to respect the rights, privileges, and property of other people. Faculty are required to report to the Office of Student Conduct and Community Standards any disruptive behavior that interrupts their ability to teach, compromises the safety of the learning environment, or inhibits students' ability to learn. Faculty in the HSC Schools and the School of Medicine are required to follow their school-specific procedures. Further information about most academic matters can be found in the Undergraduate Bulletin, the Undergraduate Class Schedule, and the Faculty-Employee Handbook.

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