Fall 2025

Stanford

AA 174A/CS 137A/EE 160A: Principles of Robot Autonomy I

Instructor:
Prof. Marco Pavone
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Location and time: CoDa B60, Tuesday and Thursday, 10:30am – 11:50am.

Office hours:
Prof. Pavone: Tuesdays, 1:00 – 2:00pm (Durand 261), after class, and by appointment.
Course assistants:

- Wednesday, Durand 270, 4:30 - 6:30pm
- Thursday, Durand 270, 4:30 - 6:30pm

Sections:
- Friday 9:30am – 11:30am, Skilling Lab space.
- Friday 2:30pm – 4:30pm, Skilling Lab space.

Sign up here for the preferred section slot by 12pm on Thursday, September 25th.

Units: 3 or 4. Taking this class for 4 units entails additionally completing a paper review at the end of the quarter, with details to be announced later.

Prerequisites:
- Familiarity with programming (e.g., CS 106A or equivalent). Previous experience with Python is *strongly* recommended.
- College calculus, linear algebra (e.g., CME 100 or Math 51 or equivalent).
- Differential equations (e.g., CME 102 or Math 53 or equivalent).
- Basic probability and statistics (e.g., CME 106 or equivalent).

Course URLs:

- For course content: https://stanfordasl.github.io/PoRA-I/aa174a_aut2526.
- For course announcements:
  https://canvas.stanford.edu/courses/214652/announcements
- For course-related questions:
  https://edstem.org/us/courses/87236/discussion/
- For homework submissions: https://www.gradescope.com/courses/1137718
- For urgent questions: aa174a-aut2526-staff@lists.stanford.edu

Textbooks: There is no required textbook. Additional recommended reading material:

- D. Gammelli, J. Lorenzetti, K. Luo, G. Zardini, M. Pavone. *Principles of Robot Autonomy*. Pre-print, 2025. Available at:
  https://stanfordasl.github.io/PoRA-I/aa174a_aut2526/resources/PoRA.pdf
- R. Siegwart, I. R. Nourbakhsh, D. Scaramuzza. *Introduction to Autonomous Mobile Robots*. MIT Press, 2nd Edition, 2011, ISBN-10: 0262015358.
- S. Thrun, W. Burgard, D. Fox. *Probabilistic Robotics*. MIT Press, 2005, ISBN-10: 0262201623.
- S. M. LaValle. *Planning Algorithms*. Cambridge University Press, 2006, ISBN-10: 0521862051. 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.
- J. M. O'Kane. *A Gentle Introduction to ROS*. 2013, ISBN-10: 1492143235. 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.

Course content: Basic principles for endowing mobile autonomous robots with planning, perception, and navigation capabilities. Algorithmic approaches for trajectory optimization; robot motion planning; perception; localization; and simultaneous localization & 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, trajectory optimization, motion planning, perception, localization, and SLAM. 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, space robots, and mobile autonomous robots in general; and
- Be able to apply such knowledge in applications using ROS.

Course structure and homework policy: The class comprises four main topics, namely:

1. Robot Operating System (week 1);
2. Controls & Motion Planning (weeks 2-4);
3. Perception (weeks 5-8);
4. State Estimation, Localization & SLAM (weeks 8-11).

There will be a total of **four** problem sets. Rules:

- Because of the multiple topics that will be pursued in the course, it is important to keep up with the assignments. To account for unforseen extraordinary circumstances, students are given a total of 6 free late days that may be used for the homework; a maximum of 3 late days will be allowed on a given assignment.

- 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 case of **academic dishonesty**.

- **Homework policy**. Homework submissions must be typeset (e.g., in LaTeX or Word.) Homework will be graded based on completion rather than correctness. For each homework question:

  1. **Submit the Deliverable:** If you have produced an output—such as a plot or numerical result—please submit that.
  2. **Submit Process and Approach:** Submit an account of your process. If you are unable to produce an output, please describe any challenges you encountered and provide an assessment of what may have gone wrong.

Sections: In addition to lectures, students are expected to attend a 2-hour section every Friday. These sections will provide a chance for students to work on hands-on exercises that *complement* the lecture material and develop skills necessary for working with robotic hardware. Students will work in groups of 3 - 4 and progressively build towards a full autonomy software stack throughout the quarter. Section grades are broken down to three parts:

1. **Attendance.** Students are allowed to miss up to one section without grade penalty to accommodate for unforeseen circumstances.
2. **Group Participation.** Students will perform peer evaluation among group members by the end of the quarter.
3. **Final Section Demo.** Students will submit the final autonomy stack and demo it to the course staff during the last two sections. The grade will take into account coding style, stack capabilities, and the ability to answer instructors' questions about the stack. Extra credit will be given to groups that implement additional features within the autonomy stack.

Participation on Edstem: Edstem will be the main tool for class discussion. A student will get an extra of 0.2 points towards the final grade each time he/she answers a question about lecture material or homework. Answers need to be endorsed by one of the CAs in order to receive credit. A student can accrue a maximum of 1 extra point.

Course grade calculation:

- (40%) Homework.
- (20%) Midterm exam.
- (40%) Sections:
  - (16%) attendance;
  - (8%) group participation; and
  - (16%) final section demo.
- (extra 1%) Participation on Edstem.
- (extra 4%) Final demo with additional autonomy features.
- (extra 5%) In-person classroom attendance

Schedule: subject to some slippage

Date	Topic	Assignments
09/23	Course overview, intro to robotic systems and ROS	
09/25	Fundamentals of ROS & vectorized computation in Python	
09/26	⋆ Section 1 – UNIX, Git, and Python	HW1 out
09/30	State space dynamics – definitions and modeling	
10/02	State space dynamics – computation and simulation	
10/03	⋆ Section 2 – ROS, workspaces, packages, nodes	
10/07	Trajectory optimization	HW2 out
10/09	Trajectory tracking	
10/10	⋆ Section 3 – Launch files & RVIZ	HW1 due
10/14	Motion planning I: graph search algorithms	
10/16	Motion planning II: sampling-based methods	
10/17	⋆ Section 4 – Controller gain tuning in hardware	HW2 due
10/21	Robotic sensors & introduction to computer vision	HW3 out
10/23	Camera models and camera calibration	
10/24	⋆ Section 5 – Running a point-to-point navigator	
10/28	Image processing, feature detection, & feature description	
10/30	Information extraction	
10/31	⋆ Section 5 cont. & Section 6 head start	HW3 due, HW4 (part 1) out
11/04	No Lecture – Democracy Day	
11/06	*In-class midterm*	
11/07	⋆ No Section	
11/11	Deep learning for computer vision	
11/13	Intro to state estimation & filtering theory	
11/14	⋆ Section 6 – Object detection	HW4 (part 2) out
11/18	Parametric filtering (KF and EKF)	HW4 (part 1) due
11/20	Markov localization and EKF-localization	
11/21	⋆ Section 7 – Frontier exploration	
11/25		
11/27	*Thanksgiving*	
11/28		
12/02	Multi-sensor perception & sensor fusion	HW4 (part 2) due
12/04	Simultaneous localization and mapping (SLAM)	
12/05	⋆ Section 7 cont.	

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 the 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/`).