Machine Learning

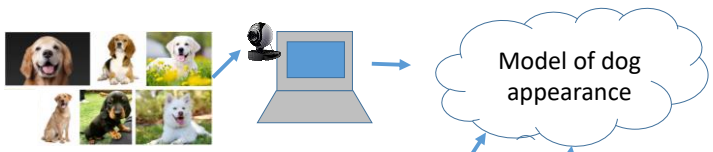
CISC 5800

Dr Daniel Leeds

What is machine learning

- Finding patterns in data
- Adapting program behavior

Dog photos and the internet



Search for "dog" from web images:

Change radio channel when user says "change channel"

- Distinguish user's voice from music
- Understand what user has said

What's covered in this class

- Theory: describing patterns in data
  - Probability
  - Linear algebra
  - Calculus/optimization
- Implementation: programming to find and react to patterns in data
  - Popular and successful algorithms
  - Python
  - Data sets of text, speech, pictures, user actions, neural data…

6

Outline of topics

- Groundwork: probability and slopes
- Classification overview: Training, testing, and overfitting
- Basic classifiers: Naïve Bayes and Logistic Regression
- Advanced classifiers: Neural networks and support vector machines

  Deep learning **Kernel methods**
- Dimensionality reduction: Feature selection, information criteria
- Graphical models: Hidden Markov Model
- Expectation-Maximization
- Learning theory

7

What you need to do in this class

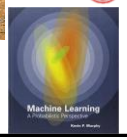
- Class attendance
- Assignments: homeworks (4-5) and final project
- Exams: midterm and final
- Don't cheat
  - You may discuss course topics with other students, but your submitted work must be your own. Copying is not allowed.

8

Resources

- Office hours: Wednesday 4-5pm and by appointment LL 610H

  Teaching Assistant: TBA LL 6th floor
- Course web site: http://storm.cis.fordham.edu/leeds/cisc5800
- Fellow students
- Textbooks/online notes
- Python



Andrew Ng's Stanford course notes

CS229 Machine Learning Autumn 2016

9

Probability and basic calculus

10

Probability and basic calculus

11

Probability

What is the probability that a child likes chocolate?

- Ask 100 children
- Count who likes chocolate
- Divide by number of children asked

Name	Chocolate?
Sarah	Yes
Melissa	Yes
Darren	No
Stacy	Yes
Brian	No

P("child likes chocolate") = $\frac{85}{100} = 0.85$

In short: P(C=true)=0.85 C="child likes chocolate"

12

General probability properties

P(A) means "Probability that statement A is true"

- $0 \leq Prob(A) \leq 1$
- Prob(True)=1
- Prob(False)=0

13

Random variables

A variable can take on a value from a given set of values:
- {True, False}
- {Cat, Dog, Horse, Cow}
- {0,1,2,3,4,5,6,7}

A random variable holds each value with a given probability
Example: **binary variable** LikesChocolate
- P(LikesChocolate) = P(LikesChocolate=True) = 0.85

14

Complements

C="child likes chocolate"

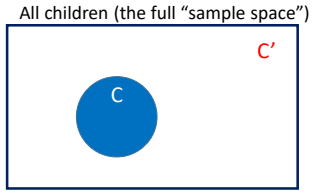
P(C=true) = $\frac{85}{100} = 0.85$

What is the probability that a child DOES NOT like chocolate?

Complement: C=false <-> "child doesn't like chocolate"

P(C=false) =

In general: P(A=false) =



16

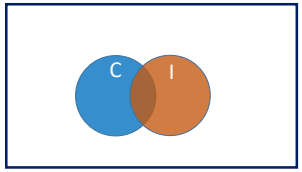
Addition rule

Prob(A=tr or B=tr) = ???

