CS 181 – Machine Learning

Instructor:	Finale Doshi-Velez
Lectures:	Monday and Wednesday, 9-10:30am
Location:	Northwest Building B103
Section:	1:30-2:30pm Monday, 4:30-5:30pm Monday, 10:30-11:30am Tuesday, 3-4pm Tuesday, 4:30-5:30pm Wednesday
URL:	`https://harvard-ml-courses.github.io/cs181-web/`

1 Course Description

This course provides a broad and rigorous introduction to machine learning, probabilistic reasoning and decision making in uncertain environments. We will cover provide an overview of three major areas in machine learning: supervised learning, unsupervised learning, and reinforcement learning.

Our learning approach will be conceptual, theoretical, and practical. We will discuss the motivations behind common machine learning algorithms, and the properties that determine whether or not they will work well for a particular task. You will derive the mathematical underpinnings for many common methods, as well as apply machine learning to challenges with real data.

Prerequisites The material is aimed at an advanced undergraduate level. Students should be comfortable with writing non-trivial programs (e.g., CS 51 or equivalent). All staff-provided code will be in Python, and the staff will not support questions in any other language. Students should also have a background in basic probability theory (e.g. STAT 110 or equivalent), and some level of mathematical sophistication, including calculus and linear algebra (e.g., Math 21a and 21b or equivalent). We note that CS181 only requires portions of all of these courses; Part I of *Math for Machine Learning*, available at `https://mml-book.com` reviews nearly all the prerequisite mathematics.

Every year, many motivated students are successful in CS181 without all of these prerequisites. I want to continue to welcome those hard-working students who are willing and able to independently fill in any gaps that they might have in their knowledge. *That said, it will by YOUR responsibility to learn any prerequisite material on your own. The course staff will not be responsible for teaching basic coding, matrix manipulation, etc.*

2 Course Logistics

2.1 Lecture, Section, Office Hours

Team The CS181 team consists of a course instructor (responsible for the content and grade assignments), a course manager (responsible for the logistics of the course—posting things, managing exceptions, etc.), and a large staff of TFs lead by a head-TF (responsible for section, most of the office hours, and grading).

Lectures Lectures will be used to introduce new content. They will occur on the board and will not be recorded. During lecture, I may remind the class about upcoming deadlines, clarify points in the homework, and respond to questions about upcoming assignments and midterms. Not all of these interactions may make it to the class announcements. Thus, if you miss a lecture, we strongly recommend asking friends about anything that was mentioned.

Sections Sections are optional problem-solving sessions, and another great place to find study partners! Sections will employ a flipped classroom format, in which students will work on questions that will be good preparation for both homeworks and midterms. The teaching staff will introduce the questions, assist students in solving them, and wrap up with the solutions. These solutions will be posted. Extended sections will cover the same material but with more time for students to work on solutions. *The staff may post additional practice questions or pointers to other practice resources. We do not guarantee solutions for these additional resources.*

Office Hours The office hour times will be posted on the website. Please make use of office hours! In addition to getting questions answered by the staff, office hours are also a great place to find study partners and teammates.

2.2 Materials and Resources

Textbook The textbook for the course is *Pattern Recognition and Machine Learning* by Bishop. It largely overlaps with the material in the course, but not completely.

This year, we also have a version 0.0 of course notes available at `https://github.com/harvard-ml-courses/cs181-textbook`. We emphasize that these notes are due to the awesome effort of a past CS181 student who decided to create a course textbook as a senior thesis. *Expect errors.* When you spot errors, be a good citizen and put in a pull request. We hope that this resource can become the course textbook in future years.

Course Website The course web site will be used for posting lecture/section notes and links to assignments, and includes pointers to other resources we'll use, including Piazza and Canvas.

Canvas The Canvas site will be used for submiting assignments, posting grades, and sending announcements.

Piazza The piazza site for the course will be used for three purposes:

- **Content** questions are technical questions posted to other students. (Please keep in mind collaboration policies when asking about code or solutions.) The course staff will *not* be responsible for immediate responses but will answer when possible; technical questions to TFs should be brought to office hours (or to section when appropriate).
- **Clarification** questions are posts about logistical details (Is there really class on XYZ holiday or is that a mistake?) or questions about homework phrasing or typos (Should question 1a of the homework be asking for the integral of x, not y?). We will make every effort to respond to these questions as quickly as possible. Tag clarification questions as "clarification."
- **Private Message** There may be times when you wish to send a private messages. These may include procedural things such as requests for additional time on midterms, additional late days, regrades; you may also have other concerns that you wish to share. We ask you to send those as *private* messages on Piazza with the *appropriate tag*: Regrade, Extension, Special Midterm, and Other. We will be using these tags to make sure that the right people get your request. We will *only* consider procedural requests via this form (this is as much for you as it is for us: we want to have a record of all requests to hold us accountable).

