

Lecture 1 – Learning From Data



DSC 40A, Spring 2023

Agenda

1. Who are we?
2. What is this course about?
3. How will this course run?
4. How do we turn the problem of learning from data into a math problem?

Who are we?

Hi, everyone!

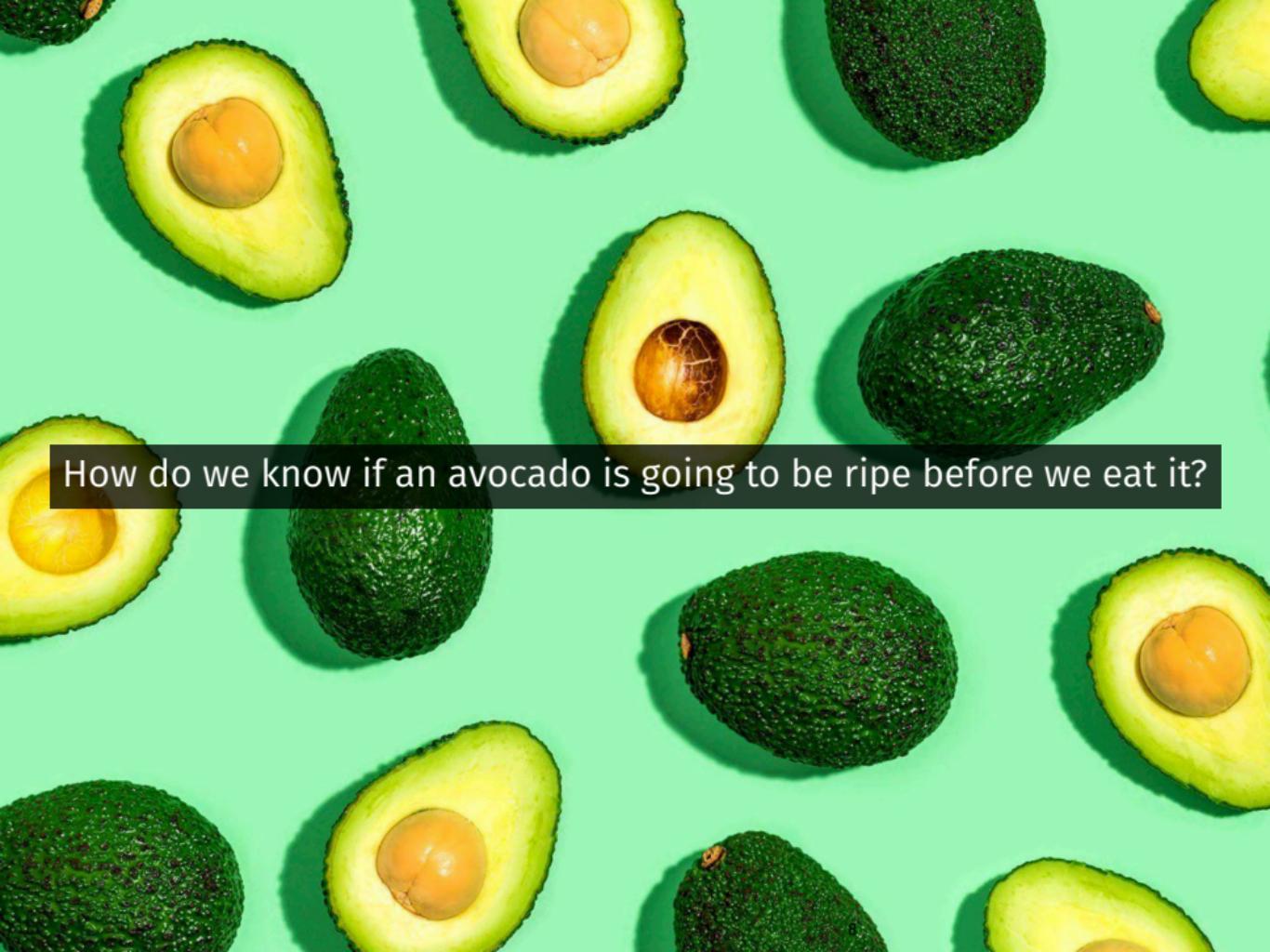
Janine Tiefenbruck (call me Janine)