C="child likes chocolate"
I="child likes ice cream"

Name	Chocolate?	Ice cream?
Sarah	Yes	No
Melissa	Yes	Yes
Darren	No	No
Stacy	Yes	Yes
Brian	No	Yes

All children



17

Joint probabilities

C="child likes chocolate"
I="child likes ice cream"

Across 100 children:
- 55 like chocolate AND ice cream P(I=True, C=True)
- 30 like chocolate but not ice cream
- 5 like ice cream but not chocolate
- 10 don't like chocolate nor ice cream

P(I=False, C=True)
P(I=True,C=False)

P(I=True)
P(C=True)

18

Conditional probability

Across 100 children:
- 55 like chocolate AND ice cream
- 30 like chocolate but not ice cream
- 5 like ice cream but not chocolate
- 10 don't like chocolate nor ice cream

Also, **Multiplication Rule:**

P(A,B) = P(A|B) P(B)

P(A,B):Probability A and B are both true

- Prob(C|I) : Probability child likes chocolate given s/he likes ice cream

$$P(C|I) = \frac{P(C,I)}{P(I)} = \frac{P(C,I)}{P(C=true,I)+P(C=false,I)}$$

20

Marginal and conditional probabilities

For two **binary** random variables A and B
- P(A) = P(A, B=True) + P(A, B=False)
- P(B) = P(A=True,B)+P(A=false,B)

For **marginal probability** P(X), "marginalize" over all possible values of the other random variables

- Prob(C|I) : Probability child likes chocolate given s/he likes ice cream

$$P(C|I) = \frac{P(C,I)}{P(I)} = \frac{P(C,I)}{P(C=true,I)+P(C=false,I)}$$

22

Independence

If the truth value of B does not affect the truth value of A, we say A and B are **independent**.

- P(A|B) = P(A)

- P(A,B) = P(A) P(B)

23

Multi-valued random variables

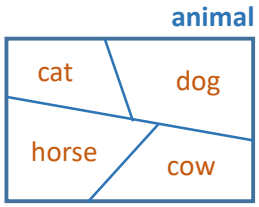
A random variable can hold more than two values, each with a given probability
- P(Animal=Cat)=0.5
- P(Animal=Dog)=0.3
- P(Animal=Horse)=0.1
- P(Animal=Cow)=0.1

24

Probability rules: multi-valued variables

For given random variable *A*:

- P($A = a_i$ and $A = a_j$) = 0 if $i \neq j$
- $\sum_i P(A = a_i) = 1$
- $P(A = a_i) = \sum_j P(A = a_i, B = b_j)$



a **is a value assignment for variable *A***

25

Probability table

- P(G=C,H=True)
- P(H=True)
- P(G=C|H=True)
- P(H=True|G=C)

Grade	Honor-Student	P(G,H)
A	False	0.05
B	False	0.05
C	False	0.05
D	False	0.1
A	True	0.3
B	True	0.2
C	True	0.15
D	True	0.1

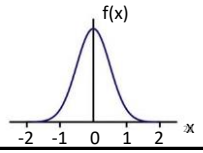
27

Continuous random variables

A random variable can take on a continuous range of values

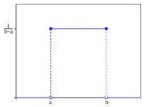
- From 0 to 1
- From 0 to ∞
- From −∞ to ∞

Probability expressed through a "probability density function" **f(x)**

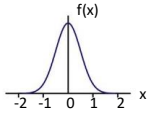


Common probability distributions

- Uniform: $f_{uniform}(x) = \begin{cases} \frac{1}{b-a} & if\ a \leq x \leq b \\ 0 & otherwise \end{cases}$



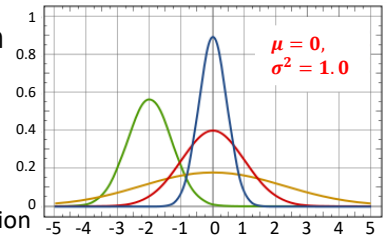
- Gaussian: $f_{gauss}(x) = \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{(x-\mu)^2}{2\sigma^2}}$



30

The Gaussian function

$$f_{gauss}(x) = \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{(x-\mu)^2}{2\sigma^2}}$$



- Mean μ – center of distribution
- Standard deviation σ – width of distribution

- Which color is $\boldsymbol{\mu}$**=-2,** $\boldsymbol{\sigma^2}$**=0.5**?
- Which color is $\boldsymbol{\mu}$**=0,** $\boldsymbol{\sigma^2}$**=0.2**?

