EECS C106B/ EE C206B / BIOE C106B

Robotic Manipulation and Interaction

Spring 2019

TL;DR

- **This syllabus is the foremost authority on course policies and deadlines.** It should be treated as a living document and will be updated throughout the semester. After the first two weeks of the semester (during which policies may be slightly in flux), any updates to this document will be accompanied by a bCourses announcement.
- The hub for this class, and your source of all relevant files and resources, is the class's **bCourses** website.
- Our primary method of official communication with you will be through **bCourses announcements**. Make sure you are signed up to receive them by navigating to Account > Notifications and ensuring that the check mark next to "Announcement" is green.
- Your primary communication with us should be through **Piazza**, which can be accessed here or directly through bCourses. Unless you have a reason to contact only a single course instructor, Piazza is the best way to get a response within a reasonable time frame. Note that the framework supports private "instructor-only" messages.

Overview

This course is an introduction to the field of robotics, focusing on dynamics and grasping and manipulation. It covers the fundamentals of kinematics, dynamics, and control of robot manipulators, robotic vision, soft robotics and sensing.

Course Content

The course is a sequel to EECS C106A/Bioengineering C106A and EECS C206A which covers kinematics, dynamics and control of a single robot. This course will cover dynamics and control of groups of robotic manipulators coordinating with each other and interacting with the environment including people. Concepts will include an introduction to grasp modeling with friction, grasp planning. The course will also cover constrained manipulation, perception guided manipulation, including concepts of holonomy and non-holonomy. Throughout, we will emphasize design and human-robot interactions and applications in manufacturing, service robotics, and locomotion. We will also experiment with soft robots.

Logistics

This course will be taught in a seminar style, with homework, four small projects/labs, and a final project. All submissions will go through Gradescope (Course Entry Code: MG32V3), which you all should have been added to. A piazza page has been created for students to discuss homeworks and projects. Note that there will be no exams in this course.

If you need disability-related accommodations in this class, if you have emergency medical information you wish to share with us, or if you need special arrangements in case the building must be evacuated, please inform us immediately. Please see the professor or GSIs privately after class or in the office.

Prerequisites

Students are expected to have taken EECS C106A / BioE C106A / EECS C206A, which should be sufficent prepearation for all material in this class. A strong programming background, knowledge of Python and Matlab, and some coursework in feedback controls (such as EE C128 / ME C134) are also useful. Students who have not taken EECS C106A / BioE C106A / EECS C206A should have a strong programming background, knowledge of Python and Matlab, and exposure to upper division linear algebra, Lagrangian dynamics, mechatronics, and feedback controls.

Instructors & Office Hours

Role	Name	Email	Office Hours	Location
Prof.	Ruzena Bajcsy	`bajcsy@eecs.berkeley.edu`	By Appointment	719 SDH
GSI	Valmik Prabhu	`valmik@berkeley.edu`	Monday 1-2, Wednesday 4-5	111 Cory
GSI	Chris Correa	`chris.correa@berkeley.edu`	Thursday 2-4	111 Cory
Reader	Nandita Iyer	`nandita@berkeley.edu`	NA	NA

Questions regarding **homeworks** and **labs** should be directed to **Valmik** and **Chris**. Questions regarding **discussions** and **course logistics** should be directed to **Valmik**. All questions can and should be directed to **Piazza** for the fastest response. When emailing a GSI, please prefix the subject line with **[EE106B]**.

Resources

The required text is Richard Murray, Zexiang Li and S. Shankar Sastry's *A Mathematical Introduction to Robotic Manipulation* (first edition digitally available here). Additional lectures will cover the basics of computer vision, path planning, state estimation, and control.

Disability Accommodations & Emergencies

If you need disability-related accommodations in this class, if you have emergency medical information you wish to share with us, or if you need special arrangements in case the building must be evacuated, please inform us immediately. Please see the professor or GSIs privately after class or send us an email.

Grading & Late Policies

Grading Breakdown

Homeworks	15%
Lab 1	15%
Lab 2	15%
Lab 3	10%
Lab 4	10%
Final Project	35%

Two mid-semester feedback surveys will be posted, each worth 0.25% of your grade. These survey points will serve in lieu of rounding. Final grades will *not* be rounded.

Homeworks

Homeworks will be collected and graded using the Gradescope system. Create an account on gradescope.com with your Berkeley email account and SID. Add this course with the code MV32V3.

There will be a total of 5 homeworks with the following tentative due dates:

Assignment	Posted Date	Due Date
HW 1	01/25/18	02/03/18
HW 2	02/03/18	02/17/18
HW 3	02/18/18	03/03/18
HW 4	03/04/18	03/17/18
HW 5	03/18/18	04/06/18

Each student is allocated **5 total days of extension**, to be used on any homework assignment with no loss of points. To allow for homework solutions to be released in a timely manner, **no more than 2 extension days may be used on a single assignment**. After the extension days have elapsed, homeworks will be accepted for a geometrically decreasing number of points (i.e., 1 day late → half credit, 2 days late → quarter credit, ..., N days late → $^1/_{2^N}$ credit).

