EE P 545 A Au 21: The Self Driving Car: Intro To AI For Mobile Robots

Edit

COVID-19 Safety: Masks and vaccines required Everyone at UW is required to wear a mask while indoors, and you must be vaccinated for COVID-19 unless you've received an exemption from the University. You must wear your mask during lectures and while working with the cars. Eating and drinking are prohibited in the classroom, although quick sips of water are permitted. We will provide breaks that can be used to eat outside or in designated areas such as the Allen Center lobby. Any student who refuses to wear a mask will be asked to leave the classroom. Students who refuse to comply with these policies may be subject to disciplinary action.

In general, you must comply with the **UW Covid Protocols (link)** (https://www.washington.edu/coronavirus/autumn-quarter-health-and-safety/) for Autumn quarter. Note that policies may change during the quarter depending on circumstances.

COVID-19 Safety: If you're Ill, stay home! Please **do not** come to class if you are feeling unwell or have any cold or flu symptoms, and especially if you have COVID-19 symptoms. Stay home and take care of yourself! The class will be streamed live on Zoom, and Zoom recordings and slides will also be available afterwards.

Instructor:

- **Name:** Professor Joshua R. Smith ("Josh")
- **E-mail:** jrs@cs.washington.edu

Teaching Assistants:

- **Names:** Paolo Torrado, Pratik Gyawali
- **E-mails:** patorrad@uw.edu , gyawali@uw.edu,

Schedule:

- **In-person Lecture:** Monday 6:00 PM - 9:50 PM (**ECE 125**)
- Zoom Lecture: **https://washington.zoom.us/j/97533943289** (https://washington.zoom.us/j/97533943289)
- **Office hours (ECE 165):** In person attendance at office hours is preferred, but Zoom is available as a backup option if you cannot be on campus.

- **Saturday 10 am - 12 pm: Paolo Torrado https://washington.zoom.us/j/8868669741 (https://washington.zoom.us/j/8868669741)**
- **Sunday 1 pm - 3 pm: Pratik Gyawali https://washington.zoom.us/s/9843367663 (https://washington.zoom.us/s/9843367663#success)**

Course Overview: In this course, we will cover topics related to state estimation (particle filters, motion models, sensor models etc), control (PID and other control methods), planning, and perception and learning.

Each of the assignments will involve student teams implementing the algorithms learned in lecture on 1/10th sized rally cars. Concepts from all of the assignments will culminate into a partially open-ended final project with a final demo on the rally cars. The course will involve programming in a Linux and Python environment along with ROS for interfacing to the robot.

Course Goals: By the end of this course, students will

- Become comfortable with tools such as ROS and Python for operating a real robot platform
- Understand algorithms from state estimation, control, planning, perception, and learning, as well as how each of these areas contributes to the development of autonomous vehicles
- Implement these algorithms on a real robot platform
- Analyze both the theoretical and practical strengths and weaknesses of these algorithms

Prerequisites:

- Proficiency in coding in a procedural language (e.g. C, C++, Python, Java, etc) is required
- Knowledge of basic probability is required
- Experience with Python is recommended

Grading:

- **Assignments**: 60%
- **Final Project:** 35%
- **Class Participation:** 5%

Lecture Schedule (approximate and subject to change):
• Week 1: Course Logistics. Introduction to Python and ROS
• Week 2: ROS Cont'd. Introduction to Control
• Week 3: PID Control. Model Predictive Control. LQR Control
• Week 4: Bayesian State Estimation. Motion and Sensor Models
• Week 5: Particle Filters for Localization
• Week 6: Introduction to Planning and Search
• Week 7: Planning on Roadmaps.
• Week 8: Introduction to Computer Vision for Autonomous Driving
• Week 9: Introduction to Neural Networks and PyTorch
• Week 10: Introduction to Reinforcement Learning

Assignments: The course includes the following assignments:

- **Getting Started:** Introduction to Python, Numpy, ROS, and the robot
- **Methods for Local Control:** Path following
- **State Estimation:** Localization with a particle filter
- **Planning:** Navigation in a known map, integration with state-estimation for closed-loop control

The default is to do the assignments and projects using the physical car robots. However, you can choose to do a simulation-only option.

Final Project: A final project allows you to combine or extend concepts from all of these assignments. One option for the final project is to autonomously navigate a course as quickly as possible. Another option is for you to propose, execute, and present a research project extending concepts covered in the course.

Textbook: There is no required textbook for this course, but we will be providing reading notes as the course progresses.

Questions and Discussion: We encourage you to use the discussion board on our Canvas page. If you have class/lab related questions, check the discussion board first to see if the question has already been asked and answered. Post your questions on the discussion board if you can't find feasible answers. And you are more than welcome to help your classmate if you know the answers to questions from other students!

