



Worcester Polytechnic Institute

RBE 450X: Vision-based Robotic Manipulation Robotics Engineering Department A-Term

Instructor:

Berk Calli
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TA:

Yash Patil
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TA Office hours: TBA

Textbook (and/or other Required Materials):

This course does not have a primary textbook. It utilizes various research papers, and some chapters of the following books:

Springer Handbook of Robotics, Editors: Bruno Siciliano, Oussama Khatib, ISBN-13: 978-3319325507, available online at WPI library website [here](#).

A Mathematical Introduction to Robotic Manipulation by Richard M. Murray, Zexiang Li, S. Shankar Sastry, ISBN-13: 978-0849379819, Available online [here](#).

Course Description:

This course focuses on the role of visual sensing in robotic manipulation. It covers fundamental manipulation concepts such as grasp matrix, grasp taxonomies, and grasp stability metrics. Various grasp planning strategies in the literature are studied. 2D and 3D vision-based control algorithms are covered. Point cloud processing techniques that allow object detection, segmentation, and feature extraction are studied and utilized. Integrating all these aspects, the whole vision-based robotic manipulation pipeline is designed.

Recommended Background:

RBE 3001 and RBE 3002

Communication:

You are strongly encouraged to participate in the class, ask questions or give comments during the lecture. Please take full advantage of the office hours! You can ask any questions regarding the course content and/or discuss any topic regarding robotics. In addition, please do not hesitate to contact me anytime regarding any questions and concerns. Please feel free to provide me feedback (positive or negative) anytime.



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Important note: We will be using discussion boards actively in this course. When you have a question about the course content, HW, or project, please do not email me directly but post it to the discussion boards. I (or our TA) will respond to your questions there. This way of communication has several advantages: everyone in the class will have the same and equal information, you will be seeing other people's perspective, and the teaching staff will be able to respond to your questions more efficiently. Also, let's create a community around these boards, especially while coding. You can respond to each other's posts (without posting the solutions of the HW questions, of course), help each other solve coding issues and debug the problems.

Important note 2: While asking questions via the discussion boards, never post your solution and ask "is this the correct way of approaching it?". Such posts may result in penalties in your HW score. Our TA and I will not respond to such questions via emails or in office hours either. Your questions should be targeted, clearly pointing out the topics that you are having difficulty about. It is an engineering skill to ask the right questions and using the right terminology, and we will be practicing it during this course.

Important note 3: If you have objections regarding your grades, please discuss it with the TA first by joining their office hours. If the disagreement between you and the TA persists, I can then look into it in my office hour.

For all other inquiries, I am committed to respond to e-mails ASAP, no later than 24 hours.

Statement of Diversity, Equity, and Inclusion

I am committed to creating a safe and inclusive learning environment for students coming from all background and identities. Any kind of harassment or discrimination will not be tolerated. I am open to your suggestions, comments, and criticism to improve the inclusiveness and effectiveness of the learning environment for yourself or for other students.

Course Approach:

- There will be lectures on Tuesdays and Fridays 10am-12pm at Atwater Kent 232.
- There will be a lab session on Wednesday 10am-12pm at Innovation Studio 105 Active Learning Classroom.
- Starting from the second week, there will be in-class quizzes every week.
- There will be weekly HW assignments.
- There won't be exams in this course.
- We will be using Gazebo simulator and ROS along with various motion planning and point cloud processing libraries.

Course Requirements:

- **Grade Determination Breakdown**
Homework Assignments (85%)
Quizzes (15%)



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- **Assignments**

Homework assignments are typically posted on every Wednesday 2pm and are typically collected on next week's Friday 6pm (approximately 9 days per assignment).

- **Late Work Policy**

- Submission deadlines are at 6pm EST. Submitting after the deadline in the same day (until 11.59pm EST): -%5. (Please be very careful submitting your work before the deadline. There can always be some technical difficulties. It is your responsibility to calculate the risks and not go for last minute submissions to avoid late penalty. When you submit research work (papers, report, proposals), you will see that the deadline is strictly enforced. This is what we do here too.)
- Every 24 hours delay is -%10.
- The submission closes 5 days after the deadline.

- **Class Participation Expectations and Criteria**

Joining to the lectures are essential for this course. I highly encourage you to actively participate in this course with your questions, discussions, and comments.

