MEAM 520: Introduction to Robotics

(last updated: August 30, 2020)

Description

This course introduces the fundamental kinematic, dynamic, and computational principles underlying most modern robotic systems. The main topics of the course include: homogeneous transformations, manipulator forward kinematics, manipulator inverse kinematics, Jacobians, and trajectory planning. The purpose of the course is to provide you with a mathematical and practical foundation for future explorations into the robotics field.

Course Objectives

By the end of this course, you should be able to:

- Describe the geometry and configuration of a robot
- Compute the forward and inverse kinematics of a manipulator arm
- Write and understand the standard equations for manipulator dynamics
- Implement a variety of trajectory planning algorithms
- Apply these concepts to a real-world robot manipulator

Prerequisites

You should have knowledge of simple geometry (sine, cosine), previous exposure to linear algebra (matrices and vectors), and previous programming experience. Although MEAM 211 is listed as a prerequisite, it is not strictly required. Previous experience in simple rigid body kinematics will be useful. Experience with Linux will be helpful but is not required.

Required Materials

Computer with the ability to run a Linux virtual machine or partition. Recommended hardware specifications are at least 1 GB RAM and at least 8 GB of hard-drive space.

Teaching Staff

Professor:	Cynthia Sung	crsung@seas.upenn.edu Zoom link: TBA OH: Tuesday 1:30pm-2:30pm, Friday 10am-11am
Teaching Assistants:	Shane Rozen-Levy	Jake Welde
	Raymond Bjorkman	Gabriel Unger
	Zichen Lao	Nagarathshith Sreenivasulu

Office Hours

The professor and TA's will hold office hours every week. We will announce the schedule during the first week of class and also post it on the Google calendar in Canvas. Please check the calendar for any updates throughout the semester.

Course Website

We will use Canvas (http://canvas.upenn.edu) for assignments and posting any additional resources for the class, such as lecture slides, handouts, and supplemental reading.

We also have a Piazza page: http://piazza.com/upenn/fall2020/meam5202020c
If you have any questions about the class, please post to Piazza! Use email only for sensitive topics. We will do our best to respond to your questions in a timely manner. If you see others' questions that you can answer or answers that you can improve, do it! Students who have contributed thoughtful comments, questions, and answers throughout the semester will earn extra credit in the class.

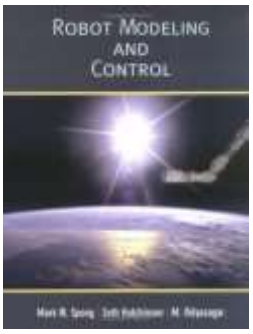
That said, while hints and suggestions are great contributions, Piazza should not be used for sharing or distributing solutions to any assignments in the class. Our goal is for everyone to understand the material.

Lectures and Online Learning

Our scheduled lecture slot is on Tuesdays and Thursdays 12:00pm – 1:20pm over Zoom (link to be announced). All lectures will be recorded and posted on Canvas for students who are not able to attend class during our normal time slot. However, I encourage everyone who is able to attend to attend the live Zoom session since this is an opportunity to ask questions and clear up confusions in real time.

Lectures are intended to be interactive. We will leverage Zoom's interaction tools, including the chat and raising your hand. An overview of these features will be presented during the first week of class. If you have a question, please speak up so we can clear up any confusions right away. If you think I have made a mistake in an explanation, please ask about it and help to fix the error or explain the confusion. Participating constructively in these ways will help make the class as good as it can be.

Textbook



Robot Modeling and Control
Spong, Hutchinson, and Vidyasagar (SHV)
Wiley & Sons (2006)

On reserve at Van Pelt Library

A list of errata can be found on Canvas

Other resources

On reserve at Van Pelt Library
Craig, *Introduction to Robotics: Mechanics and Control*, Addison-Wesley Publishing (2003)

Electronic resource available through Penn Library
Springer Handbook of Robotics, Eds. Siciliana and Khatib, Springer (2016)

Additional resources will be posted on Canvas as needed.