Resources

Course VM images

ROS Tutorials

Python Tutorials

Code Editor (VS Code)

Below is the draft class schedule for 2021. I have also reproduced the schedules for 2020 and 2019, with the lecture materials presented. In general the slides from 2020 should be better than those from 2019. However, in 2020 everything was in simulation because of the pandemic. Therefore, there may be cases in which the 2019 slides are helpful.

2021 Class Schedule (Subject to change)

Week	Date	Lecture Topic	Lecture notes and material
1	10/4	Introduction; Robotics; Coordinate frames; Car Kinematics; Car HW; Intro to ROS; ROS & car demo	Week1: Introduction Week 1: Intro to ROS Recorded: Lecture 1 (https://washington.zoom.us/rec/play/uvjgmkQD6xUb-yw-NndMZ810icpeVEUqiH6jLNq5EojhGmfTAO87xg3AX__Y2Drmjn7AVCzLIAP7MFb6.qT7VSF_3FiiihEZ7)
2	10/11	Control Systems PID, Pole Placement, LQR, MPC	Slides Recorded : Lecture 2 (https://washington.zoom.us/rec/play/D0gBXMOXPxv-zLTASEbSLd_uPI9PX-kG5ANhsf8xVcXvSK2ryl-e2zn-AC_974HiKiQXLvCxx8qPFaGB._FDN3VhxvedWO0I6)
3	10/18	MPC Pt2; Computer Vision Pt 1 (Pinhole camera); Intro to Bayesian Filtering (Probability Pt 1)	Main slides Vision slides

			Recorded: Lecture 3 (https://washington.zoom.us/rec/play/Rn-D41LWErBVDGMnuStXPLB1s-xJDnLXt2-05bgqF3z-bjSVhOlp2SDEH6iFS1kqnFI7U-pH_xAXD2iv.ujGQXMvsnIN3x4d_)
4	10/25	Particle Filters, Sensor Models, Re-Sampling (Probability Pt 2)	Slides Recorded: Lecture 4 (https://washington.zoom.us/rec/play/VGzEmcTND0pRTNFvPhRgrfyzJsaUrbjjNMd0h3ylmGn_kRg_tmzK__4HS58nLV0HeltlbQnAdN1Emrkl.lnjZ0_5OU7lJo2h
5	11/1	Guest Jim Youngquist Sensor Models & Motion models for particle filtering. Revisiting Resampling. Intro to Motion Planning & Heuristic Search (Dijkstra & A*)	Main slides Youngquist slides Recorded: Lecture 5 (https://washington.zoom.us/rec/play/oprl3ZYbxsIPF5sJ4h-LwAkp0gL6ZcWpXb38DhqnV2pjKMSq5o8GtKs7gpk6BV6wXZ_EKbNm7GNPVyXZ.8yqutMoCqlsk7_DZ)
6	11/8	Guest Chris Mavrogiannis (https://chrismavrogiannis.com/) (Multi-agent coordination slides) Planning pt 2 (Laplace & RRT)	Main slides Recorded : Lecture 6 (https://washington.zoom.us/rec/play/k3wZl2a1WxBpth8wdPbEKNcAOopV5k4snbmAGHTXVq9rMe027LcpBPtPY__E00AYE1ah3ZzHM71T80Ho.rTzZqwnBH
7	11/15	Guest Nolan Wagener (https://scholar.google.com/citations?user=SgGIYH0AAAAJ&hl=en) : Information-Theoretic MPC Slides Linear Regression; Intro NN	Main slides Guest Lecturer: Nolan Wagener (MPPI) (https://washington.zoom.us/rec/play/VFhdLhZjLio4nqctOJrLnsML1UhmZ1ns3w-R_9b7_iJnZaz1y6V30fOr8Y3FUifYgOkV9Gw9HcXEi6lj.4fFmfmSWb0HRcSCD) Recorded: Lecture 7 (https://washington.zoom.us/rec/play/TgDV6gyjLOlJYE97nwJl6qsQBi3zeeuxFVrb-i8biBH7agb7Lvm-eT_OQHNriN83Xqfd_MID77DvdZ9m.4skAhXBs0Hd19zGB)
8	11/22	Guest Taylor Whittaker (https://www.linkedin.com/in/tjlwhitaker/) & Chris Rampolla (https://www.linkedin.com/in/rampolla/) , Astrobotic (https://www.astrobotic.com/) (Planetary mobility platforms) Gradient Descent, Multi-Layer Perceptrons, Intro to Learning Main slides	Recorded: Lecture 8 (https://washington.zoom.us/rec/play/y2FPpHUFy4zfbrG1deRMKfonuEaQtLcW9rB9T55pDHSNj3pXmAHsxrXre7N6TcWBHymXzRCT8aOpywsZ.GvR2fD1YoJ
9	11/29	Guest Ryan (https://www.law.uw.edu/directory/faculty/calo-	

		ryan) Calo, UW Law (law & robotics) Learning Pt 2	
10	12/6	Final Race	
11	12/13	Research Project	
11	12/16	Research Project	

