

CS59200-RBM: Robot Manipulation

Fall 2024

Course Information

Course Number	CS59200-RBM
Meeting Time	TTH 1:30-2:45pm
Course Room	LWSN 1106
Course Credits	3.0
Instruction Modality	Face-to-Face

Instructor Contact Information

Instructor	Zachary Kingston, Assistant Professor of Computer Science
Instructor Email	zkingston@purdue.edu
Instructor Office	TBD
Office Hours	TBD and by appointment

I am available via email and will try to respond as soon as I can (usually with 24-48 hours, might be longer on weekends). When emailing me, please put the course number in the subject line of the email (e.g., “[CS59200-RBM] Help with assignment”) to make sure I see it.

Course Description

There have been tremendous recent advances in the capabilities of robots to achieve complex tasks, and the field sits at a precipice of broader impact; robots are moving beyond *a priori* engineered factory settings to un/semi-structured domains, such as moving packages around a warehouse, providing automated delivery in restaurants and hospitals, advancing human telepresence in distant locales such as underwater and in space, and more. Despite this progress (and the abundance of cool demo videos), it’s still *incredibly difficult* to make a robot do any one thing, let alone have a generalizable system that can handle a significant breadth of tasks in various environments. So, what’s so hard about making a robot interact with the world?

This course will answer that question and provide an in-depth understanding of the state-of-the-art in robot manipulation by surveying important landmark papers in the field as well as current recently published works. In particular, this course will have an algorithmic and computational focus, providing an understanding of the fundamental techniques necessary for manipulation. We will also cover modern advances in how statistical machine learning (particularly approaches known as deep learning, generative AI, or foundation models) are applied and used by model- and optimization-based methods to handle the uncertainties of the real world.

Learning Outcomes

After successfully completing this course, a student should be able to:

1. understand the trade-offs and design decisions made for robot manipulation systems and for the individual components, and be able to evaluate the system both holistically and as individual components for efficacy compared to baseline approaches.
2. develop solutions for robot manipulation problems and improve components of integrated systems.
3. write a research paper in the domain of robot manipulation, give an effective research presentation, and understand and critically evaluate published work in this field.
4. identify areas of future work within robot manipulation.

Prerequisites

1. Programming experience in Python and/or C++, as well as Linux systems.
2. Background in linear algebra and calculus.
3. It will be helpful (but not required!) to have background in artificial intelligence, planning, machine learning, computer vision, control, optimization, sensing, kinematics, and dynamics.

Learning Resources, Technology and Texts

There is no required textbook for this course. Lecture notes, research papers, and online resources will be provided throughout the course. For the interested reader, there are recommended textbooks that cover much of the basic background necessary:

1. [Planning Algorithms](#) by Steven M. LaValle
2. [Modern Robotics](#) by Kevin M. Lynch and Frank C. Park
3. [Robotic Systems](#) by Kris Hauser
4. [Robotic Manipulation: Perception, Planning, and Control](#) by Russ Tedrake
5. [Automated Planning and Acting](#) by Malik Ghallab, Dana Nau, and Paolo Traverso

(Tentative) Course Schedule

	Covered Topics	Project Timeline
Week 1	Introduction to Manipulation	
Week 2	Sampling-based Motion Planning	
Week 3	Trajectory Optimization	
Week 4	Other Motion Planning Paradigms	Project Proposed
Week 5	Task Planning	
Week 6	Task and Motion Planning	
Week 7	Abstractions and Representations	
Week 8	Multi-Modal Manipulation and Locomotion	
Week 9	Grasping	Project Midterm Report
Week 10	Benchmarking and Evaluation	
Week 11	Sensing and Manipulation	
Week 12	Mobile Manipulation and Humanoids	
Week 13	Real-time Performance and Hardware Acceleration	
Week 14	Behavior Cloning and Imitation Learning	
Week 15	Miscellaneous Topics	Project Final Report
Week 16	Project Presentations	

Reading List

Final reading list TBD. All readings will be provided to students.

Assessment and Grading

Reading Assignments	20%
Paper Presentations	20%
Course Project	50%
Participation and In-Class Activities	10%

Regrade requests can only be made within one week of the submission deadline.

Paper Reading and Presentation

You are expected to present two research papers during the course. The instructor will ask students to sign up to present papers by the end of the first week. If you are presenting a paper, you will be responsible for reading the assigned paper a week before your presentation date and developing 2–3 discussion questions that will be shared with the rest of the class. Your presentation in class should cover the motivation, related work, methodology, and results of the paper, as well as discuss your own thoughts and criticisms of the work. If you are not presenting a paper, you are expected to read the assigned paper and respond to the provided discussion questions before class, and be an active participant in the lecture.