Virtual Labs

This is a project-based course. There will be a total of 6 labs and a final project.


http://www.lynxmotion.com/

Lab handouts will be posted on Canvas every other Wednesday. With the exception of Lab 0, there will be two deliverables:

- Pre-labs: To be turned in after 1 week, completed individually. Typically consists of theoretical questions related to the lab to enforce understanding.
- Lab reports: To be turned in after 2 weeks, completed in pairs. Labs contain both a coding and experimental portion. The code and a short <10 page write-up should be submitted on Canvas. More details will be included on the lab handouts.

Simulations via ROS

Typically, students of MEAM 520 interact with a Lynxmotion hardware robotic system. Unfortunately, because we will be virtual this semester, we will not be able to work physically with the arm. However, this gives us the opportunity to work in simulation with the Robot Operating System (ROS), a commonly used Linux-based platform that roboticists in academia and industry use to model and control robotic systems. This will require students to have access to a Linux partition on their computer or to set up a virtual machine. An introduction to ROS and its setup will be given in the first few weeks of class.

Paper Readings

Robotics is a young and dynamic field, and many interesting and important topics are not covered in textbooks. To prepare you for your future learning in robotics, we will read approximately four papers on special topics related to the content of the course. You will be asked to read the paper and submit a summary and questions by midnight the day before we discuss the paper in class.

Final Project

The final project will be an open-ended project that must be relevant to the course material. The final project can be done in groups of up to four people. It should reflect a substantial effort (equivalent to at least 1 lab/person).

Possible final projects include:

- An implementation and evaluation of a method or procedure we learned in class
- A literature review covering recent results in an area discussed in class
- A research project on an open robotics problem in an area discussed in class

This project does NOT have to be an isolated effort. You are strongly encouraged to do a project that you are actually interested in. I support doing a project related to your work in another course (such as MEAM 517 or senior design) or in a research group.

You will submit a project proposal by Friday, November 20, an in-class presentation in the last week of the semester, and a final project report (with group and individual components) by the last day of class on Thursday, December 10. A no-penalty extension will be automatically granted on the final project report to anyone who wishes to submit by the end of Reading Days on Monday, December 14. Further details will be provided in class.

Grading

Assignments in the class will be graded according to the following point distribution:

Get Started Quiz	**1 pts**	
Lab 0	**5 pts**	
Labs 1-5	**50 pts**	**/ ea**
Pre-lab	(5 pts)	
Lab code	(20 pts)	
Lab report	(25 pts)	
Paper readings (~4)	**10 pts**	
Final project	**75 pts**	
Project proposal	(5 pts)	
Presentation	(10 pts)	
Group report	(50 pts)	
Peer evaluation	(10 pts)	

Your final grade will be computed as a percentage of points earned out of the total points.

Late assignments will be accepted up to 72 hours after the deadline with a penalty of 25% per day. Exceptions to these deadlines will be granted only for exceptional cases. Post a private message to Piazza to request an extension.

We will do our best to grade your submitted assignments quickly and accurately. If you believe we have made a grading error, write your reasoning as a private post to the instructors on Piazza (not on Canvas). Do not bring up these issues before or during lecture so that we can focus that time on teaching. The evidence for your request must be in your Canvas submission. Do not submit supplementary material.

University Policies and Resources

This course will be conducted in accordance with all university policies. The university and the School of Engineering & Applied Science also offer numerous resources to students that may be useful. Please let the instructors know if you have any questions or concerns related to the following:

Code of Academic Integrity:

In accordance with the University's Code of Academic Integrity (available at https://catalog.upenn.edu/pennbook/code-of-academic-integrity/), all work turned in by students should be an accurate reflection of their knowledge, and, with the exception of working in groups for homework assignments, should be conducted alone. Violation of University Code of Academic Integrity may result in failure of the course.

Students with Disabilities and Learning Differences

Students with disabilities are encouraged to contact Weingarten Learning Resource Center's Office for Student Disabilities Services for information and assistance with the process of accessing reasonable accommodations. For more information, visit http://www.vpul.upenn.edu/lrc/sds/, or email lrcmail@pobox.upenn.edu.

Counseling and Psychological Services (CAPS)

CAPS is the counseling center for the University of Pennsylvania. CAPS offers free and confidential services to all Penn undergraduate, graduate, and professional students. For more information, visit http://www.vpul.upenn.edu/caps/.