Winter 2019

Stanford
AA 274: Principles of Robotic Autonomy

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Location and time: 420-041, Mondays and Wednesdays, 1:30 – 2:50pm.

Office Hours:
Prof. Pavone: Mondays, 3:00 – 5:00pm (Durand 261), after class, and by appointment.

Course assistants:

- Homework / class material support: Tuesdays, 2:00 – 4:00pm, and Fridays, 2:00 – 4:00pm, Room: Durand 023.

- ROS / software engineering support: Wednesdays 5:00 – 7:00pm, and Thursdays 5:00 – 7:00pm, Skilling Lab space.

Units: 3.

Course websites:

- For course content and announcements: `http://asl.stanford.edu/aa274/`
- For course-related questions: `https://piazza.com/stanford/winter2019/aa274`
- For homework submissions: `https://www.gradescope.com/courses/35120`
- For urgent questions: aa274-win1819-staff@lists.stanford.edu

Textbooks: There is no required textbook. Recommended reading material:

- R. Siegwart, I. R. Nourbakhsh, D. Scaramuzza. *Introduction to Autonomous Mobile Robots*. MIT Press, 2nd Edition, 2011, ISBN-10: 0262015358. Price: $49.37.
- S. Thrun, W. Burgard, D. Fox. *Probabilistic Robotics*. MIT Press, 2005, ISBN-10: 0262201623. Price: $56.22.
- S. M. LaValle. *Planning Algorithms*. Cambridge University Press, 2006, ISBN-10: 0521862051. Price: $72.91. Free electronic version available at `http://planning.cs.uiuc.edu/`

Additional ROS reading material:

- P. Goebel. *ROS By Example*. 2013, ISBN: 9781365690136. Price: $17.13.
- 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: $40.74.
- 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/`.
- J. Lentin. *Mastering ROS for Robotics Programming*. 2015, ISBN-10: 1783551798. Price: $49.99. eBook available at `https://www.packtpub.com/hardware-and-creative/mastering-ros-robotics-programming`

Course Content: Basic principles for endowing mobile autonomous robots with perception, planning, and decision-making capabilities. Algorithmic approaches for robot perception, localization, and simultaneous localization and mapping; control of non-linear systems, learning-based control, and robot motion planning; introduction to methodologies for reasoning under uncertainty, e.g., (partially observable) Markov decision processes. 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, perception, localization & SLAM, and planning & 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 (01/07 – 01/16);
2. perception, from classic to deep learning approaches (01/23 – 02/06);
3. localization and SLAM (02/11 – 02/27);
4. planning, decision making, and system architecture (03/04 – 03/13).

There will be a problem set for each module, for 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. Late homework will be accepted only in **extraordinary** circumstances; you must email the course staff list `aa274-win1819-staff@lists.stanford.edu` to request a deadline extension.
- 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.)

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., MATH 19, MATH 51).
- Basic probability and statistics (e.g., CS 109 or equivalent).

Scribe Notes: As part of the class, students are required to help maintain a shared set of lecture notes. Scribe notes should be a natural integration of the presentation of the lectures with the material in the slides and, possibly, with material from textbooks and articles. These notes are compiled in Latex online in a git repository (`https://github.com/StanfordASL/AA274_lecture_notes`). Each student will be required to polish and improve the scribe notes of *one* lecture. The students assigned to a particular lecture should work together and submit a single *pull request* with their changes no later than one week after the class. The instructors will review the changes to check the technical content and the quality of writing. They will also give feedback and ask for revisions if necessary. After the changes are accepted, the updated notes will be added to the course website.

Participation on Piazza: Piazza will be the main tool for class discussion. A student will get an extra point each time he/she (1) asks a question about lecture material; (2) answers a question about lecture material; or (3) answers 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 Piazza.

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, 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 January 14, 2019.

Course Grade Calculation:

- (72%) homework.
- (23%) final project.
- (5%) scribe quality.
- (extra 5%) participation on Piazza.

Schedule subject to some slippage (SNS:$j.k$ refers to section k of chapter j of the Siegwart, Nourbakhsh, & Scaramuzza book):

Date	Topic	Assignment	Readings
01/07	Course overview, mobile robot kinematics, introduction to motion control		SNS:3.1-3:5;
01/09	The Robot Operating System (ROS)	HW1 out	Lecture notes
01/11	*Recitation*: Python (optional)		
01/14	Open-loop and closed-loop motion control		SNS:3.6
01/16	Robotic sensors and introduction to computer vision		SNS:4.1-4.2
01/18	*Recitation*: dynamical systems (optional)		
01/21	Martin Luther King, Jr., Day (no classes)		
01/23	Camera models and camera calibration	HW2 out, HW1 due	SNS:4.2
01/25	*Recitation*: advanced Python (optional)		
01/28	Stereo vision and image processing		SNS:4.3-4.5
01/30	Feature detection & description, information extraction, and "classic" visual recognition		SNS:4.7
02/05	Machine learning for robot autonomy		Lecture notes
02/06	Deep learning for visual recognition		Lecture notes
02/11	Localization I	HW3 out, HW2 due	SNS:5:1-5:4
02/13	Localization II		SNS:5.5-5.6
02/18	Presidents' Day (no classes)		
02/20	Localization III		SNS:5.6-5.7
02/25	SLAM I		SNS:5.8
02/27	SLAM II		SNS:5.8
03/04	Motion planning I: combinatorial motion planning	HW4 out, HW3 due	SNS:6.1-6.5
03/06	Motion planning II: sampling-based motion planning		Lecture notes
03/11	Decision making and reinforcement learning		Lecture notes
03/13	State machines and "architecting" the autonomy stack	HW4 due	Lecture notes
TBD	**Final project**, TBD		

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 dated in the current quarter in which the request is made. 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: `http://studentaffairs.stanford.edu/oae`).