Course Project

The course project serves as a means for students to get “hands-on” experience with manipulation research. Students are expected to work either alone or in groups (no more than three students in a group, and the distribution of work *must* be documented and described in any reports and may affect grading). You may pick any topics related to robot manipulation (e.g., an improvement to grasping method, a motion planner that addresses some specific need, a task abstraction for a specific problem case, etc.) as your project, and the instructor will release a list of sample project ideas that can be used either as-is or as inspiration for your own project. Students are encouraged to connect the course project to their own research. Before submitting the project proposal, you are expected to develop your project idea and discuss it with the instructor for feedback on project feasibility, relevance, novelty, potential, and significance.

The course project will consist of the following:

1. a project proposal which outlines the problem you aim to solve.
2. a midterm report on current project progress.
3. a final report, formatted as a conference publication that describes the motivation, related work, methodology, results, and future directions of the project.
4. a final presentation, given in the last week of classes.

More specific details and expectations of each of these components will be given later.

Missed or Late Work

Late submissions will be penalized by a 20% reduction in grade for each day late. Missed assignments may only be made up when you notify me ahead of time with an explanation and plan for completion. These requests will be accepted at my discretion. Asking for an extension does not guarantee it will be granted.

Attendance Policy

Students are expected to be present for every meeting of the class. When conflicts or absences can be anticipated, such as for many University sponsored activities and religious observations, the student should inform the instructor of the situation as far in advance as possible. For unanticipated or emergency absences when advance notification to an instructor is not possible, the student should contact the instructor as soon as possible by email. When the student is unable to make direct contact with the instructor and is unable to leave word with the instructor’s department because of circumstances beyond the student’s control, and in cases of bereavement, the student or the student’s representative should contact the Office of the Dean of Students via email or phone at [765-494-1747](tel:765-494-1747).

Academic Integrity

Academic integrity is one of the highest values that Purdue University holds. Individuals are encouraged to alert university officials to potential breaches of this value by either emailing integrity@purdue.edu or by calling 765-494-8778. While information may be submitted anonymously, the more information that is submitted provides the greatest opportunity for the university to investigate the concern. Please also refer to Purdue's student guide for academic integrity. The Purdue Honor Pledge states: "As a boilermaker pursuing academic excellence, I pledge to be honest and true in all that I do. Accountable together—we are Purdue."

Use of Artificial Intelligence (AI) or Large Language Models (LLMs) in this Course

Students are permitted to use generative AI tools (e.g., ChatGPT) for any class assignments. If such tool was used in any part of the assignment completion, students are expected to state how the tool was used in detail in the submitted work.

Accessibility and Accommodations

Purdue University strives to make learning experiences as accessible as possible. If you anticipate or experience physical or academic barriers based on disability, you are welcome to let me know so that we can discuss options. You are also encouraged to contact the Disability Resource Center at: drc@purdue.edu or by phone: 765-494-1247.

Nondiscrimination Statement

Purdue University is committed to maintaining a community, which recognizes and values the inherent worth and dignity of every person; fosters tolerance, sensitivity, understanding, and mutual respect among its members; and encourages each individual to strive to reach his or her own potential. In pursuit of its goal of academic excellence, the University seeks to develop and nurture diversity. The University believes that diversity among its many members strengthens the institution, stimulates creativity, promotes the exchange of ideas, and enriches campus life. Purdue University prohibits discrimination against any member of the University community on the basis of race, religion, color, sex, age, national origin or ancestry, genetic information, marital status, parental status, sexual orientation, gender identity and expression, disability, or status as a veteran. The University will conduct its programs, services, and activities consistent with applicable federal, state, and local laws, regulations, and orders and in conformance with the procedures and limitations as set forth in Executive Memorandum No. D-1, which provides specific contractual rights and remedies. Any student who believes they have been discriminated against may visit the University's website to submit a complaint to the Office of Institutional Equity. Information may be reported anonymously.

Emergency Preparation

In the event of a major campus emergency, course requirements, deadlines, and grading percentages are subject to changes that may be necessitated by a revised semester calendar or other circumstances beyond the instructor's control. Relevant changes to this course will be posted on the course website or can be obtained by contacting the instructor via email. You are expected to read your @purdue.edu email on a frequent basis.

Mental Health Statement

If you are struggling and need mental health services: Purdue University is committed to advancing the mental health and well-being of its students. If you or someone you know is feeling overwhelmed, depressed, and/or in need of mental health support, services are available. For help, such individuals should contact [Counseling and Psychological Services \(CAPS\)](#) at 765-494-6995 during and after hours, on weekends and holidays, or by going to the CAPS office on the second floor of the Purdue University Student Health Center (PUSH) during business hours.

Basic Needs Security

Any student who faces challenges securing their food or housing and believes this may affect their performance in the course is urged to contact the Dean of Students for support. There is no appointment needed and Student Support Services is available to serve students 8 a.m.–5 p.m. Monday through Friday.

Disclaimer

This syllabus is subject to change, and students will be notified accordingly of any changes.

Acknowledgements

Parts of this syllabus were adapted and inspired by syllabi from Ming Yin at Purdue, Sabrina Neuman at Boston University, and the [Purdue Syllabus Guidelines](#).