- $N(\mu_1, \sigma_1^2) + N(\mu_2, \sigma_2^2) = N(\mu_1 + \mu_2, \sigma_1^2 + \sigma_2^2)$

31

Probability and basic calculus

33

Calculus: finding the slope of a function

What is the minimum value of: f(x)=x^2-5x+6

Find value of x where slope is 0

General rules: slope of f(x): $\frac{d}{dx} f(x) = f'(x)$

- $\frac{d}{dx} x^a = a x^{a-1}$
- $\frac{d}{dx} k f(x) = k f'(x)$
- $\frac{d}{dx} [f(x) + g(x)] = f'(x) + g'(x)$

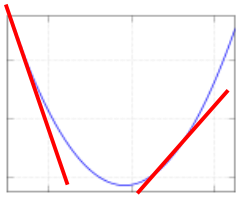
34

Calculus: finding the slope of a function

What is the minimum value of: f(x)=x^2-5x+6

- f'(x)=
- What is the slope at x=5?
- What is the slope at x=-3?

- What value of x gives slope of 0?



35

More on derivatives: $\frac{d}{dx}f(x) = f'(x)$

- $\frac{d}{dx}f(w) = 0$ -- w is not related to x, so derivative is 0
- $\frac{d}{dx}\big(f(g(x))\big) = g'(x) \cdot f'(g(x))$
- $\frac{d}{dx}\log x = \frac{1}{x}$
- $\frac{d}{dx}e^x = e^x$

37

Review of classifiers

38

The goal of a classifier

- Learn function C to maximize correct labels (Y) based on features (X)

C(x)=y

lion: 16
wolf: 12
monkey: 14
broker: 0
analyst: 1
dividend: 1

C → jungle

lion: 0
wolf: 2
monkey: 1
broker: 14
analyst: 10
dividend: 12

C → wallStreet

39

Giraffe detector

- Label x : height
- Class y : True or False ("is giraffe" or "is not giraffe")

Learn optimal classification parameter(s)

- Parameter: x^{thresh}

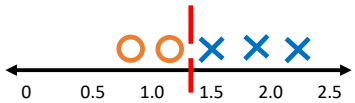
Example function:

$$C(x) = \begin{cases} True & \text{if } x > x^{thresh} \\ False & \text{otherwise} \end{cases}$$

40

Learning our classifier parameter(s)

- Adjust parameter(s) based on observed data
- Training set: contains features and corresponding labels

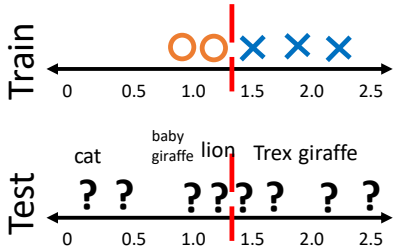


	X	Y
	1.5	True
	2.2	True
	1.8	True
	1.2	False
	0.9	False

The testing set

Testing set must be distinct from training set!

- Does classifier correctly label new data?



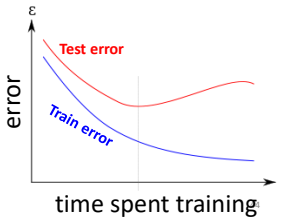
Example "good" performance: 90% correct labels

Be careful with your training set

- What if we train with only baby giraffes and ants?
- What if we train with only T rexes and adult giraffes?

Training vs. testing

- **Training**: learn parameters from set of data in each class
- **Testing**: measure how often classifier correctly identifies new data
- More training reduces classifier error ε
- Too much training data causes worse testing error – overfitting



Dividing data sets

Three way divide: Train / test / validate

Cross-validation
- k-fold
- Leave-one-out

45

What is "good" classifier performance?

How well can you do if:
- You guess randomly?

- You guess the most-common class?

46