Machine Learning: Course Overview

CS 760@UW-Madison
Class enrollment

• typically the class was limited to 30
• we’ve allowed ~100 to register
• the waiting list full

• unfortunately, many on the waiting list will not be able to enroll
• but CS760 will be offered in the next semester!
Instructor

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  office: CS 1351
Monday, Wednesday and Friday?

- we’ll have ~30 lectures in all, just like a standard TR class
- will push the lectures forward (finish early, leave time for projects and review)

- see the schedule on the course website:
  http://pages.cs.wisc.edu/~yliang/cs760_spring20
Course emphases

• a variety of learning settings: supervised learning, unsupervised learning, reinforcement learning, active learning, etc.

• a broad toolbox of machine-learning methods: decision trees, nearest neighbor, neural nets, Bayesian networks, SVMs, etc.

• some underlying theory: bias-variance tradeoff, PAC learning, mistake-bound theory, etc.

• experimental methodology for evaluating learning systems: cross validation, ROC and PR curves, hypothesis testing, etc.
Two major goals

1. Understand what a learning system should do

2. Understand how (and how well) existing systems work
Course requirements

• 7-8 homework assignments: 30%
  • programming
  • computational experiments (e.g. measure the effect of varying parameter $x$ in algorithm $y$)
  • some written exercises

• Midterm Exam #1: 20%
• Midterm Exam #2: 20%

• final project: 30%
  • project group: 3-5 people
Expected background

- CS 540 (Intro to Artificial Intelligence) or equivalent
- good programming skills
- probability
- linear algebra
- calculus, including partial derivatives
Programming languages

• for the programming assignments, you can use
  C
  C++
  Java
  Perl
  Python
  R
  Matlab

• suggest: Python

• programs must be callable from the command line and must run on the CS lab machines (this is where they will be tested during grading!)
Course readings

Recommend to get one of the following books

Course readings

- the books can be found online or at Wendt Commons Library

- additional readings will come from online articles, surveys, and chapters
- will be posted on course website
Machine Learning Examples
What is machine learning?

“A computer program is said to learn from experience E with respect to some class of tasks T and performance measure P, if its performance at tasks in T as measured by P, improves with experience E.”

What is machine learning?

• the study of algorithms that improve their performance $P$ at some task $T$ with experience $E$

• to have a well-defined learning task, we must specify: $<P, T, E>$
ML example: image classification

indoor

outdoor
ML example: image classification

- $T$: given new images, classify as indoor vs. outdoor
- $P$: minimize misclassification costs
- $E$: given images with indoor/outdoor labels
ML example: spam filtering

$250,000 life insurance policy for around $10/month

nature news alert
Your weekly update from Nature's global news team.
ML example: spam filtering

- $T$: given new mail message, classify as spam vs. other
- $P$: minimize misclassification costs
- $E$: previously classified (filed) messages
ML example: predictive text input

Your mom and I are going to divorce next month
what??? why! call me please?
I wrote Disney and this phone changed it. We are going to Disney.

DAMNYOUAUTOCORRECT.COM
ML example: predictive text input

- $T$: given (partially) typed word, predict the word the user intended to type
- $P$: minimize misclassifications
- $E$: words previously typed by the user (+ lexicon of common words + knowledge of keyboard layout)

domain knowledge
ML example: Netflix Prize
ML example: Netflix Prize

• $T$: given a user/movie pair, predict the user’s rating (1-5 stars) of the movie
• $P$: minimize difference between predicted and actual rating
• $E$: histories of previously rated movies (user/movie/rating triples)
ML example: autonomous helicopter

video of Stanford University autonomous helicopter from http://heli.stanford.edu/
ML example: autonomous helicopter

- $T$: given a measurement of the helicopter’s current state (orientation sensor, GPS, cameras), select an adjustment of the controls
- $P$: maximize reward (intended trajectory + penalty function)
- $E$: state, action and reward triples from previous demonstration flights
Google DeepMind's Deep Q-learning playing Atari Breakout
From the paper “Playing Atari with Deep Reinforcement Learning”,
by Volodymyr Mnih, Koray Kavukcuoglu, David Silver, Alex Graves, Ioannis Antonoglou,
Daan Wierstra, Martin Riedmiller
ML example: AlphaGo
Reading assignment