- ▶ Grew up in NJ. Undergrad Math/CS major at Loyola, MD.
PhD in Math (Combinatorics) at UCSD.
- ▶ Lecturer in DSC for 5 years. Developed original versions of
DSC 10, 40A, 40B. Mostly teaching 10 and 40A these days.
- ▶ For fun: board games, baking, hiking, crafts

Course Staff

- ▶ 1 TA, who will lead the discussion and help run the class.
 - ▶ Dylan Stockard, a MS student in DSC.
- ▶ Undergrad tutors, who will hold office hours, grade assignments, and help run the class.
 - ▶ Tunan Li, Pallavi Prabhu, Pranav Rebala, Harshi Saha, Yutian (Skylar) Shi, Aryaman Sinha, Zelong (Alan) Wang, Benjamin Xue, Luran (Lauren) Zhang
- ▶ All previous students of DSC 40A eager to help!
- ▶ Read about them at dsc40a.com/staff.

What is this course about?

The image shows a variety of avocados on a solid green background. There are whole, unripe dark green avocados and ripe, cut-open avocados revealing their yellow-green flesh and brown pit. Some avocados are shown from a side-on perspective, while others are cut in half to show the interior.

How do we know if an avocado is going to be ripe before we eat it?

Try a little
tenderness



How do you know when we're ripe?

