CSCI 545: Introduction to Robotics

Units: 4

Spring 2024, Mondays & Wednesdays, 4:00pm to 5:50pm

Location: ZHS 352

Instructor: Daniel Seita
Office: PHE 212
Office Hours: 5:50pm to 7:00pm
Contact Info: seita@usc.edu

Note: please refer to the website for updated information: https://danielseita.github.io/cs545-sp2024.html

Course Description

This class will introduce students to the fundamental questions in robotics: what are good models of the world and how to integrate them reliably into the planning of deployed robotic systems physically interacting with the environment. All these problems arise from the uncertainty due to sensor noise, modeling limitations, approximations in algorithmic computations and inherent unpredictability of action outcomes. The course will explore probabilistic techniques that allow robots to act reliably and exhibit a variety of different behaviors in spite of different sources of uncertainty. We will first cover algorithms for state estimation in both known and unknown environments. We will then explore functional aspects of robot's interaction with the world, such as the geometry of configuration spaces and manipulation planning in these spaces. We will wrap up the course by exploring the interplay of inference and planning and its applications in robot autonomy, especially as it pertains to robot manipulation.

Learning Objectives and Outcomes

In this course, you will be introduced to probabilistic techniques that allow state estimation, manipulation and planning in robotics. By the end of this course you should be able to:

- demonstrate proficiency in the tools that support state estimation, manipulation and planning with sensor and modeling noise.
- implement these techniques and test them with real-world datasets.
- integrate your algorithms with state-of-the-art simulation environments.
- explain the computational and practical challenges of applying these techniques in real-world interaction settings and compare them in terms of robustness, scalability and performance.

Recommended Preparation and Prerequisites: Students are required to have a solid background of probability theory, linear algebra and calculus. Students should also be proficient in Python. Recommended preparation includes robotics at the undergrad level (CSCI 445L) but it is not required.

Course Notes

The course is a standard letter grade course. We will have as much material on the course website as possible. The course will also involve working with the Robot Operating System. For this, we will enroll the class in VMware so that all students get a license. This will make doing the labs much easier. We will use Piazza for discussion and Gradescope for handling grades.

Technological Proficiency and Hardware/Software Required

The course consists of standard lectures on Mondays and Wednesdays. However, we will have labs on (some) Tuesdays which will let students get experience working with physical robots. We will provide instructions to the students as those labs occur. For labs, students will be able to use personal laptops.

Required Readings and Supplementary Materials

There is no required reading and much of the information is freely available online. We will draw our material from the following:

- Modern Robotics, by Lynch and Park. (Use the December 2019 version). (LP)
- Robotic Manipulation: Perception Planning and Control, by Russ Tedrake. (RT)
- Robotics: Modelling, Planning, and Control, by Bruno Siciliano, Lorenzo Sciavicco, Luigi Villani, and Giuseppe Oriolo. (SS)
- Probabilistic Robotics, by Sebastian Thrun, Wolfram Burgard, and Dieter Fox. (TBF)
- Principles of Robot Motion, by Howie Choset, Kevin M. Lynch, Seth Hutchinson, George Kantor, Wolfram Burgard, Lydia E. Kavraki, and Sebastian Thrun. (CL)

The first two textbooks are freely available online.

Description and Assessment of Assignments

The homeworks will contain a mix of theoretical (math-oriented) questions and some basic programming questions (in Python) to verify some of the theory. The labs will be similar but more implementation-heavy

and rely on the Robot Operating System (ROS) for programming the robot. The labs will be done by a team of students. Students will be in the same group for all their labs.

Grading Breakdown

Tentative grading breakdown:

Assignment	Points	% of Grade
Homework	10	10
Labs	30	30
Midterm	30	30
Final	30	30
TOTAL	100	100

Note that students must submit all homeworks and labs to get a passing grade for the course, and to take both exams. (The homeworks and labs may be incomplete.)

Grading Scale

We will tentatively consider course grades under the following scale, but if turns out that the exams are particularly difficult, we will make the grading scheme more generous to students.

A [90, 100)
A- [85, 90)
B+ [80, 85)
B [75, 80)
B- [70, 75)
C+ [65, 70)
C [60, 65)
C- Grades lower than this are handled on a case-by-case basis.