• read
  • Chapter 1 of Murphy
  • article by Jordan and Mitchell on course website

• course website:
  http://pages.cs.wisc.edu/~yliang/cs760_spring20/
HW1: Background test

- posted on course website
- will set up how to submit the solutions on Canvas

- Two parts: minimum and medium tests

- if pass both: in good shape
- if pass minimum but not medium: can still take but expect to fill in background
- if fail both: suggest to fill in background before taking the course
Minimum background test

- 80 pts in total; pass: 48pts
- linear algebra: 20 pts
- probability: 20 pts
- calculus: 20 pts
- big-O notations: 20 pts
Minimum test example

\[ X = \begin{pmatrix} 9 \\ 7 \\ 6 \end{pmatrix} \quad \text{\(y = \begin{pmatrix} 9 \\ 8 \end{pmatrix} \quad \text{\(z = \begin{pmatrix} 7 \\ 6 \end{pmatrix} \quad \]

1. What is the inner product of the vectors \(y\) and \(z\)? (this is also sometimes called the *dot product*, and is sometimes written as \(y^T z\))

2. What is the product \(Xy\)?

3. Is \(X\) invertible? If so, give the inverse, and if no, explain why not.

4. What is the rank of \(X\)?
Minimum test example

1. If $y = 4x^3 - x^2 + 7$ then what is the derivative of $y$ with respect to $x$?

2. If $y = \tan(z)x^{6z} - \ln\left(\frac{7x+z}{x^4}\right)$, what is the partial derivative of $y$ with respect to $x$?
Medium background test

• 20 pts in total; pass: 12 pts
• algorithm: 5 pts
• probability: 5 pts
• linear algebra: 5 pts
• programming: 5 pts
Match the distribution name to its probability density / mass function. Below, $|x| = k$.

(a) Laplace

(b) Multinomial

(c) Poisson

(d) Dirichlet

(e) Gamma

(f) $f(x; \Sigma, \mu) = \frac{1}{\sqrt{(2\pi)^k \Sigma}} \exp \left( -\frac{1}{2} (x - \mu)^T \Sigma^{-1} (x - \mu) \right)$

(g) $f(x; n, \alpha) = \binom{n}{x} \alpha^x (1 - \alpha)^{n-x}$ for $x \in \{0, \ldots, n\}$; 0 otherwise

(h) $f(x; b, \mu) = \frac{1}{2b} \exp \left( -\frac{|x - \mu|}{b} \right)$

(i) $f(x; n, \alpha) = \frac{n!}{\prod_{i=1}^k x_i!} \prod_{i=1}^k \alpha_i^{x_i}$ for $x_i \in \{0, \ldots, n\}$ and $\sum_{i=1}^k x_i = n$; 0 otherwise

(j) $f(x; \alpha, \beta) = \frac{\beta^\alpha}{\Gamma(\alpha)} x^{\alpha-1} e^{-\beta x}$ for $x \in (0, +\infty)$; 0 otherwise

(k) $f(x; \alpha) = \frac{\Gamma(\sum_{i=1}^k \alpha_i)}{\prod_{i=1}^k \Gamma(\alpha_i)} \prod_{i=1}^k x_i^{\alpha_i-1}$ for $x_i \in (0, 1)$ and $\sum_{i=1}^k x_i = 1$; 0 otherwise

(l) $f(x; \lambda) = \lambda^x \frac{e^{-\lambda}}{x!}$ for all $x \in \mathbb{Z}^+$; 0 otherwise
Draw the regions corresponding to vectors $\mathbf{x} \in \mathbb{R}^2$ with the following norms:

1. $||\mathbf{x}||_1 \leq 1$ (Recall that $||\mathbf{x}||_1 = \sum_i |x_i|$)
2. $||\mathbf{x}||_2 \leq 1$ (Recall that $||\mathbf{x}||_2 = \sqrt{\sum_i x_i^2}$)
3. $||\mathbf{x}||_\infty \leq 1$ (Recall that $||\mathbf{x}||_\infty = \max_i |x_i|$)
THANK YOU

Some of the slides in these lectures have been adapted/borrowed from materials developed by Mark Craven, David Page, Jude Shavlik, Tom Mitchell, Nina Balcan, Elad Hazan, Tom Dietterich, and Pedro Domingos.