AVOCADO COLOUR & RIPENESS CHART

Colour
Rating

HASS
Look &
Touch



Firmness
Rating

Hard

Effegi puncture (kgf) -
using 11mm tip

Rubbery

5kgf

Softening

2kgf

Firm Ripe

1kgf

Medium to
Soft Ripe

0.65kgf

Soft to
Over Ripe

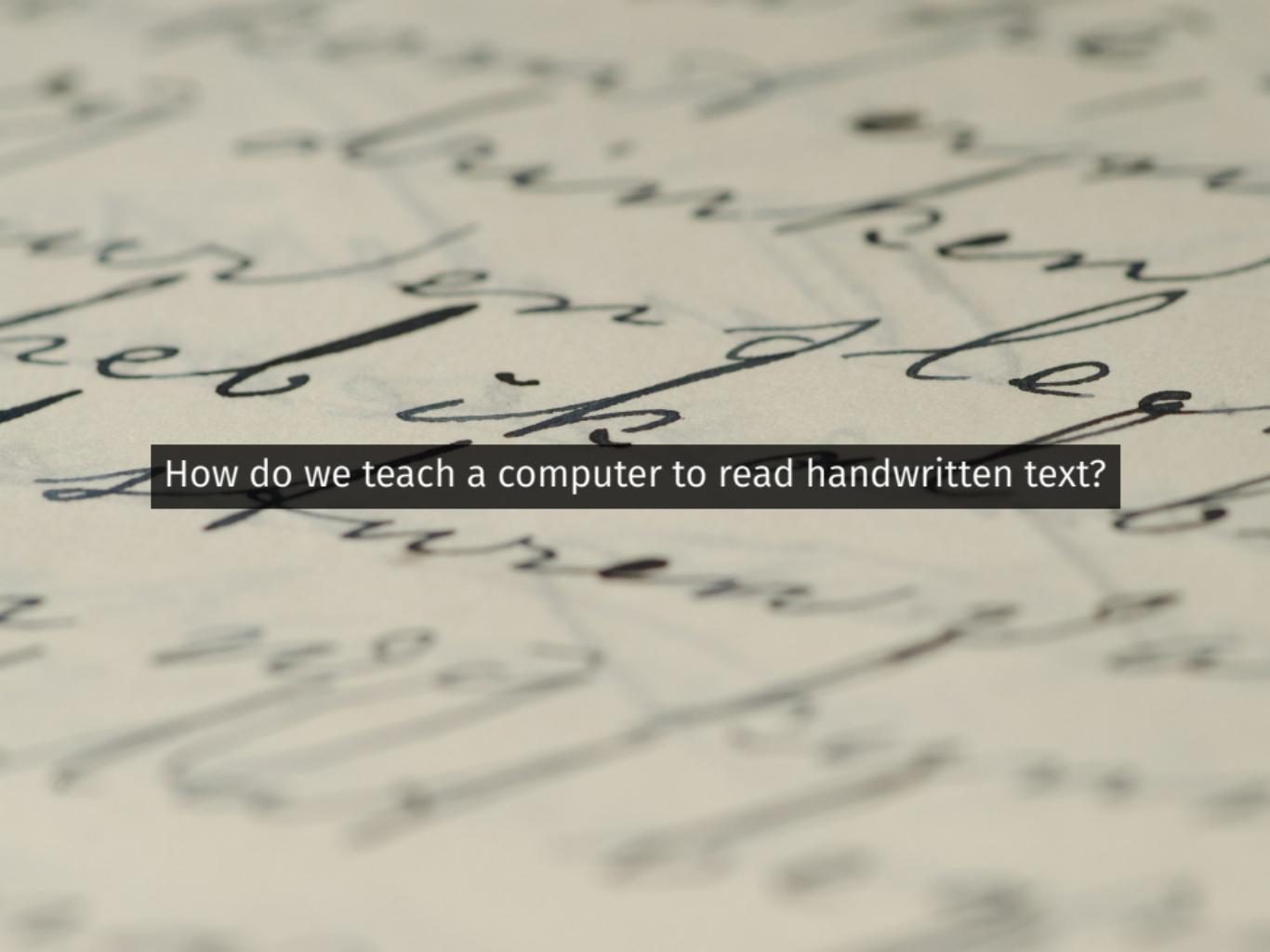
0.45kgf

**GREEN
SKINS**

Touch

(Shepard, Wurtz,
Sharwil, Reed)



A close-up, slightly blurred photograph of handwritten cursive text on lined paper. The text is written in black ink and appears to be in English. The lines of text are somewhat overlapping and out of focus.

How do we teach a computer to read handwritten text?



How do we predict a future data scientist's salary?

...by **learning** from data.

How do we learn from data?



The fundamental approach:

1. Turn learning from data into a math problem.
2. Solve that problem.

Course overview

Part 1: Learning from Data (Weeks 1 through 5)

- ▶ Summary statistics and loss functions; empirical risk minimization.
- ▶ Linear regression (including multiple variables) .
- ▶ Clustering.

Part 2: Probability (Weeks 6 through 10)

- ▶ Set theory and combinatorics; probability fundamentals.
- ▶ Conditional probability and independence.
- ▶ Naïve Bayes classifier.

Learning objectives

After this quarter, you'll...

- ▶ understand the basic principles underlying almost every machine learning and data science method.
- ▶ be better prepared for the math in upper division: vector calculus, linear algebra, and probability.
- ▶ be able to tackle the problems mentioned at the beginning.

How will this course run?

Basics

- ▶ The course website, dsc40a.com, contains all content.
Read the syllabus carefully!
- ▶ We won't use Canvas.
- ▶ [Campuswire](#) will be used for announcements and communication. You can sign yourself up. **Ask questions here instead of email!**
- ▶ Fill out this [Welcome Survey](#).

Lectures

- ▶ Lectures are held MWF at 10am and 11am in WLH 2204.
- ▶ Lecture slides will be posted on course website before class.
- ▶ Suggestion: don't write everything down! I'll post my annotated slides after class.
- ▶ Value of lecture: **interaction** and **discussion**.

Discussion

- ▶ Discussions on Weds at 7pm and 8pm in FAH 1101.
- ▶ Discussion will be used primarily for **groupwork**.
 - ▶ Come to the discussion you're enrolled in, and work on problems in small groups of size 2-4.
 - ▶ You may work in a self-organized group outside of the scheduled discussion sections for 80% credit.
You may not work alone.
 - ▶ Value of attending: **TA/tutor support**.
- ▶ Submit groupwork to Gradescope by **11:59pm Weds.**
 - ▶ Only one group member should submit and add the other group members.

Assessments and exams

- ▶ **Homeworks:** Due **Tuesdays at 11:59pm** on Gradescope.
Worth 40% of your grade.
- ▶ **Groupworks:** Due **Wednesdays at 11:59pm**. Worth 10% of your grade.
- ▶ **Exams:** Two midterms and a two-part final exam, which can redeem low scores on the midterms. Exams are Friday, May 5 during lecture, Monday, June 5 during lecture, and Saturday, June 10 from 9am to 11am.

Support

- ▶ **Office Hours:** many hours throughout the week to get help on homework problems. Plan to attend at least once a week because the homework is hard!
 - ▶ See the calendar on the course website for schedule and location.
 - ▶ Janine has office hours today 12:30-2:30 if you want to stop by!
- ▶ **Campuswire:** Use it! We're here to help you.
 - ▶ Don't post answers.

How do we turn the problem of learning from data into a math problem?



How do we predict a future data scientist's salary?