Please note that Piazza is not a formally secure, private, or confidential form of communication, and what you send may be seen by the entire course staff. If you have a sensitive concern for which such a medium is not appropriate, then please catch Finale in person before or after class or catch Finale/TFs at their OHs. (Note, after a conversation, we may still ask you to create a generic request via Piazza so we have record of a promised extension, etc.) Email should be used sparingly if at all.

3 Requirements and Grading

There are four practicals, making up 30% of the final grade. There are five individual homeworks, making up 30% of the final grade. There are two midterms, each counting for 20% of the final grade. The first midterm is on March 11 during class time, the second midterm will occur on the last day of class (May 1) and will focus on the material in the second half of the course.

Practicals and homeworks will be returned with grades and solutions. Due to the volume of the grading, it may not always be possible for the staff to provide detailed feedback. It

is your responsibility to look at the solutions, identify gaps, and come to office hours to fill those gaps. If you believe there has been a grading error, please use the google form above. However, please note that a) we will regrade the entire assignment, which may result in your total grade going up or down and b) we will only allow one regrade request per problem.

More broadly, we understand that sometimes life throws a set of circumstances that impact your perfomance in the course. Should this happen to you, please let me or the course manager know so we can help determine a plan to navigate a tough situation.

3.1 Practicals

Practicals will be done in teams of three. If needed, you can seek partners via Piazza. The goal of the practicals in the course is twofold: to help you master the technical material, and to show you how the techniques we are learning can be used to build powerful and cool applications. We call them "practicals" rather than "homeworks" to make the point that they are meant to be open-ended and encourage creativity. Practicals are usually due two weeks after being handed out. Each practical will generally be centered around a particular methodology and task and involve programming. You will need to consider some conceptual issues, write a program to solve the task, and evaluate your program through experiments to compare the performance of different algorithms and methods.

Your main deliverable will be a short report. You'll be assessed on effort, the sophistication of your technical approach, the clarity of your explanations, the evidence that you present to support your evaluative claims, and the performance of your implementation. A high-performing approach with little explanation will receive little credit, while a careful set of experiments that illuminate why a particular direction turned out to be a dead end may receive close to full credit.

Collaboration Policy Outside your group, you may not share write-ups or code. You may discuss your high-level approach (we focused on feature engineering) and high-level results (we got 90% test accuracy). You must cite any sources used (online or otherwise.)

3.2 Homeworks

The homeworks help you practice the core concepts. These involve components that are theoretical and conceptual, and also require some programming. There will be five of these homeworks. Homework solutions must be submitted in LaTeX. *It is a honor code violation to look at the answer key if you haven't yet turned in your assignment (e.g. using late days). It is also an honor code violation to look at solutions from the internet.*

Collaboration Policy You may not share write-ups or code. If you brainstorm with others, you must note their names in your write-up. We encourage you to spend time thinking

about and understanding the homeworks on your own before collaborating with others to practice for the midterms. *Other than the preclusion of using answer keys, you can make use of textbooks and online sources to help in answering questions but you must cite your sources (and you should be ready to explain your answer to a member of the teaching staff.)*

3.3 Late Days Policy

Homeworks and practical writeups should be submitted electronically by midnight on the due date, via the Canvas course website. This is a strict deadline, enforced by the Canvas site, so submit early enough that you don't accidentally discover that your clock is slow. Only one submission is required for each team of students for the practicals.

You have **five late days** that can be used for homework assignments and the write-ups on the practicals (note that the Kaggle competitions will close a day before the practicals are due, and that will not be extended). Up to **two late days** can be used on any assignment. Start early and plan ahead!

4 Philosophy

The goal of this course is to instill a strong technical background for you to responsibly apply machine learning in the world. Thus, in addition to the derivations and the practicals, each class will include a story about realworld applications of machine learning and one full lecture and part of an assignment will be devoted to the ethical implications.

To be blunt: Given the the increasing use of machine learning systems, the users and developers of these systems must hold themselves to high professional and ethical standards. One can cause real harm by pursuing a good cause via poor engineering choices. Quoting one of our favorite superheroes: with great power (to run any kind of analysis) comes great responsibility (to do it properly)!

Relatedly, we expect all participants in this course—instructors, staff, students—to be committed to a open, professional, and inclusive environment. Just like the maths, these qualities take cultivation and effort. I will start with the premise that we're all decent people trying our best and encourage constructive feedback to improving the course environment.