Assignment Rubrics

The assignments and labs will tentatively be graded on a 5-point scale (in order) as: check++, check+, check, check-, check--, with a check++ as the best possible grade. More specific rubrics will be developed as the assignments get closer.

Grading Timeline

We will use Gradescope to upload assignments and exams, and will strive to give feedback within 1 week of submission time (with an extra 1 week for regrade requests).

Assignment Submission Policy

See the tentative syllabus for when assignments are due. Students will submit homeworks and labs via Gradescope.

Academic Integrity

Unless otherwise noted, this course will follow the expectations for academic integrity as stated in the USC Student Handbook. The general USC guidelines on Academic Integrity and Course Content Distribution are provided in the subsequent "Statement on Academic Conduct and Support Systems" section. Please ask the instructor if you are unsure about what constitutes unauthorized assistance on an assignment, or what information requires citation or attribution.

Use of Generative AI in This Course

We will be generous with the tools and resources that students are allowed to use (which includes allowing the use of Generative AI), but they must be detailed when citing the resources used for homeworks and labs. Our assigments will have instructions about how to cite these tools properly, and failing to cite this in the proper format will result in immediate grade deductions.

Course Schedule: A Weekly Breakdown

This is the tentative schedule. The course website has a more detailed and up-to-date schedule. Tentatively we have 4 homeworks: (1) Math Basics, (2) Kalman Filters, (3) Inverse Kinematics, and (4) Imitation Learning. We also have 4 labs: (1) Introduction to ROS, (2) Monte Carlo Localization, (3) RRT for a Manipulator, (4) Task Space Regions.

	Topics/Daily Activities	Readings and Homework	Deliverable/ Due Dates
Week 1	Introduction and math review	SS Appendix A HW 1 released	
Week 2	Probability review	Lab 1 released	
Week 3	Bayesian networks and Bayesian filters	TBF Ch. 2, 3.1-3.2.3 HW 2 released	HW 1 due
Week 4	Kalman filters and Particle filters	TBF Ch. 3.3.1-3.3.3 Lab 2 released	Lab 1 due
Week 5	Math optimization and configuration spaces	MR Ch. 2 HW 3 released	HW 2 due
Week 6	Transformations, forward/inverse kinematics	MR Ch. 3	Lab 2 due
Week 7	Motion planning (optimization)	RT Ch 6	HW 3 due
Week 8	Motion planning (sampling-based)	CL 7.1.1, 7.2.2	
Week 9	**Midterm**, POMDPs	Lab 3 released	
Week 10	Dynamics, nonlinear control	SS Ch. 8.6.2, Appendix C3	
Week 11	Acting with uncertainty; perception in robotics	RT Ch 4, 10 HW 4 released	Lab 3 due
Week 12	Perception in robotics, imitation learning	RT Ch 4, 10 Lab 4 released	
Week 13	Reinforcement learning	RT Ch 11	HW 4 due
Week 14	Sim-to-real, large language models for robots.	Sim-to-real: https://arxiv.org/abs/1703.06907	Lab 4 due
Week 15	Advanced topics, course wrap-up		
FINAL	Final Exam.		Wednesday May 01 from 4:30pm to 6:30pm, exact location to be decided.

Statement on Academic Conduct and Support Systems

Academic Integrity:
The University of Southern California is a learning community committed to developing successful scholars and researchers dedicated to the pursuit of knowledge and the dissemination of ideas. Academic misconduct, which includes any act of dishonesty in the production or submission of academic work, comprises the integrity of the person who commits the act and can impugn the perceived integrity of the entire university community. It stands in opposition to the university's mission to research, educate, and contribute productively to our community and the world.

All students are expected to submit assignments that represent their own original work, and that have been prepared specifically for the course or section for which they have been submitted. You may not submit work written by others or "recycle" work prepared for other courses without obtaining written permission from the instructor(s).

Other violations of academic integrity include, but are not limited to, cheating, plagiarism, fabrication (e.g., falsifying data), collusion, knowingly assisting others in acts of academic dishonesty, and any act that gains or is intended to gain an unfair academic advantage.