2020 Class Schedule (for Reference)

Week	Date	Lecture Topic	Lecture notes and material	To read	Lab
1	9/30/2020	Introduction; Robotics; Coordinate frames; Car Kinematics; Car HW; Intro to ROS; ROS & car demo	Week1-Intro-sml.pdf (https://canvas.uw.edu/courses/1397408/files/68387461/download?download_frd=1) Week1-Intro to ROS.pdf (https://canvas.uw.edu/courses/1397408/files/68387458/download?download_frd=1)	mushr-paper.pdf (https://canvas.uw.edu/courses/1397408/files/68141276/download?download_frd=1) Lynch-Park-p448-453.pdf (https://canvas.uw.edu/courses/1397408/files/68141287/download?download_frd=1) Lynch-Park-p441-442.pdf (https://canvas.uw.edu/courses/1397408/files/68141284/download?download_frd=1) Lynch-Park-p10-15.pdf (https://canvas.uw.edu/courses/1397408/files/68141283/download?download_frd=1) Ackermann steering geometry.pdf (https://canvas.uw.edu/courses/1397408/files/68141280/download?download_frd=1)	PMP_Assignment1.pdf (https://canvas.uw.edu/courses/1397408/fil download_frd=1)

				13.1.2.1 A simple car.pdf (https://canvas.uw.edu/courses/1397408/files/68141279/download?download_frd=1)	
2	10/07/2020	Control Systems PID, Pole Placement, LQR, MPC	Week2-Control.pdf (https://canvas.uw.edu/courses/1397408/files/68637588/download?download_frd=1)	Thrun-Stanley-rob.20147.pdf (https://canvas.uw.edu/courses/1397408/files/68387631/download?download_frd=1) Steve Brunton's Inverted Pendulum Simulation	PMP_Assignment2.pdf (https://canvas.uw.edu/courses/1397408/fil download_frd=1)
3	10/14/2020	Control part 2: PID; State Space control; Quaternions; MPC preview	Week3-Control-pt2.pdf (https://canvas.uw.edu/courses/1397408/files/68831660/download?download_frd=1)	Probabilistic Robotics text (https://docs.ufpr.br/~danielsantos/ProbabilisticRobotics.pdf)	PMP_Assignment3.pdf (https://canvas.uw.edu/courses/1397408/fil download_frd=1)
4	10/21/2020	MPC; Probability, Pt 1	b.pdf (https://canvas.uw.edu/courses/1397408/files/69151693/download?download_frd=1) Week4-MPC-Prob-pt1-b.pdf (https://canvas.uw.edu/courses/1397408/files/69151759/download?download_frd=1)	Probabilistic Robotics text	
5	10/28/2020	Sensor Model & Motion Model for particle filter	Week5-MPC-Pt2-Prob-pt2.pdf (https://canvas.uw.edu/courses/1397408/files/69493696/download?download_frd=1)	Probabilistic Robotics text	PMP_Assignment4.pdf (https://canvas.uw.edu/courses/1397408/fil download_frd=1)
6	11/05/2020	Improved Sensor Model, Motion Model, Improved-Resampling, PF Implementation Issues	Week6-Prob-pt3-pt4.pdf (https://canvas.uw.edu/courses/1397408/files/69870437/download?download_frd=1)	Probabilistic Robotics text	
	11/12/2020	No Class			
7	11/19/2020	Intro to Motion Planning(Laplace	Week7-Planning.pdf	LaplacePlanning.pdf	EEPMP_Assignment5.pdf