Learning from data

- ▶ Idea: ask a few data scientists about their salary.
 - ▶ StackOverflow does this annually.
- ▶ Five random responses:

90,000 94,000 96,000 120,000 160,000

Discussion Question

Given this data, how might you predict your future salary?

median, ranges, location

Some common approaches

- ▶ The **mean**:

$$\frac{1}{5} \times (90,000 + 94,000 + 96,000 + 120,000 + 160,000)$$
$$= 112,000$$

- ▶ The **median**:



- ▶ Which is better? Are these good ways of predicting future salary?

Quantifying the goodness/badness of a prediction

- ▶ We want a metric that tells us if a prediction is good or bad.
- ▶ One idea: compute the **absolute error**, which is the distance from our prediction to the right answer.

$$\text{absolute error} = |(\text{actual future salary}) - \text{prediction}|$$

- ▶ Then, our goal becomes to **find the prediction with the smallest possible absolute error**.
- ▶ There's a problem with this:

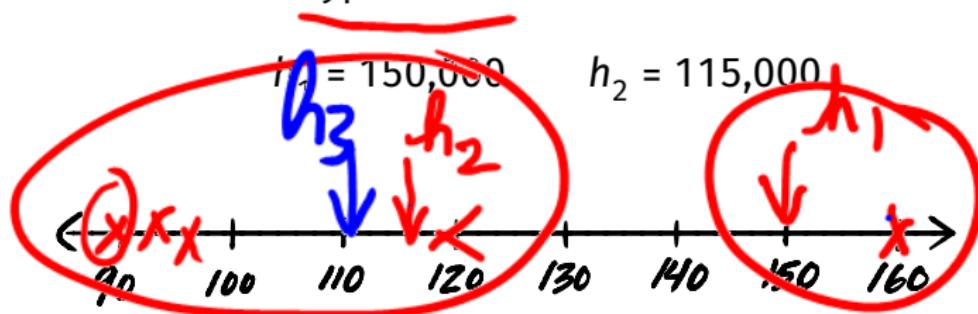
you don't know actual future salary

What is good/bad, intuitively?

- The data:

90,000 94,000 96,000 120,000 160,000

- Consider these hypotheses:



Discussion Question

Which do you think is better, h_1 or h_2 ? Why?

closer to data

errors generally smaller

Quantifying our intuition

- ▶ Intuitively, a good prediction is close to the data.
- ▶ Suppose we predicted a future salary of $h_1 = 150,000$ before collecting data.

prediction

salary	absolute error of h_1
90,000	$ -150,000 = 60,000$
94,000	56,000
96,000	54,000
120,000	30,000
160,000	10,000

sum of absolute errors: 210,000

mean absolute error: 42,000

Summa.
rize

Quantifying our intuition

- Now suppose we had predicted $h_2 = \underline{115.000}$

salary	absolute error of h_2
90,000	$-115,000 =$
94,000	25,000
96,000	21,000
120,000	19,000
160,000	5,000

sum of absolute errors: 115,000

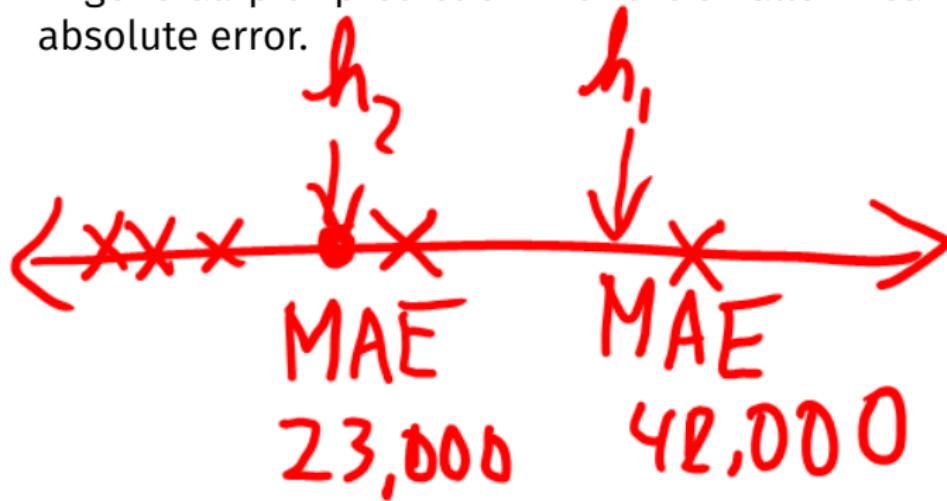
mean absolute error: $\underline{23,000}$

Mean absolute error (MAE)

- ▶ Mean absolute error on data:

$$h_1 : 42,000 \quad h_2 : 23,000$$

- ▶ Conclusion: h_2 is the better prediction.
- ▶ In general: pick prediction with the smaller mean absolute error.