Technical Requirements:

For the coding assignments you will need to install ROS 2 Humble Hawksbill. ROS works best on a Linux-Ubuntu operating system. The Ubuntu version that Humble Hawksbill runs is Ubuntu 22.04. If you do not want to completely convert your computer's operating system to Ubuntu and also need a Windows or MacOS operating system, you have two basic choices:

- Dual installation (**RECOMMENDED**) (e.g. installing Windows/MacOS and Linux alongside each other). This is the recommended way. There are many resources on the internet on how to do this. I recently used this one for installing Ubuntu 22.04 alongside Windows 10, which worked perfectly: <https://www.how2shout.com/linux/install-ubuntu-22-04-jammy-alongside-windows-10-dual-boot/>
- Install a virtual machine to your Windows/MacOS. This may sometimes be too slow while using the Gazebo simulator and might cause unexpected errors that are difficult to debug, but may still to the job.

Some homework assignments will require Matlab.

Library Access:

As a student at WPI, you have access to a variety of resources through the library. Use the link [here](#) to access databases, e-journals, and/or e-books. You will be required to log in with your WPI username and password to access materials.



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POLICIES

Academic Integrity:

You are expected to be familiar with the *Student Guide to Academic Integrity at WPI* that is downloadable from [here](#). Consequences for violating the Academic Honest Policy range from earning a zero on the assignment, failing the course, or being suspended or expelled from WPI. Common examples of violations include:

- Copying and pasting text directly from a source without appropriately citing it.
- Paraphrasing, summarizing, or rephrasing from a source without appropriately citing it.
- Collaborating on individual homework assignments (penalty strongly enforced)
- Turning in work where a good portion of the work is someone else's, even if properly cited.

Academic Accommodations:

We at WPI strive to create an inclusive environment where all students are valued members of the class community.

If you need course adaptations or accommodations because of a disability, or if you have medical information to share with us that may impact your performance or participation in this course, please let the instructor know as soon as possible, and get in touch with the Office of Accessibility Services.

Students with approved academic accommodations should plan to submit their accommodation letters through the [Office of Accessibility Services Student Portal](#). Should you have any questions about how accommodations can be implemented in this particular course, please contact me as soon as possible.

Students who are not currently registered with the Office of Accessibility Services (OAS) but who would like to find out more information regarding requesting accommodations and what that entails should plan to contact them via:

Email: AccessibilityServices@wpi.edu and/or

Phone: (508) 831-4908.

On Campus – Daniels Hall, First Floor 124

Writing Center:

The Writing Center offers one-on-one consultations, both in-person (in SL 233) and over Zoom, to help you improve as a writer. Writing Center tutors will read your written work, give you feedback about your document's strengths and weaknesses, and help you chart a path forward as you revise. Consultations are free and open to all WPI students for all classes and projects, and tutors will happily work with you at any stage of the writing process (early brainstorming, revising a draft, polishing sentences in a final draft). To see our appointment options for both in-person and synchronous online meetings, go to the Writing Center homepage:

wpi.edu/+writing



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Grading Policy:

Final course grades are based on a student's performance as follows:

Letter Grade	Percentage
A	90 - 100
B	80 - 89
C	70 - 79
D	60 - 69
F	< 60

Learning Outcomes (LOs):

At the end of the semester, you will be able to

- LO1: navigate through the past and recent manipulation literature
- LO2: derive kinematic models for a robotic grasp
- LO3: utilize methods to calculate grasp stability
- LO4: utilize basic image processing tools
- LO5: implement vision-based control techniques
- LO6: synthesize grasps for a given object
- LO7: employ vision-based techniques to grasp unknown objects
- LO8: implement a full manipulation pipeline

RBE Department Student Outcomes (SOs):

Each of the Course Learning Outcomes (LOs) addresses one or more of the RBE Department Student Outcomes (SOs) listed below:

- SO 1: Identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics
- SO 2: Apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors
- SO 3: Communicate effectively with a range of audiences
- SO 4: Recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts
- SO 5: Function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives
- SO 6: Develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions
- SO 7: Acquire and apply new knowledge as needed, using appropriate learning strategies
- SO 8: Evaluate and integrate the mechanical, electrical, and computational components of a cyber-physical system
- SO 9: Recognize and take advantage of entrepreneurial opportunities

Our Course LOs relates to RBE Department SOs according to the following table:



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		RBE Department Student Outcomes (SOs)									Measured by				
		SO 1	SO 2	SO 3	SO 4	SO 5	SO 6	SO 7	SO 8	SO 9	HWs	Exams	Labs	Projs	Others (Specify)
Course LOs	LO 1	X		X	X										Reading Materials
	LO 2	X	X					X			X				
	LO 3	X	X					X			X				
	LO 4	X	X					X			X				
	LO 5	X	X				X		X		X				
	LO 6	X	X				X		X		X				
	LO 7	X	X			X	X		X					X	
	LO 8	X	X	X		X	X		X	X				X	
Extent of Coverage	No														
	Small			X	X					X					
	Mod					X									
	Large	X	X				X	X	X						