Modern Robotics I: Arm-type Manipulators

Semester: Fall 2023
Number of Credits: 3
Course: MENG 4930, 5930

Instructor Info

Dr. Madi Babaiasl

Office Hrs: Thu. 1pm - 3pm

Office Location: MDD 2051

Website: https://github.com/madibabaiasl/modern-robotics-I-course

Email: madi.babaiasl@slu.edu

Course Info

Suggested Prerequisites: CSCI 1060, ESCI 2100, 2150, MENG 2400, PHYS 1610, MATH 1510, MATH 3550

Class days: Mon, Wed, & Fri

Class hours: 10am-11am

Class Location: Mechatronics Lab (MDD LL 0001)

Course Description

The Czech playwright Karel Capek is credited with coining the word "robot" in his 1920 play, R.U.R. (Rossum's Universal Robots), but the concept of robots as machines that can sense, process, and act has been around for centuries. For example, the ancient Greeks created stories about automatons, which were self-moving machines that could perform tasks. The Unimate was the first industrial robotic arm that was used for welding, painting, and assembly. Since then, robots have been developed for a wide range of other applications, including warehousing & logistics, manufacturing, healthcare, agriculture, construction, cleaning, and even entertainment. Although the field of robotics is still under development (it is an active research area), the basic principles of robot design (modeling, perception, planning, and control) are well understood. In Modern Robotics I, we will use both theory and practice to learn these basics specifically for arm-type manipulators. You will have the opportunity to work with a physical robotic arm that is controlled by the Robot Operating System (ROS) to learn about these topics through hands-on experience. Watch the introduction course video HERE.

Course Objectives

After this class:

- You will learn the fundamentals of robot motion (such as tools to express robot position and orientation as well as velocities and forces), forward and inverse kinematics, velocity kinematics and statics, dynamics, motion planning, and control through experiential learning.
- You will be able to integrate your previous knowledge of vectors, matrices, statistics, statics, dynamics, physics, and programming to serve an actual application.
- You will be able to translate some of the skills that you will learn such as screw theory applications in robotics to not only robotic arms but also to other areas of robotics such as soft robots, continuum robots, etc.
- You will become familiar with enough technical tools (Python, MATLAB, ROS, OpenCV, RoboDK, etc.) to be able to translate your ideas into code and make yourself competitive in the current job market.
- You will be able to see how the different components of a robot work individually and together to make the robot move and perform tasks. Specifically, you will be able to use different sensors such as a camera to make the robot understand its environment and use this information to perform the required task by translating a high-level task into trajectories that the robot can follow.
- You will be able to interact with others in a team. Robotics is an interdisciplinary field and robotic systems can be complex for just one person to handle. Teamwork is an essential part of completing a successful robotics project.
- You will be able to organize and document your work effectively to make a competitive portfolio and be able to handle a complex project in the future.

Resources

Recommended Textbooks:

- Modern robotics: Mechanics, planning and control, Kevin Lynch and Frank Park, 2019, Cambridge University Press
- Robotics, Vision and Control: Fundamental Algorithms in Python, Peter Corke, 2023, Springer Nature
- A mathematical introduction to robotic manipulation, Murray, Li and Sastry, 1994, CRC press

Note that the material that I will teach is a combination of many sources (some are not listed above and some are developed by myself) and I will give the required text to you. The books above can be used as a reference.

Software Packages and programming languages:

Robot Operating System (ROS), MoveIt, RViz, Gazebo, Python, MATLAB, RoboDK, Linux (Ubuntu)

Hardware:
PincherX 100 Robot Arm from Trossen Robotics, Interbotix ROS Arm Vision Kit, Computer running Ubuntu 22.04

Teaching method & Assessment

This class is based on flipped classroom and experiential learning techniques. It means that most lessons have a combination of text and video that you will peruse at home, and during class time, we will review the lesson with your help, solve some problems, and do mini-projects that will utilize the knowledge that you gained in the lecture and apply it to the ROS-based robotic arm. These mini-projects are considered "labs" for this class. You will also have the chance to apply the knowledge and technical tools that you learned to a complete project.

Your learning in this class is assessed through different media:

- Quizzes: There will be multi-choice, coding, or calculation-based quizzes that focus on the key objectives of each lesson. These quizzes should be completed individually and you cannot collaborate on those (even web-based sources).
- Homework: Each lesson will have a proceeding homework that should be submitted online one week after the corresponding class. Homework can be turned up to one week late for half credit. You can collaborate with another classmate (you should disclose their name in your report) to solve the problems but each person should submit their own report. If the homework involves a coding or practical assignment, you should also submit a video (1-3 minutes in length) introducing yourself and then showing that your code works with enough explanations (you can also comment about the challenges that you faced and how you solved them). You should be able to answer questions upon request.
- Mini-projects: Most of the classes will have mini-projects that should be completed in class and you will submit a report and a video one week after the class. The video should start with you introducing yourself and then showcasing that your implementation of the lab on the robot actually works. Mini-projects can be completed in groups of three students and one report per group suffice (you should work together to write the report). Active participation in labs in mandatory and students will also be assessed at the end based on their participation in labs.
- A complete project: The class will have one or several complete projects in which you will combine the knowledge that you gained from the lessons, and mini-projects and apply it to the robotic arm performing a specific task. Each group will consist of three students and one report and video submission per group suffice. All group members should contribute equally and should be able to answer questions upon request.
- Midterm & final exams: The exams will give you a chance to apply what you have learned in the quizzes and homework/labs in a more comprehensive way. The questions on the exams will be similar to those on the quizzes and homework. Midterm and final exams will be taken individually.