		& RRT) & Heuristic Search (Dijkstra & A*)	(https://canvas.uw.edu/courses/1397408/files/70391810/download?download_frd=1)	(https://canvas.uw.edu/courses/1397408/files/70392159/download?download_frd=1) Lav98c.pdf (https://canvas.uw.edu/courses/1397408/files/70392171/download?download_frd=1) kuffner_icra2000.pdf (https://canvas.uw.edu/courses/1397408/files/70392200/download?download_frd=1)	(https://canvas.uw.edu/courses/1397408/fil download_frd=1)
8	11/26/2020	Planning with kinematic constraints; Discuss additional project options; Machine learning;	Week8-ML-pt1.pdf (https://canvas.uw.edu/courses/1397408/files/70721611/download?download_frd=1)		
9	12/2/2020	Deep learning Reinforcement learning (Pt 1) RL slides courtesy of Byron Boots	Week9-0-ML-pt2-pt3.pdf (https://canvas.uw.edu/courses/1397408/files/70851817/download?download_frd=1) Week9-1-EE545_DL.pdf (https://canvas.uw.edu/courses/1397408/files/70851885/download?download_frd=1) Week9-2-RL-MDPs1.pdf (https://canvas.uw.edu/courses/1397408/files/70859437/download?download_frd=1) Week9-3-RL-MDPs2.pdf (https://canvas.uw.edu/courses/1397408/files/70859443/download?download_frd=1)		
10	12/9/2020	Reinforcement learning (Pt 2) Recent research using learning Course Summary	Week10-2-RL-Boling.pdf (https://canvas.uw.edu/courses/1397408/files/71199456/download?download_frd=1) Week10-Summary.pdf (https://canvas.uw.edu/courses/1397408/files/71199426/download?download_frd=1)		
Exam	12/16/2020	Final project			

week		presentations			
Exam week	12/18/2020	Final report due			

2019 Class Schedule (for Reference)

	Date	Lecture Topic	Lecture notes and material	Reading	Lab
1	10/4	Introduction; Robotics; Coordinate frames; Car Kinematics; Car HW; Intro to ROS; ROS & car demo	1a-Week1-Intro-sml.pdf 1b-Week1-Intro to ROS.pdf	mushr-paper.pdf Lynch-Park-p10-15.pdf Lynch-Park-p441-442.pdf 13.1.2.1 A simple car.pdf Lynch-Park-p448-453.pdf Ackermann steering geometry.pdf	Lab 0 :Intro to ROS
2	10/11	Control Systems PID, Pole Placement, LQR, MPC	2a-Week2-Control-Pt1-v3.pdf	Stanley: The Robot that Won the DARPA Grand Challenge Steve Brunton's Inverted Pendulum Simulation	Lab 1: Control Lab 0 Due
3	10/18	Control pt 2; Intro to Bayesian Filtering (Probability Pt 1)	Week3-Control-pt2-state-est-pt1.pdf	Probabilistic Robotics text Amazon (https://www.amazon.com/Probabilistic-Robotics-INTELLIGENT-ROBOTICS-AUTONOMOUS/dp/0262201623/) Draft (https://docs.ufpr.br/~danielsantos/ProbabilisticRobotics.pdf)	
4	10/25	Particle Filters, Sensor Models, Re-Sampling (Probability Pt 2)	Week4-Prob-pt2.pdf	Probabilistic Robotics text	Lab 2:State estimation Lab 1 Due
5	11/1	Sensor Models & Motion models for particle filtering	Week5-Prob-pt3.pdf	Probabilistic Robotics text	
6	11/8	Revisiting Resampling. Intro	Week6-Prob-	Calo-law-and-driverless cars.pdf	Lab 3:Planning

		to Motion Planning & Heuristic Search (Dijkstra & A*)	PlanningPt1.pdf		Lab 2 Due
7	11/15	Planning pt 2 (Laplace & RRT)	Week7-Plan-pt2-v2.pdf	Lav98c.pdf LaplacePlanning.pdf kuffner_icra2000.pdf	
8	11/22	Linear Regression, Gradient Descent, Multi-Layer Perceptrons, Intro to Deep Learning	Week8-ML-pt1.pdf Week8_DL-pt1.pdf	strang-learning.pdf	Lab 4: Learning Lab 3 Due
9	11/29	Learning Pt 2	Week9-ML-pt2.pdf Week9_DL-pt2.pdf		
10	12/6	Final Project			Final Project Demo
10	12/12	Final Project			Final Project Report Due

Religious accommodation policy: Washington state law requires that UW develop a policy for accommodation of student absences or significant hardship due to reasons of faith or conscience, or for organized religious activities. The UW's policy, including more information about how to request an accommodation, is available at **Religious Accommodations Policy (https://registrar.washington.edu/staffandfaculty/religious-accommodations-policy/)** (https://registrar.washington.edu/staffandfaculty/religious-accommodations-policy/). Accommodations must be requested within the first two weeks of this course using the **Religious Accommodations Request form (https://registrar.washington.edu/students/religious-accommodations-request/)** (https://registrar.washington.edu/students/religious-accommodations-request/).

Academic Integrity: We expect you to follow the Academic Integrity rules of the Department of Electrical and Computer Engineering (**link** (https://vannevar.ece.uw.edu/academics/undergrad/AcademicMisconduct.html)), the College of Engineering, and the University of Washington. For example, solutions you submit must be your own work. You are not allowed to re-use solutions from prior years or the TA's prior solutions. Students suspected of plagiarism will be reported to the College of Engineering for investigation and possible punishment.