Fall 2022

Stanford

AA 174A/AA 274A/CS 237A/EE 260A/ EE 160A: Principles of Robot Autonomy I

Instructor:
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Logistics:

- For general course information: course website
- For annoucements: Canvas
- For course-related questions: Edstem
- For homework submissions: Gradescope
- For urgent questions: `cs237a-aut2223-staff@lists.stanford.edu`

Location and time: Gates Computer Science, B1. In-person lectures will take place Tuesdays and Thursdays 10:30 AM – 11:50 AM; lecture recordings will be made available to all students on Canvas.

In-person attendance is not required to participate in this course (including lectures, sections, and final project). There is a mixture of in-person and online office hours. The course staff will accommodate students who may have to isolate due to COVID-19.

Office hours:
Prof. Bohg: Friday, 1pm – 2pm, and by appointment.

Course assistants: Mondays 1 – 3pm (in-person), `garydai, ...,`
Tuesdays 2pm – 4pm (virtual) `masonmc, snewdick`,
Thursdays 6pm – 8pm (virtual) `alvinsun, bdobkows`.
Friday 10am – 12pm (virtual) `alvinsun, li2053`.

Sections:
Monday: 5:30 – 7:30pm (virtual) `alvinsun`
Tuesday: 10:00am – 12:00pm (in-person) `li2053`
Tuesday: 4:30 – 6:30pm (in-person) `garydai`
Wednesday: 10:00am – 12:00pm (in-person) `masonmc`
Wednesday: 12:30 – 2:30pm (in-person) `snewdick`
Wednesday: 6:00 – 8:00pm (in-person) `bdobkows`
Thursday: 9:30 – 11:30am (virtual) `li2053`
Thursday: 12:00 – 2:00pm (in-person) `alvinsun`
Thursday: 4:30 – 6:30pm (virtual) `garydai`
Friday: 9:30 – 11:30am (in-person) `snewdick`
Friday: 12:00 – 2:00pm (in-person) `bdobkows`
Friday: 2:30 – 4:30pm (in-person) `masonmc`

Units

- AA174A: 4.
- AA 274A/CS 237A/EE 260A: 3 or 4. Taking this class for 4 units entails completing an additional homework problem per problem set and also writing a one-page review of a paper at the end of the quarter.

Prerequisites:

- Familiarity with programming (e.g., CS 106A or equivalent). Previous experience with Python would be helpful, but is not required.
- College calculus, linear algebra (e.g., CME 100 or equivalent).
- Basic probability and statistics (e.g., CME 106 or equivalent).

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.

Course content: Basic principles for endowing mobile autonomous robots with planning, perception, and decision-making capabilities. Algorithmic approaches for trajectory optimization; robot motion planning; robot perception, localization, and simultaneous localization and mapping (SLAM); state machines. 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, state machines, 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;
- Devise novel methods and algorithms for robot autonomy.

Course structure and homework policy: The class comprises four modules, roughly of equal length, namely:

1. motion control and planning (09/27 – 10/13);
2. robotic perception (10/18 – 10/27);
3. localization and SLAM (11/01 – 11/17);
4. system architecture, state machines, additional topics (11/22 – 12/08).

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 homeworks; 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 submissions must be typeset** (e.g., in LaTeX or Word.)

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 develop skills necessary for the final project. Part of your grade will come from attending, participating in, and completing tasks in your section each week. You must sign up for a section time using the link posted in a Canvas announcement by Friday, 09/30/22. These sign ups are first-come first-serve.

Participation on Ed Discussion: Ed Discussion will be the main tool for class discussion. A student will get an extra point each time they (1) ask a question about lecture material; (2) answer a question about lecture material; or (3) answer a question about homework. Questions or answers should be endorsed by one of the CAs in order to receive credit. A student can accrue a maximum of five extra points. Additional details will be provided in a pinned note on the discussion board.

Final project: For the final project, students will be assigned the task of deploying the autonomy stack incrementally built through the problem sets on a TurtleBot robot within a simulation environment (namely, Gazebo), with the ultimate goal of enabling self-driving capabilities in a mock urban environment. This task will involve combining *all* the skills the students have learnt from the class. More details about the final project will be given during the week of November 8, 2022 (Week 7).

Course grade calculation:

- (20%) final project.
- (60%) homework.
- (20%) sections.
- (extra 5%) participation on Ed Discussion.

Schedule:

Date	Topic	Assignment
09/27	Course overview, mobile robot kinematics	
09/29	Introduction to the Robot Operating System (ROS)	HW1 out
10/04	Trajectory optimization	
10/06	Trajectory tracking & closed loop control	
10/11	Motion planning I: graph search methods	HW1 due, HW2 out
10/13	Motion planning II: sampling-based methods	
10/18	Robotic sensors & introduction to computer vision	
10/20	Camera models & camera calibration	
10/25	Image processing, feature detection & description	HW2 due, HW3 out
10/27	Information extraction & classic visual recognition	
11/01	Intro to localization & filtering theory	
11/03	Parametric filtering (KF, EKF, UKF)	
11/08	*No lecture (Democracy Day)*	HW3 due, HW4 out
11/10	Nonparametric filtering (PF)	Final project released
11/15	Object detection/tracking, EKF localization	
11/17	Simultaneous localization and mapping (SLAM)	
11/22	*No lecture (Thanksgiving)*	
11/24	*No lecture (Thanksgiving)*	
11/29	Multi-sensor perception & sensor fusion I	HW4 due
12/01	Multi-sensor perception & sensor fusion II	
12/06	Stereo vision	Final project check-in
12/08	State machines	
12/15	*Final Project (3:30 – 6:30pm)*	Final Project Presentation and Demo

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 Center for Professional Development (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 `https://canvas.stanford.edu/courses/159179`. 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 `cs237a-aut2223-staff@lists.stanford.edu`.