Note: Each semester and based on the class and students, a combination of these methods will be used for assessment.

Grading Criteria:

30%	Labs
20%	Complete project
20%	Homeworks
10%	Midterm Exam
10%	Final Exam
10%	Quizzes

Grades will follow the standard scale: $A \geq 93\%, 93\% > A- \geq 90\%, 90\% > B+ \geq 87\%, 87\% > B \geq 83\%, 83\% > B- \geq 80\%, 80\% > C+ \geq 77\%, 77\% > C \geq 73\%, 73\% > C- \geq 70\%, 70\% > D+ \geq 65\%, 65\% > D \geq 60\%, 60\% > F$.

Please be aware that I retain the discretion to adjust the assessment weights according to the specific requirements of each class.

Important information:

- Class attendance is mandatory as class activities are the main part of the learning process. Three unexcused absences will result in an “F” for the course. Active participation of each member in lab activities is mandatory and part of the assessment.
- Failure to complete any of the labs, complete projects, and exams will result in a grade of “I” (incomplete) for the course.

- Make-up exams or assignments will only be allowed for students who have a substantiated excuse approved by the instructor before the due date.
- For labs and the complete projects that are completed in teams, each member should have a significant contribution to the project.
- You cannot collaborate (in any form including using web-based sources) on quizzes but you can use collaborators for mini-projects, complete projects, and homeworks contingent on disclosing all your collaborators on top of your report (human collaborators cannot be outside of your class). You must be able to fully explain your answers upon demand. Web-based resources including AI Language Models are considered collaborators. They are allowed but you should disclose them.

Tentative Topics

The following are topics that will be covered in Modern Robotics I:

- Foundations: Degrees of freedom, task space & workspace, coordinate frames, tool orientation (rotation matrices, roll-pitch-yaw angles, unit quaternions, Euler angles, etc.), tool pose (homogeneous transformation matrices), screws, twists, and wrenches.
- Forward, velocity, and Inverse kinematics
- Dynamics
- Trajectory generation, motion planning
- Robot control including vision-based control
- Grasping and Manipulation

Academic Integrity

Academic integrity is honest, truthful and responsible conduct in all academic endeavors. The mission of Saint Louis University is "the pursuit of truth for the greater glory of God and for the service of humanity." Accordingly, all acts of falsehood demean and compromise the corporate endeavors of teaching, research, health care, and community service through which SLU fulfills its mission. The University strives to prepare students for lives of personal and professional integrity, and therefore regards all breaches of academic integrity as matters of serious concern. The full University-level Academic Integrity Policy can be found on the Provost's Office website at: https://www.slu.edu/provost/policies/academic-and-course/academic-integrity-policy.pdf.

Additionally, each SLU College, School, and Center has its own academic integrity policies, available on their respective websites.

Disability Accommodations

Students with a documented disability who wish to request academic accommodations must formally register their disability with the University. Once successfully registered, students also must notify their course instructor that they wish to use their approved accommodations in the course.

Please contact the Center for Accessibility and Disability Resources (CADR) to schedule an appointment to discuss accommodation requests and eligibility requirements. Most students on the St. Louis campus will contact CADR, located in the Student Success Center and available by email at accessibility_disability@slu.edu or by phone at 3149773484. Once approved, information about a student's eligibility for academic accommodations will be shared with course instructors by email from CADR and within the instructor's s official course roster. Students who do not have a documented disability but who think they may have one also are encouraged to contact to CADR. Confidentiality will be observed in all inquiries.

Title IX

Saint Louis University and its faculty are committed to supporting our students and seeking an environment that is free of bias, discrimination, and harassment. If you have encountered any form of sexual misconduct (e.g. sexual assault, sexual harassment, stalking, domestic or dating violence), we encourage you to report this to the University. If you speak with a faculty member about an incident of misconduct, that faculty member must notify SLU's Title IX coordinator, Anna R. Kratky (DuBourg Hall, room 36;akratky@slu.edu; 314-977-3886) and share the basic facts of your experience with her. The Title IX coordinator will then be available to assist you in understanding all of your options and in connecting you with all possible resources on and off campus. If you wish to speak with a confidential source, you may contact the counselors at the University Counseling Center at 314-977-TALK. To view SLU's sexual misconduct policy and for resources, please visit the following web addresses: www.slu.edu/here4you and https://www.slu.edu/general-counsel.

Wellness

All students experience stressors and challenges at some point, and seeking support is beneficial. Such challenges may be the result of academic concerns (such as those related to particular assignments or content in a course), or they may be more personal in nature (such as concerns related to relationships, mental health, loss, identities, alcohol or drugs, housing or food security, or finances, among other things). If you experience these or other difficulties, please consider seeking support from the resources available to you.

- For concerns related to this course, please contact me. I am invested in your success and will support your success in the ways I can.
- Additionally, you have access to the many resources SLU provides in support of your personal wellness. You will find a list of available resources on the Well-being page of the SLU website.

If you or someone you know is experiencing a crisis: please consult the Crisis Support and Warning Signs on the University Counseling Center website.

In the spirit of cura personalis, the University sees your academic success as connected to your health and well-being and provides resources to support your holistic wellness.