Fall 2025

Stanford

CS 237A/AA 274A/ME274A/EE 260A: Principles of Robot Autonomy I

Instructor:
Prof. Mac Schwager
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Course Assistants:

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Lecture Time and Place:

Location: Skilling Auditorium

Time: Tuesdays and Thursdays 1:30 PM – 2:50 PM

Recordings: Lecture recordings will be made available to all students on Canvas.

Course Content: Basic principles for endowing mobile autonomous robots with planning, perception, and decision-making capabilities. Algorithmic approaches for trajectory tracking, trajectory optimization; robot motion planning; robot perception, localization, and simultaneous localization and mapping (SLAM). Extensive use of the Robot Operating System (ROS) for demonstrations and hands-on activities.

Course Goals: To learn the *theoretical*, *algorithmic*, and *implementation* aspects of main techniques for robot autonomy, in particular modeling & controls, motion planning, perception, localization & SLAM, and decision making. To learn how to apply such techniques in applications and research work by leveraging the Robot Operating System (ROS). With this class, the student will:

- Gain a fundamental knowledge of the "autonomy stack" behind self-driving cars, drones, and mobile autonomous robots in general;
- Be able to apply such knowledge in applications and research work by using ROS;
- Learn how to deploy these algorithms on robot hardware.

Prerequisites:

- Familiarity with programming (e.g., CS 106A or equivalent). Previous experience with Python and Object Oriented Programming required.
- College calculus, linear algebra (e.g., CME 100 or equivalent).
- Basic probability and statistics (e.g., CME 106 or equivalent).

Logistics:

- For syllabus, supp. material, and announcements: Canvas
- For course-related questions and discussion: Edstem
- For homework submission and grading: Gradescope
- For urgent questions: `cs237a-aut2526-staff@lists.stanford.edu`
- For general course information (same as syllabus): Course Website

Office hours:
Prof. Schwager: Tuesday, 3pm – 4pm, Durand 266.
Course assistants:
Monday 5:30pm – 7:30pm (hybrid, Durand 023), `rheamal`
Tuesday 11am – 1pm (hybrid, Durand 450) `asumuk`
Wednesday 3pm – 5pm (hybrid, Durand 270) `purush`
Thursday 6:30pm – 8:30pm (in Skilling Lab) `jingyuny`

In-person Sections:
Location: Skilling Laboratory (above Skilling Auditorium, near Durand building)
Monday: 9:30am – 11:30pm, `esrincon, jcontr83`
Monday: 12:00pm – 2:00pm, `rheamal, purush`
Tuesday: 3:00pm – 5:00pm, `jcontr83, ngao4`
Tuesday: 5:00pm – 7:00pm, `purush, asumuk`
Wednesday: 9:30am – 11:30am, `esrincon, jatucker`
Wednesday: 12:00am – 2:00pm, `rheamal, asumuk`
Wednesday: 6:30pm – 8:30pm, `ngao4, jingyuny`
Thursday: 4:30pm – 6:30pm, `asumuk, jingyuny`
Friday: 12:30 – 2:30pm, `purush, jatucker`

Virtual Section (CGOE Only):
Friday: 6:30 – 8:30pm, `jingyuny`

Structure and Expectations:
The course is organized around **Lectures**, **Homeworks**, **Laboratory Sections**, and **Exams**. In-person attendance at lectures is encouraged, but not required. Lab Sections are integral to the class, and students should plan to attend them each week (in person or virtually). We will also have a mixture of in-person and online office hours, where attendance is optional. The course staff will accommodate students who may have to isolate due to COVID-19.

Lectures: Lectures will cover foundational and theoretical aspects of the course material, which will be applied in homework problems, and in laboratory exercises in ROS in the weekly Sections. The class comprises four modules, roughly of equal length, namely:

1. motion control and planning;
2. robotic perception;
3. localization and SLAM;
4. system architecture, and additional topics.

Homeworks: There will be a total of **five** homeworks. Rules:

- Homeworks are due on the day posted on the syllabus at 5PM PST. Late homeworks will be accepted for 48 hours after the original deadline, with a 20% for each 24 hour block late. Extensions/exceptions to this policy will only be accepted with explicit permission from course staff.
- Cooperation is allowed in doing the homework. You are encouraged to discuss approaches to solving homework problems with your classmates, however **you must always prepare the solutions on your own**. You **must** write on your problem set the names of the classmates you worked with. Copying solutions, in whole or in part, from other students or any other source will be considered a violation of Stanford's honor code.
- **Homework submissions must be typeset in LaTeX**. A good tool for typesetting is Overleaf.com.

Sections: In addition to lectures, students are expected to sign up for a 2 hour section time that they will attend once per week. These sections will provide a chance for students to work on hands-on exercises that *complement* the lecture material and integrate algorithms that they developed in homework problems on real robots. Part of your grade will come from attending, participating in, and completing tasks in your section each week. Sections scheduling will be done through a ranked matching process, and students are expected to fill out a form (available on Canvas) with their preferences no later than Thursday September 29th at midnight. Section placement will be announced on Friday September 30th.

Exams: Exams for this course will be in a take-home format. The midterm exam will be a take-home given in Week 6 of the course (details on distribution and submission times will be announced in lecture). The exam will be open for a 48 hour period, in which a 5 hour window can be used to take the exam. The final exam, also a take home, will be released on Sunday, December 7 at 6:30 PM (PST) and will be due on Tuesday, December 9 at 6:30 PM (PST). You will have a 48-hour window to start the exam and 5 hours to complete it once opened. Submissions will be through Gradescope.

