Syllabus: Robot Dynamics and Control
ME 446 / ECE 489 / SE 422 AL, Spring 2026

Time: TR 9:30am–10:50am
Room: 144 Loomis Laboratory

Course Summary:
This course is cross listed in Mechanical Science and Engineering, Electrical and Computer Engineering, and Industrial & Enterprise Systems Engineering. It is intended for seniors and first year graduate students from a wide variety of engineering disciplines and backgrounds. The course will emphasize the fundamentals of kinematics, dynamics, and motion and force control of robots and with focus on serial manipulators (robot arms). Transformations from task space to joint space will allow joint level control. The study of forward and inverse kinematics, along with differential kinematics will provide a foundation for designing robots and their controllers. We will examine robots operating in free space as well as in contact with environments. Advanced topics will look at the dynamics and control of other underactuated and mobile robotic systems. It is assumed the students have a basic knowledge of rigid-body dynamics and linear control theory, including feedback and feedforward control. This is a hands-on course with multiple lab sections. Students are expected to study independently and work on their projects outside of class. It is very helpful if students have already taken Introduction to Robotics (ME445/ECE470/AE482).

Learning objectives:
By the end of this course, you will be able to:
- Model and analyze the kinematics and dynamics of robots
- Design motion and force controllers based on mathematical models of robots
- Implement theoretical concepts of signal processing and controls in real robots
- Work with real robot hardware

Course webpages:
- Lecture: https://canvas.illinois.edu/courses/65004
- Lab: http://coecsl.ece.illinois.edu/ME446/

Instructors:
- Lecture: Justin Yim jkyim@illinois.edu – Office: 4411 Mechanical Engineering Lab (MEL)
  Office hours: TBD or by appointment @ 4411 MEL
- Lab: Dan Block d-block@illinois.edu – Office hours: by appointment @ 3071 ECE Bldg

Teaching Assistants:
- Gihyeok Na gihyeok2@illinois.edu – Lab office hours: TBD @ 3071 ECE Bldg
- TBD – Homework office hours: TBD @ TBD

Lecture and lab hours:
- Lecture: Tuesdays and Thursdays 9:30-10:50am @ 144 Loomis Laboratory
- Lab Section 1 (AB1): Friday 12:00pm – 2:50pm @ room 3071 ECE Bldg
- Lab Section 2 (AB2): Wednesday 11:00am – 1:50pm @ room 3071 ECE Bldg
- Lab Section 3 (AB3): Friday 09:00am – 11:50am @ room 3071 ECE Bldg

Textbooks:

- *Robot Modeling and Control* - Spong, Hutchinson & Vidyasagar – Wiley
- Other suggested: *Modern Robotics: Mechanics, Planning, and Control* – Lynch and Park, 2017

Grading breakdown:

- Homework and lecture participation: 30%
- Midterm: 20%
- Lab participation and reports: 30%
- Final project demo and report: 20%

Grading scheme:

- 90% "A-" is guaranteed
- 80–89.9% "B-" is guaranteed
- 70–79.9% "C-" is guaranteed
- 60–69.9% "D-" is guaranteed
- <60% "F"

Homework and lab report evaluation:

- There will be approximately ten homework assignments during the course.
- Homework will be turned in virtually (in .pdf format only) via canvas by the deadline.
- The lowest homework grade will be dropped.
- **No late homework will be accepted without documented justification.**
- Complete homework and lab reports must include:
  - Clear demonstration of formulas and concepts used.
  - Complete and neat mathematical derivations to obtain the final answer.
  - MATLAB (or other) source code used.
  - Neat and informative figures, tables, and diagrams with proper labels and units.

Examination:

- One midterm is scheduled tentatively at March 12th at regular lecture time/location.
- You can bring one letter/A4 sheet of paper with personal notes (front and back).
- Requests for a conflict or make-up examination will be individually evaluated. Only requests that, by the instructor's judgement, are fully justified (i.e., with appropriate written documentation) will be granted.
- Students can ONLY request a re-grading of their exams within the first 48 hours of receipt of their midterm. Note that re-graded exams may potentially receive a lower grade, if applicable.

Final project demonstration:

In the end of the course, students will control a real manipulator to complete a series of physical tasks such as inserting a peg in the whole or pushing buttons. Students will demonstrate the capabilities of their algorithms during a friendly competition that will award the fastest and the most accurate robot.

Course schedule:

Week	Class	Day	Lecture topics	Lab topics	Comments
1	1	Jan 20	Class intro Robot examples Rigid-body, DoF	-	
		Jan 21	-	-	No lab this week
	2	Jan 22	Rotation and HTMs	-	
2	3	Jan 27	HTMs Forward Kin. (DH par.)	-	HW 1 (HTMs, Matlab) released
		Jan 28	-	Lab 1	
	4	Jan 29	Workspace Inverse Kinematics Diff. Kin. (Analytical Jacob.)	-	
3	5	Feb 03	Manipulability Ellipsoid Singularity General Jacobian form Jacobian computation	-	HW 1 due HW 2 (FK, DH, IK) released
		Feb 04	-	Lab 1	
	6	Feb 05	Jacobian in MATLAB Jacobian and statics Lagrangian formulation Lagrangian examples	-	
4	7	Feb 10	Kin & Pot energy Inertia Tensor Task-space inertia Manipulator equation	-	HW 2 due HW 3 (Jacobians) released
		Feb 11	-	Lab 1	
	8	Feb 12	EoM example (linear) EoM example (rotary) EoM MATLAB	-	
5	9	Feb 17	Properties of M(q) FD and ID Numerical Simulation	-	HW 3 due HW 4 (Lagrangian dynamics) released
		Feb 18	-	Lab 2	
	10	Feb 19	Newton-Euler Formulation	-	
6	11	Feb 24	Motor and transmission dynamics	-	HW 4 due HW 5 (Simulation, motors) released
		Feb 25	-	Lab 2	
	12	Feb 26	Joint PD control	-	
7	13	Mar 03	PD Practical considerations	-	HW 5 due
		Mar 04	-	Lab 2	
	14	Mar 05	Joint PID control Feedforward control PD control + feedforward	-	
8	15	Mar 10	Midterm review	-	
		Mar 11	-	Lab 3	
	16	Mar 12	Midterm (up to HW5)	-	
9	-	Mar 17	Spring Break		
		Mar 18			