Collaboration on homework sets is encouraged, but all students must write up their own solution set. Additionally, every student is accountable for the solutions they submit and may be asked to discuss them with a GSI or instructor. **Please list all collaborators at the top of each submitted homework set.**

Labs

The lab in 111 Cory is open for use for the labs/mini-projects and the final project. Please do not use the hardware until the discussion on lab safety, which will occur on 1/23. The robots/hardware will be shared. Please reserve times on the following calendars:

Robot	Calendar
Baxter/Sawyer	Baxter Calendar
Turtlebot	Turtlebot Calendar
Soft Robots	Soft Robots Calenadar

There are no official lab sections or checkoffs, as there are in 106A. Instead, students will work on their own time and turn in a lab report to Gradescope. Labs should be completed in groups of 2-3.

Final Project

The final project will constitute the largest single portion of your grade for this course and must include sensing, planning, and actuation components on real hardware. Whereas the 106A project was an implementation-based project, this project should be research-based. Project deliverables include a proposal, a live demo and poster session, an academic-style paper, a small website, and several intermediate check-ins. Further information will be forthcoming; in the meantime, feel free to explore the list of previous projects available on bCourses!

Due to the types of deliverables involved (e.g., live demonstrations), late work will not be accepted.

Office Hours

The instructors will hold weekly office hours to discuss lecture content, homework assignments, projects, and other course material. We will try our best to schedule them so that each student has the opportunity to attend at least one office hour each week. When discussing a current homework assignment, instructors will **not** provide solutions. Rather, instructors will be happy to help clarify fundamentals and to guide students' reasoning in related problems.

A Note on Late Work

While we will abide by the policies listed above regarding specific assignment types, we understand that unforeseen circumstances do happen. If you feel that you will not be able to complete an assignment on time under the policies listed above due to truly extenuating circumstances, please inform a course instructor as soon as possible and **before** the associated deadline to discuss your situation. Once the deadline has passed, accommodations are unlikely.

Regrade Requests

If you feel that your work has been graded unfairly, you may request a regrade by submitting a request on Gradescope with a written statement explaining the mistake. Be aware that points may be deducted as well as added if a regrade is requested.

Weekly Schedule

Lecture

LEC 001	T/Th	11a-12:30p	Ruzena Bajcsy	521 Cory

Discussion

DIS 201	M/W	2-3p	Valmik Prabhu	111 Cory
DIS 202	M/W	3-4p	Valmik Prabhu	111 Cory

Semester Roadmap

Week	**Lecture/Discussion**	**Lab***	**Resources**
1/21	L1 – Introduction, Rigid Body Motion Review of Manipulator Kinematics	Lab 1A	MLS Ch 2, 3
	D1 – Review and Lab 0		
	L2 – Review of Dynamics (Andrew Barkan)		MLS Ch 4.2, 4.3
1/28	D2 – Robot Dynamics, Lab 1A Intro	Lab 1A	
	L3 – Lyapunov Stability (Aaron Ames)		MLS 4.4
	D3 – Linear and Nonlinear Stability		
	L4 – Controls		
2/04	D4 – Controls Review	Lab 1B	
	L5 – Trajectory Tracking		MLS 4.5
	D5 – Tuning Tips Lab 1B Intro		
	L6 – Impedance Control		
2/11	D6 – Fun Controls Extras	Lab 1B	
	L7 – Intro to Grasping (Jeff Mahler)		MLS 5.1, 5.2
	D7 – Grasping		
	L8 – Force Closure (Jeff Mahler)		MLS 5.3
2/18	D8 – *Presidents' Day, No Instruction*	Lab 2	

	L9 – Grasp Planning		MLS 5.4 Carlo Ferrari and John Canny, "Planning Optimal Grasps" Suarez et al. "Grasp Quality Measures" Nguyen, "Constructing Force Closure Grasps" Scribed Lecture Notes
	D9 – Lab 2 Intro		
	L10 – Cooperative Grasping		MLS 5.5, 5.6 Springer Handbook of Robotics Ch 28: Grasping Antonio Bicchi, "On the Closure Properties of Robotic Grasping" Prof Goldberg's Handwritten Notes Scribed Lecture Notes
2/25	D10 – Grasping	Lab 2	
	L11 – Differential Geometry (Shankar Sastry)		
	D11 – Differential Geometry		
	L12 – Differential Geometry (Shankar Sastry) Constrained Dynamics		MLS 4.6, 6.1
3/04	D12 – Something	Lab 2	
	L13 – Holonomy vs Non-holonomy more constrained dynamics		Vijay Kumar Slides, UPenn
	D13 – Something		
	L14 – Hand Dynamics Coordinated Lifting		MLS 6.2, 6.3
3/11	D14 – Something, Lab 3 Intro	Lab 3	
	L15 – Soft Robotics (or more dynamics)		
	D15 – Something		
	L16 – Soft Robotics (or more dynamics)		
3/18	D16 – Something	Lab 3	
	L17 – Soft Robotics		
	D17 – Something		
	L18 – Soft Robotics		
3/25	*Spring Break, No Lecture or Discussion*		
4/01	D18 – Something, Lab 4 Intro	Lab 4	
	L19 – Special Topics (or more soft robotics)		
	D19 – Something		
	L20 – Special Topics (or more soft robotics)		

4/08	D20 – Something	Lab 4
	L21 – Path Planning	
	D21 – Something	
	L22 – Path Planning	
4/15	D22 – Something	*none*
	L23 – Special Topics	
	D23 – Something	
	L24 – Special Topics	
4/22	D24 – Something	*none*
	L25 – Special Topics	
	D25 – Something	
	L26 – Special Topics	
4/29	D26 – Something	*none*
	L27 – Special Topics	
	D27 – Something	
	L28 – Special Topics	
5/06	*Dead Week*	
5/13	*Finals Week*	