WISCONSIN
UNIVERSITY OF WISCONSIN–MADISON

ME 601 Advanced Robotics: Modern Motion Planning, Estimation, and Control

Xiaobin Xiong, UW Madison, Fall 2025

1. Core Information

Canvas: https://canvas.wisc.edu/courses/468819 (Managed by the Instructor)
Piazza: https://piazza.com/wisc/fall2025/me601 (Managed by the TA)
Time: Monday & Wednesday, 4-5:15pm
Zoom: Https://uwmadison.zoom.us/j/8909032411 (for guest lectures & office hours)
Location: ME 1143.

Note: This course will be offered at 700 level in the future. Students can use it to meet the 700 level requirement upon the approval of the graduate committee.

2. Instructor

Main Instructor: Xiaobin Xiong, Assistant Professor.
Office hours: Scheduled for the later part of the course either in person or over zoom.
Additional office hours can be scheduled by appointment.
Location: ME 2031.
Email: xiaobin.xiong@wisc.edu

TA: Jiarong Kang, PhD student in ME.
Office Hour: Wednesday 1-2pm.
Location: ECB 1025.
Email: kang248@wisc.edu

4. Course Description

Rigid body models of robots, constraints and contact, motion planning methods including sampling based, trajectory optimizations, state estimation algorithms including linear observers and filters, Kalman filters, optimization-based filters, feedback control methods including PD, Impedance Control, optimization-based controllers, Differential Dynamic Programming, Lyapunov Analysis and Design, and Underactuation.

5. Requisites

Enroll Info: Knowledge of robotic systems [such as ME439, ME441] is encouraged, however not required. Knowledge of Basics of Undergrad-level Rigid Body Kinematics and Dynamics, and Dynamical System (such as ME340) is necessary.

6. Learning Outcomes

Upon successful completion of this course, you will be able to

- Understand the mathematical models of general robotic systems.
- Plan motion that realizes certain desired tasks.

- Estimate robot states from available sensors.
- Control robot motion using appropriate controller designs.

7. Relevant Materials

There is no required textbook for this course. The following materials are available for reference:

1. Choset H, Lynch K M, Hutchinson S, et al. Principles of robot motion: theory, algorithms, and implementations[M]. MIT press, 2005.
2. Tedrake R. Underactuated robotics: Learning, planning, and control for efficient and agile machines course notes for MIT 6.832[J]. Working draft edition, 2009, 3(4): 2. Underactuated Robotics
3. Lynch K M, Park F C. Modern robotics[M]. Cambridge University Press, 2017. Modern Robotics - Northwestern Mechatronics Wiki
4. Optimized Robotics - Advanced Robotics: www.nathanratliff.com

8. Grading

In-class Participation - 10%
Homework - 35%
Midterm Exam - 20%
Final Project - 35%

Midterm: There will be one written midterm exam. It will be a take-home exam. Further policies will be posted on the canvas course page.

Final Project and Presentation: A project will be used to evaluate your understanding of the course material. The work for the project will start midway through the semester with a project proposal due after the midterm. Students can form a team of size 1-4. The goal of the project will be to implement the various planning, estimation, and control learned in the course on a robotic system (either in simulation or hardware). Examples of the robotic system are quadrotors, segways, robot arms, and legged robots. There will be a final presentation scheduled for all teams. Grading will be based on reviews from the peers, TA, and the instructor.

Homework Assignments (Mini-Projects): There will be 3 graded homework assignments throughout the semester. You will have more than one week to complete each assignment. The rules are:

- It is your responsibility to ensure that what you turn in fully documents and explains your solution
- Submit your homework as a short report through Canvas; MATLAB scripts should be attached.
- Explain your work: write in words how you solved the problem.
- You are encouraged to discuss homework problems. However, the work you turn in must be your own. If you use any external sources, be sure to cite your sources. You must be able to demonstrate that you understand your solution.

In-class Participation: Attending to the lectures is important to ensure the learning outcome. There will be short and quick in-class quiz questions for students to participate. For some lectures, I may select students to type the notes from the lecture, document in LaTeX Format (template will be provided) and submit them to TA directly through email. The purpose is to provide you with targeted feedback on the understanding of the course material.

9. Course Schedule (subject to minor changes):

Chapter	Week	Date	Day	Lecture Topics	Logistics
Modeling	1	9/3/2025	W	Intro to Robotic Systems	
	2	9/8/2025	M	Review: Robot Kinematics	
		9/10/2025	W	Review: Robot Dynamics	Mini-Proj 1 out
	3	9/15/2025	M	Integrators and Difference Equation	
		9/17/2025	W	Constrained Dynamics, Hybrid Dynamics	
	4	9/22/2025	M	Contact Modeling and Simulation	
		9/24/2025	W	Equilibriums, Stability & Linearization	Mini-Proj 1 Due
Control	5	9/29/2025	M	Lyapunov Analysis	Mini-Proj 2 out
		10/1/2025	W	Control Basics: Feedback Systems & Linear Controls	
	6	10/6/2025	M	Feedback Linearization	
		10/8/2025	W	Feedback Linearization, CLF	Proj Proposal Due
	7	10/13/2025	M	CLF-QP, QP based Control	
		10/15/2025	W	LQRs, Optimal Control	
	8	10/20/2025	M	Trajectory Optimization	Mini-Proj 2 Due
Mid-term		10/22/2025	W	Mid-term	
	9	10/27/2025	M	Mid-term Solution Explanation (Jiarong)	
Estimation		10/29/2025	W	Sensors & State Estimation	Mini-Proj 3 out
	10	11/3/2025	M	Probability Basics, Bayes Filter	
		11/5/2025	W	Kalman Filter, and EFK	
	11	11/10/2025	M	UKF, Particle Filter, & Optimization-based Approaches	
		11/12/2025	W	Guest Lecture: Dr. Lu Gan (Gatech) on **robot perception**	
Planning	12	11/17/2025	M	Motion Planning, Graphs & Trees, Search	Mini-Proj 3 Due
		11/19/2025	W	Sampling based methods: PRM & RRT	
	13	11/24/2025	M	Planning with Dynamics	
		11/26/2025	W	Planning with Contact	
	14	12/1/2025	M	Guest Lecture: Dr. Tao Pang (BDAI) on **robot planning**	
		12/3/2025	W	Guest Lecture: Dr. Chen Wang (UB) on **robot learning**	
Project	15	12/6/2024	M	**Final Presentation**	
		12/10/2024	W		Proj. Report Due