The impact of academic dishonesty is far-reaching and is considered a serious offense against the university. All incidences of academic misconduct will be reported to the Office of Academic Integrity and could result in outcomes such as failure on the assignment, failure in the course, suspension, or even expulsion from the university.

For more information about academic integrity see the student handbook or the Office of Academic Integrity's website, and university policies on Research and Scholarship Misconduct.

Please ask your instructor if you are unsure what constitutes unauthorized assistance on an exam or assignment, or what information requires citation and/or attribution.

Students and Disability Accommodations:
USC welcomes students with disabilities into all of the University's educational programs. The Office of Student Accessibility Services (OSAS) is responsible for the determination of appropriate accommodations for students who encounter disability-related barriers. Once a student has completed the OSAS process (registration, initial appointment, and submitted documentation) and accommodations are determined to be reasonable and appropriate, a Letter of Accommodation (LOA) will be available to generate for each course. The LOA must be given to each course instructor by the student and followed up with a discussion. This should be done as early in the semester as possible as accommodations are not retroactive. More information can be found at osas.usc.edu. You may contact OSAS at (213) 740-0776 or via email at osasfrontdesk@usc.edu.

Support Systems:
Counseling and Mental Health - (213) 740-9355 – 24/7 on call
Free and confidential mental health treatment for students, including short-term psychotherapy, group counseling, stress fitness workshops, and crisis intervention.

988 Suicide and Crisis Lifeline - 988 for both calls and text messages – 24/7 on call

The 988 Suicide and Crisis Lifeline (formerly known as the National Suicide Prevention Lifeline) provides free and confidential emotional support to people in suicidal crisis or emotional distress 24 hours a day, 7 days a week, across the United States. The Lifeline is comprised of a national network of over 200 local crisis centers, combining custom local care and resources with national standards and best practices. The new, shorter phone number makes it easier for people to remember and access mental health crisis services (though the previous 1 (800) 273-8255 number will continue to function indefinitely) and represents a continued commitment to those in crisis.

Relationship and Sexual Violence Prevention Services (RSVP) - (213) 740-9355(WELL) – 24/7 on call
Free and confidential therapy services, workshops, and training for situations related to gender- and power-based harm (including sexual assault, intimate partner violence, and stalking).

Office for Equity, Equal Opportunity, and Title IX (EEO-TIX) - (213) 740-5086
Information about how to get help or help someone affected by harassment or discrimination, rights of protected classes, reporting options, and additional resources for students, faculty, staff, visitors, and applicants.

Reporting Incidents of Bias or Harassment - (213) 740-5086 or (213) 821-8298
Avenue to report incidents of bias, hate crimes, and microaggressions to the Office for Equity, Equal Opportunity, and Title for appropriate investigation, supportive measures, and response.

The Office of Student Accessibility Services (OSAS) - (213) 740-0776
OSAS ensures equal access for students with disabilities through providing academic accommodations and auxiliary aids in accordance with federal laws and university policy.

USC Campus Support and Intervention - (213) 740-0411
Assists students and families in resolving complex personal, financial, and academic issues adversely affecting their success as a student.

Diversity, Equity and Inclusion - (213) 740-2101
Information on events, programs and training, the Provost's Diversity and Inclusion Council, Diversity Liaisons for each academic school, chronology, participation, and various resources for students.

USC Emergency - UPC: (213) 740-4321, HSC: (323) 442-1000 – 24/7 on call
Emergency assistance and avenue to report a crime. Latest updates regarding safety, including ways in which instruction will be continued if an officially declared emergency makes travel to campus infeasible.

USC Department of Public Safety - UPC: (213) 740-6000, HSC: (323) 442-1200 – 24/7 on call
Non-emergency assistance or information.

Office of the Ombuds - (213) 821-9556 (UPC) / (323-442-0382 (HSC)
A safe and confidential place to share your USC-related issues with a University Ombuds who will work with you to explore options or paths to manage your concern.

Occupational Therapy Faculty Practice - (323) 442-2850 or otfp@med.usc.edu

Confidential Lifestyle Redesign services for USC students to support health promoting habits and routines that enhance quality of life and academic performance.