Course grade calculation:

- 20% – Homeworks (5 $\times$ 4% each)
- 40% – Sections (8 $\times$ 5% each)
- 15% – Midterm
- 25% – Final

Textbooks: There is no required textbook, instead course notes will be posted alongside lecture slides on the course website. Additional recommended reading material:

- R. Siegwart, I. R. Nourbakhsh, D. Scaramuzza. *Introduction to Autonomous Mobile Robots*. MIT Press, 2nd Edition, 2011, ISBN-10: 0262015358. Price: $38.11.

- S. Thrun, W. Burgard, D. Fox. *Probabilistic Robotics*. MIT Press, 2005, ISBN-10: 0262201623. Price: $52.08.

- S. M. LaValle. *Planning Algorithms*. Cambridge University Press, 2006, ISBN-10: 0521862051. Price: $99.99. Free electronic version available at `http://planning.cs.uiuc.edu/`

Additional ROS reading material:

- M. Quigley, B. Gerkey, W. D. Smart. *Programming Robots with ROS: A Practical Introduction to the Robot Operating System*. O'Reilly Media. 1st Edition, 2015, ISBN-10: 1449323898. Price: $45.15.

- J. M. O'Kane. *A Gentle Introduction to ROS*. 2013, ISBN-10: 1492143235. Price: $12.50. Free electronic version available at `https://cse.sc.edu/~jokane/agitr/`.

- L. Joseph, J. Cacace *Mastering ROS for Robotics Programming*. 2nd Edition, 2015, ISBN-10: 1788478959. Price: $49.99.

Tentative Schedule:

Date	Topic	Homework	Lab
09/23	Course overview, perception-action loop, maps		Lab 0: Install ROS
09/25	Maps, Robot geometry, Coordinate frames and SE(2)/SE(3) transforms	HW1 out	
09/30	Collision, C-space, motion models. Path planning I: A*		Lab 1: Command line, Git, Python
10/02	Path planning II: RRT, RRT*		
10/07	Trajectory optimization		Lab 2: ROS basics
10/09	Trajectory following: PID, LQR, gain scheduled LQR	HW1 due, HW2 out	
10/14	Robotic sensors: IMU, lidar, cameras, RGB-D. Point clouds & ICP		Lab 3: RViz, Turtlebot
10/16	Pinhole camera models, camera calibration	HW2 due, HW3 Out	
10/21	Structure from Motion (SfM), features, RANSAC		Lab 4: Heading controller
10/23	Learning based perception, semantic perception		
10/28	SLAM intro, factor graphs, PGO	HW3 due	Lab 5: Nav to goal
10/29	Midterm: 48 hour window	Midterm out	
10/30	Pose graph opt, bundle adjustment		
10/31	Midterm: 48 hour window window	Midterm due	
11/04	*No Lecture (Democracy Day)*	HW4 out	
11/06	Bayes Rule, RVs, Occ. mapping (Recorded Lecture, Mac traveling)		
11/11	Occ, mapping, frontier exploration		Lab 6: Object detection
11/13	Gaussian RVs, Kalman Filtering, EKF, UKF	HW4 due, HW5 out	
11/18	Particle Filtering, Monte Carlo localization		Lab 7: Frontier exploration
11/20	Guest Lecture		
11/25	*No lecture (Thanksgiving)*		
11/27	*No lecture (Thanksgiving)*		
12/02	EKF Localization, obj tracking	HW5 due	Lab 8: Makeup
12/04	Advanced Topics: Imitation learning, VLAs, 3DGS for sim2real, world models		
12/07	48 hour window take home final start	Final Exam out, 6:30pm	
12/09	48 hour window take home final end	Final Exam due, 6:30pm	

Students with documented disabilities: Students who may need an academic accommodation based on the impact of a disability must initiate the request with the Office of Accessible Education (OAE). Professional staff will evaluate the request with required documentation, recommend reasonable accommodations, and prepare an Accommodation Letter for faculty. Unless the student has a temporary disability, Accommodation Letters are issued for the entire academic year. Students should contact the OAE as soon as possible since timely notice is needed to coordinate accommodations. The OAE is located at 563 Salvatierra Walk (phone: 723-1066, URL: `https://oae.stanford.edu/`).

Lecture recordings: Operated by the Stanford Engineering Center for Global & Online Education (CGOE, formerly SCPD), video cameras located in the back of the room will record all lectures for this course. For your convenience, you can access these recordings by logging into the course Canvas site. These recordings might be reused in other Stanford courses, viewed by other Stanford students, faculty, or staff, or used for other education and research purposes. Note that while the cameras are positioned with the intention of recording only the instructor, occasionally a part of your image or voice might be incidentally captured. If you have questions, please contact the course staff at `aa274a-aut2425-staff@lists.stanford.edu`.

Disruptions: Stanford as an institution is committed to the highest quality education, and as your teaching team, our first priority is to uphold your educational experience. To that end we are committed to following the syllabus as written here, including through short- or long-term disruptions, such as public health emergencies, natural disasters, or protests and demonstrations. However, there may be extenuating circumstances that necessitate some changes. Should adjustments be necessary, we will communicate clearly and promptly to ensure you understand the expectations and are positioned for successful learning.

AI Assistance: As specified by the Stanford Honor Code on Generative AI Policy: *Absent a clear statement from a course instructor, use of or consultation with generative AI shall be treated analogously to assistance from another person. In particular, using generative AI tools to substantially complete an assignment or exam (e.g. by entering exam or assignment questions) is not permitted. Students should acknowledge the use of generative AI (other than incidental use) and default to disclosing such assistance when in doubt.*