EECS C106A/ EE C206A / BIOE C125

Introduction to Robotics

Fall 2018

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. It covers the fundamentals of kinematics, dynamics, and control of robot manipulators, robotic vision, and sensing. The course deals with forward and inverse kinematics of serial chain manipulators, the manipulator Jacobian, force relations, dynamics, and control. It presents elementary principles on proximity, tactile, and force sensing, vision sensors, camera calibration, stereo construction, and motion detection. The course concludes with current applications of robotics in active perception, medical robotics, autonomous vehicles, and other areas.

Students are expected to have a background in linear algebra, calculus, and basic physics, as well as familiarity with the Python programming language. The lectures are supplemented with homeworks and experimental work in the laboratory using several Baxter, Sawyer, and TurtleBot robots. There are two midterms, but no final exam. The last month of the course is devoted to the design and implementation of a final project, carried out individually or in groups of $\sim$ 2-4 students.

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	Wednesday 6-7, Thursday 5-6	111 Cory
GSI	Brent Yi	brentyi@berkeley.edu	Tuesday and Thursday 11:30-12:30	TBD
GSI	Nandita Iyer	nandita@berkeley.edu	Tuesday 4-5, Thursday 1-2	111 Cory
GSI	Ravi Pandya	rpandya922@berkeley.edu	Thursday 2-3, Friday 12-1	111 Cory
GSI	Philipp Wu	phil80301@berkeley.edu	Thursday 10-12	111 Cory
GSI	Andrew Barkan	andrew_barkan@berkeley.edu	Wednesday and Thursday 3-4	Hesse Hall Lobby
LA	Sean Xu		Thursday 6-8	Cory 111
LA	Parsa Fereydouni		N/A	N/A

Questions regarding **homeworks**, **exams**, **lectures**, and **discussions** should be directed to **Brent**. Questions regarding **labs** should be directed to **Valmik**, **Nandita** or **Ravi**. Questions regarding **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 **[EE106A]**.

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	20%
Midterms	20%
Labs	20%
Final Project	40%

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 **MV5WKX**.

There will be a total of 7 homeworks, due weekly through mid-November. 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 $\rightarrow$ half credit, 2 days late $\rightarrow$ quarter credit, ..., N days late $\rightarrow$ $1/2^N$ 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.**

Midterms

There will be two midterms covering the course material, on **September 27** and **November 8**. Each midterm will be 80 minutes and will occur during lecture. If you have an anticipated conflict with one of the midterm dates, please notify the GSIs by email before the end of the second week of the term.

Labs

Mandatory lab sections will meet each week beginning the first full week of classes and will run through the week of October 30. Please ensure that you have been assigned a lab section that you are regularly able to attend, as we rely on an even distribution of students so that everyone has access to hardware. In lieu of formal reports, labs are completed by discussing your system with and demonstrating its functionality to your lab GSI during various "check-offs" specified in each lab description. **Note that all students who**

are being checked off must be present at the time of the check-off, in the interest of making sure everyone can fully explain the code and system functionality.

In the event that you cannot attend your scheduled lab section one week, please inform your lab's head GSI *before* the meeting of the lab and we will do our best to accommodate you in a different lab section for the week. Note that we cannot promise to accommodate after-the-fact requests to attend a different section.

Labs should ideally be completed by the end of your assigned lab section, and are scoped such that this should be feasible. We recognize, however, that due to different levels of previous experience with the material — as well as the challenges of working with real hardware — this will not always be possible. In order to accommodate this variation while ensuring that students do not fall behind, we have developed the following (admittedly complex) policies:

- **Labs 1-2** are a serial introduction to ROS and the other tools used in this class. They must therefore be completed by the **start*** of your assigned lab section the following week.
- **Labs 3-8** occur in blocks of two labs each (3 & 4, 5 & 6, 7 & 8); each block is dependent on the previous block, but labs within each block are not dependent on each other and may be completed in any order. **Both labs from each block** must be completed by the **start*** of your first assigned lab section for the following block.

The start of your lab section is a hard cutoff — that is, if an assignment is due at the start of lab section, you may **not check off that assignment at the start of class for full credit; it must be checked off beforehand. This policy is in place because many of the labs fully fill the allotted time, and we want to keep everyone on schedule.*

If labs are not completed and checked off by the times above, they may be checked off for half credit for one week following the deadline, after which no credit will be given. Labs may be worked on outside of class hours as long as proper safety policies are followed (namely, you have been instructed in the correct policies and etiquette for the hardware you are using, and if you are using hardware, two or more people are present in the lab). Labs may be checked off at Valmik's, Nandita's, Ravi's, Phil's or Sean's office hours as listed above, or you may request to attend a different lab section for the check-off by asking a GSI. Note that many of the labs in this class are full, and you will not be allowed to attend them.