	-	Mar 19			
10	17	Mar 24	Midterm solution review, CRS robot simulator and gravity compensation	-	HW 6 (CRS sim control) released
		Mar 25	-	Lab 3	
	18	Mar 26	Inverse dynamics and path and trajectory generation	-	
11	19	Mar 31	Semi-static force control Task-space Inv. Dyn. control	-	HW 6 due HW 7 (traj. generation) released
		Apr 01	-	Lab 3	
	20	Apr 02	Stiffness and compliance Impedance control	-	
12	21	Apr 07	Hybrid systems Impact dynamics Contact models	-	HW 7 due HW 8 (task & impedance) released
		Apr 08	-	Lab 4	
	22	Apr 09	Impact and contact sim Control constraints	-	
13	23	Apr 14	Potential fields Adaptive control Other adv. controls	-	HW 8 due HW 9 (contact) released
		Apr 15	-	Lab 4	
	24	Apr 16	Hybrid F/V Control	-	
14	25	Apr 21	Trajectory optimization Worked example	-	
		Apr 22	-	Final Project workday	
	26	Apr 23	Traj. optimization example Optimization-based control	-	HW 9 due HW 10 (final sim) released
15	27	Apr 28	Underactuated robots Linearization Partial Feedback Lin	-	
		Apr 29	-	Final Project workday	
	28	Apr 30	Other advanced topics	-	
16	29	May 05	Semester review	-	HW 10 due
		May 06	-	Final Project workday	Last day of instruction
	-	May 07	(Reading days)	-	
17	-	May 12	-	Final Project Demo 7:00pm – 10:00pm	

Useful references for robot dynamics and control:

- Modern Robotics book
- Northwestern robotics
- Roy Featherstone's page
- Rigid-body dynamics algorithms book
- MIT Underactuated robotics notes
- MIT Underactuated robotics channel
- Notre-Dame Intro to robotics
- Notre-Dame optimization-based robotics
- IHMC robotics channel
- MATLAB control systems in practice series
- HEBI Robotics IROS 2020 tutorial
- Steve Brunton YouTube Channel

Course policies:

1. Please show respect for your classmates by limiting distractive behavior. Turn your cell phones off during class and please keep any side discussions short and quiet.
2. You are expected to adhere to all the rules pertaining to academic integrity outlined in the Student Code. Failure to do so will result in an automatic F for the course.
3. It is expected that each student will be courteous and respectful to all members of the class and will carry themselves in an orderly manner for the entire duration of the course as outlined in the Student Code.
4. Regular class attendance and punctuality are expected. However, do not come to class if you are sick and potentially contagious.
5. Do not distribute course materials (slides, homework, exams, etc.) without written permission.
6. You are encouraged to discuss homework problems with your fellow classmates. But your final answers should be based on your own understanding. Copying other's work is NOT acceptable. You must list the names of partners with whom you worked at the top of your homework document.
7. Use of AI tools is allowed but must be cited in an appendix (see below) whenever used (e.g. on homework). You may NOT upload copyrighted content in prompts to online AI models: copyrighted material includes text or images from textbooks, published papers, slides, or homework. While you may not copy homework questions into prompts, you may ask questions about concepts in the homework.
    a. Cite AI tools at the end of your submitted document with the following information:
        i. The author or publisher of the AI tool.
        ii. The name of the AI tool, available version information, and URL if applicable.
        iii. The date (at least year -- 2026) of its use.
    b. In addition to the citation, add an appendix to the end of your submitted document with a copy of relevant inputs and outputs to and from the AI tool.

Special Accommodations:

If you have any condition, such as a physical or learning disability, which will make it difficult for you to carry out the work as it has been outlined or which will require special accommodations, please notify the instructor during the first week of the course with the appropriate written documentation. To contact the Division of Rehabilitation-Education Services (DRES), you may visit 1207 S. Oak St., Champaign, IL 61820, call (217) 333-1970, or email disability@illinois.edu.

Absences and Conflicts

If you have a conflict with a course activity due to religious practices and observances, work travel, or similar reason, email the professor as early as possible and no later than one week (seven days) in advance of the conflict. If an unplanned event such as an illness or family emergency impacts your ability to attend class or complete assignments, arrangements must be made with the professor via email as soon as practical.

Mental Health

Significant stress, mood changes, excessive worry, substance/alcohol misuse or interferences in eating or sleep can have an impact on academic performance, social development, and emotional wellbeing. The University of Illinois offers a variety of confidential services including individual and group counseling, crisis intervention, psychiatric services, and specialized screenings which are covered through the Student Health Fee. If you or someone you know experiences any of the above mental health concerns, it is strongly encouraged to contact or visit any of the University's resources provided below. Getting help is a smart and courageous thing to do for yourself and for those who care about you.

- Counseling Center (217) 333-3704
- McKinley Health Center (217) 333-2700
- National Suicide Prevention Lifeline (800) 273-8255
- Rosecrance Crisis Line (217) 359-4141 (available 24/7, 365 days a year)

If you are in immediate danger, call 911.