Statistical Techniques in Robotics (16-831) Spring 2020

updated 4.21.2020

Days MW
Room NSH 1305
Time 12:00 - 1:20 PM
Lecturer Kris Kitani
TAs Cormac O'Meadhra
Class Discussion and Slides `https://piazza.com/cmu/spring2020/16831/home`

Description
Probabilistic and learning techniques are now an essential part of building robots (or embedded systems) designed to operate in the real world. These systems must deal with uncertainty and adapt to changes in the environment by learning from experience (over time). Uncertainty arises from many sources: the inherent limitations in our ability to model the world, noise and perceptual limitations in sensor measurements, and the approximate nature of algorithmic solutions. Building intelligent machines requires that they adapt to their environment. Few things are more frustrating than machines that repeat the same mistake over and over again. We will explore (1) modern learning techniques that are effective at learning online, (2) reinforcement learning based techniques built to learn from expert demonstrations and (3) probabilistic inference algorithms for maintaining an estimate of itself despite uncertainty.

Prerequisites
Linear Algebra, Multivariate Calculus, Probability theory

Grading
(1) Programming and theory assignments: 70% (4 total), (2) Quizzes 10% (5 total), (3) Scribe notes:20% (once in groups of 1 or 2). Grades determined on an absolute scale. Typically 90% and above is A, 80% - 89% is B, 70% - 79% is C, 60% - 69% D, 59% or below is R. There will be extra credit opportunities.

Late Submissions
5 late days total for the semester. You can use up to 2 late days on a single assignments. Please use them wisely. Submissions beyond the allowed late days will be penalized by a deduction in points by $33.\bar{3}\%$ per day.

Educational Outcomes
(1) Able to design, implement and prove the regret bounds of a Multiplicative Weights Algorithm.
(2) Apply concepts of online learning and understand the theoretical implication to incremental supervised learning algorithms.
(3) Implement and analyze the difference between linear programming, matrix games, quadratic programming and entropy maximization formulations of inverse reinforcement learning.
(4) Implement and analyze the optimality of multi-armed bandit problems given various environments.
(5) Work in groups to summarize the essential concepts of each lecture in the form scribe notes. Develop the ability to convey theory and mathematical proofs in document form using consistent math notation and supplementary descriptions.

Academic Integrity
All encouraged to work together BUT you must do your own work (code and write up). If you work with someone, please include their name in your write up and inside any code that has been discussed. If we find highly identical write-ups or code without proper accreditation of collaborators, we will take action according to university policies. For scribe notes, you are encouraged to find pre-existing presentation material to aid your preparation. If you use someone's material, please given them credit by including a citation where necessary.

Take Care of Yourself
Do your best to maintain a healthy lifestyle this semester by eating well, exercising, avoiding drugs and alcohol, getting enough sleep and taking some time to relax. This will help you achieve your goals and cope with stress. All of us benefit from support during times of struggle. You are not alone. There are many helpful resources available on campus and an important part of the college experience is learning how to ask for help. Asking for support sooner rather than later is often helpful. If you or anyone you know experiences any academic stress, difficult life events, or feelings like anxiety or depression, we strongly encourage you to seek support. Counseling and Psychological Services (CaPS) is here to help: call 412-268-2922 and visit their website at `http://www.cmu.edu/counseling/`. Consider reaching out to a friend, faculty or family member you trust for help getting connected to the support that can help.

Class Schedule

Date	Topic	Date	Topic
01-13	Robot Learning Problems	01-15	Online Learning (PWEA, Greedy)
01-20	No Class (MLK Day)	01-22	PWEA (Halving, Rand. Greedy), Regret
01-27	PWEA (WMA, RWMA)	01-29	Lin. Classification (Perceptron, Winnow)
02-03	Online Convex Optimization (Convexity, FTL)	02-05	OCO (FTRL, Online Mirror Descent)
02-10	OCO (OMD, Duality, Regret) $\star$	02-12	OGD, NormExpGD, Hard-SVM $\star$
02-17	No Class	02-19	Soft-SVM, AdaBoost, Bandits Intro
02-24	Bandits (Explore-Exploit, UCB)	02-26	Bandits (UCB, Thompson Sampling, EXP3)
03-02	Contextual Bandits (EXP4), Filtering Intro	03-04	Filtering (Bayes, KF, EKF)
03-09	Spring Break	03-11	Spring Break
03-16	NO CLASS (Transition to Remote)	03-18	MDP, Bellman Equations, Value Function
03-23	Model-based Value-based RL	03-25	Model-free Value-based Prediction $*$
03-30	Model-free Value-based Prediction $*$	04-01	Model-free Value-based Control $*$
04-06	Value Function Approx., Policy-based RL $*$	04-08	Imitation Learning Overview
04-13	LP-IRL	04-15	LP-IRL, Matrix Game IRL
04-20	Max Margin IRL, Max Margin Planning	04-22	MaxEnt IRL
04-27	MaxEnt IRL, CCP-IRL	04-29	DAgger, AggreVaTe, GAIL

$\star$: in-class quiz, $*$: guest lecture

HW	Topic	Release Date	Submission Date	Editor
1	Weighted Majority Algorithm	01-22	02-05	-
2	Online Supervised Learning	02-12	02-26	-
3	Multi-Armed Bandit	02-26	03-25	-
4	Inverse Reinforcement Learning	04-01	04-22	-

Scribe Notes Details

Use the Overleaf project and template distributed by the teaching staff to compile your scribe notes. Each student will be assigned to a lecture as a note taker. It is recommended that you download the PDF of the lecture slides prior to class and take notes directly on the slides. Ask the instructor to upload the PDF prior to class if you do not see the files. Please see Piazza for the latest scribe assignments. If you need to change days to be the scribe, please negotiate directly with other students and report changes to the TA.

Grade Breakdown (Total 20 pts + extra credit)

- Submit scribe notes within 7 days of the lecture (1 pt)
- Add a review section briefly summarizing last lecture. 1 to 2 pages. (4 pts)
- Summary content of lecture plus citations. 5 to 7 pages (15 pts)
- Add an appendix that provides outside information, derivations, properties, inequalities, papers, books, online resources that would aid another student reading the scribe notes. (Extra Credit: 1 pts per page, up to 5 pages)