We understand that these policies are a bit nuanced, and if you have questions, please ask us! We've done our best to create a policy that allows for flexibility while encouraging people to stay on schedule and maintaining fairness; to do so, we've sacrificed simplicity.

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. Project deliverables include a proposal, a video, a live demo, a final report, 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), slack days may **not** be used on project deliverables, and 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	8-9:30a	Ruzena Bajcsy	105 North Gate

Lab

LAB 101	M	9a-12p	Nandita Iyer & Ravi Pandya	111 Cory
LAB 102	M	12-3p	Valmik Prabhu	111 Cory
LAB 103	M	3-6p	Nandita Iyer	111 Cory
LAB 104	W	9a-12p	Nandita Iyer	111 Cory
LAB 105	W	12-3p	Ravi Pandya	111 Cory
LAB 106	W	3-6p	Valmik Prabhu	111 Cory
LAB 107	F	9a-12p	Ravi Pandya	111 Cory
LAB 108	Tu	11a-2p	Phillip Wu	111 Cory
LAB 109	Tu	5-8p	Phillip Wu	111 Cory

Discussion

DIS 201	F	12-1p	Brent Yi or Andrew Barkan	293 Cory
DIS 202	F	1-2p	Brent Yi or Andrew Barkan	293 Cory
DIS 203	F	2-3p	Brent Yi or Andrew Barkan	293 Cory
DIS 204	F	3-4p	Brent Yi or Andrew Barkan	293 Cory
DIS 205	Th	5-6p	Brent Yi or Andrew Barkan	521 Cory
DIS 206	W	9-10a	Brent Yi or Andrew Barkan	521 Cory

Due Dates

Unless otherwise noted, assignments are due by **11:59p** on the date listed. Midterms will occur during lecture. Homeworks will typically be released a week before the due date.

9/6	HW1 (Rotations)
9/13	HW2 (Forward Kinematics)
9/20	HW3 (Inverse Kinematics)
09/27	**Midterm I**
10/5	Project Mini-Proposal & Team
10/11	HW4 (Velocities)
10/18	HW5 (Wrenches)
10/21	Final Project Proposal & Parts List
10/25	HW6 (Dynamics)
11/1	HW7 (Feedback)
11/8	**Midterm II**
12/7	**Final Project Presentations**
12/14	**Final Project Reports**

Semester Roadmap

Week	Lecture	Discussion	Lab*	Notes
8/22	L0 – Introduction / Project Ideas	*none*	*none*	
8/27	L1 – Rigid Body Motion L2 – Rotations	D1 – Rotations	1	
9/3	L3 – Homogeneous Coordinates L4 – Exponential Coordinates	D2 – Forward Kinematics	2	Holiday 9/3 affects M labs; info forthcoming.
9/10	L5 – Forward Kinematics L6 – Inverse Kinematics	D3 – Inverse Kinematics	3/4	
9/17	L7 – Vision L8 – Vision (cont'd)	D4 – Midterm I Review	3/4	
9/24	L9 – Midterm I Review L10 – **MIDTERM I**	Project Ideation	*none*	
10/1	L11 – Rigid Body Velocities L12 – Jacobians	D5 – Velocities & Jacobians	5/6	
10/8	L13 – Force Wrenches L14 – Masses & Moments of Inertia	D6 – Jacobians & Wrenches	5/6	
10/15	L15 – Newtonian Dynamics L16 – Lagrange Dynamics	D7 – Dynamics	Project Meetings	
10/22	L17 – Motion Planning L18 – Feedback & State Estimation	D8 – Feedback / Estimation	7/8	
10/29	L19 – Parameter Identification L20 – Contact Sensors	D9 – Midterm II Review	7/8	
11/5	L21 – Midterm II Review L22 – **MIDTERM II**	*none*	*none*	Holiday 11/12
11/12	L23 – Error Dynamics / Lyapunov L24 – Special Topics / Guest Lecture	*none*	*none*	
11/19	L25 – Special Topics / Guest Lecture L26 – *none (Thanksgiving)*	*none*	*none*	
11/26	L27 – Special Topics / Guest Lecture L28 – Special Topics / Guest Lecture	*none*	*none*	
12/03	*Dead Week*			
12/10	*Finals Week*			

* Note that for labs 3-8, each lab section will be split in half to allow all groups ample time to use the hardware. (E.g., groups will concurrently be working on lab 5, which uses the Baxter/Sawyer robots, while others will work on lab 6, which uses the TurtleBots.)