We are making an assumption...

- ▶ We're assuming that future salaries will look like present salaries.
- ▶ That a prediction that was good in the past will be good in the future.

Discussion Question

Is this a good assumption?

inflation
job supply/demand

Which is better: the mean or median?

- ▶ Recall:

mean = 112,000 median = 96,000

MAE

mean : 22,400 median : 19,200

The diagram shows handwritten calculations. At the top, 'mean = 112,000' and 'median = 96,000' are written with red circles around them. A large red bracket labeled 'MAE' spans both values. Below this, 'mean : 22,400' and 'median : 19,200' are written. Red arrows point from the circled mean and median to their respective numerical values.

- ▶ We can calculate the mean absolute error of each:
- ▶ The median is the best prediction so far!
- ▶ But is there an even better prediction?



Finding the best prediction

- ▶ Any (non-negative) number is a valid prediction.
- ▶ Goal: out of all predictions, find the prediction h^* with the smallest mean absolute error.
- ▶ This is an **optimization problem**.

the best
of all
possible
 h 's

A formula for the mean absolute error

- We have data:

90,000 94,000 96,000 120,000 160,000

- Suppose our prediction is h .
- The **mean absolute error** of our prediction is:

$$R(h) = \frac{1}{5}(|90,000 - h| + |94,000 - h| + |96,000 - h| + |120,000 - h| + |160,000 - h|)$$

minimize R=risk

A formula for the mean absolute error

- ▶ We have a function for computing the mean absolute error of **any** possible prediction.

$$\begin{aligned} R(\textcolor{blue}{150,000}) &= \frac{1}{5}(|90,000 - \textcolor{blue}{150,000}| + |94,000 - \textcolor{blue}{150,000}| \\ &\quad + |96,000 - \textcolor{blue}{150,000}| + |120,000 - \textcolor{blue}{150,000}| \\ &\quad + |160,000 - \textcolor{blue}{150,000}|) \\ &= \textcolor{red}{42,000} \end{aligned}$$

A formula for the mean absolute error

- We have a function for computing the mean absolute error of **any** possible prediction.

$$\begin{aligned} R(\textcolor{blue}{115,000}) &= \frac{1}{5} \left(|90,000 - \textcolor{blue}{115,000}| + |94,000 - \textcolor{blue}{115,000}| \right. \\ &\quad + |96,000 - \textcolor{blue}{115,000}| + |120,000 - \textcolor{blue}{115,000}| \\ &\quad \left. + |160,000 - \textcolor{blue}{115,000}| \right) \\ &= \textcolor{red}{23,000} \end{aligned}$$

A formula for the mean absolute error

- We have a function for computing the mean absolute error of **any** possible prediction.

$$R(\pi) = \frac{1}{5}(|90,000 - \pi| + |94,000 - \pi| + |96,000 - \pi| + |120,000 - \pi| + |160,000 - \pi|) - 111,096.0564\ldots$$

Discussion Question

Without doing any calculations, which is correct?

- A. $R(50) < R(100)$
- B. $R(50) = R(100)$
- C. $R(50) > R(100)$

R bigger for worse predictions

A general formula for the mean absolute error

- ▶ Suppose we collect n salaries, y_1, y_2, \dots, y_n .
- ▶ The mean absolute error of the prediction h is:

$n = \text{how many data values}$

$$R(h) = \frac{1}{n} (|y_1 - h| + |y_2 - h| + \dots + |y_n - h|)$$

- ▶ Or, using **summation notation**:

$$R(h) = \frac{1}{n} \sum_{i=1}^n |y_i - h|$$

note: $|y_i - h| = |h - y_i|$

The best prediction

- ▶ We want the best prediction, h^* .
- ▶ The smaller $R(h)$, the better h .
- ▶ Goal: find h that minimizes $R(h)$.

Summary

- ▶ We started with the learning problem:

Given salary data, predict your future salary.

- ▶ We turned it into this problem:

Find a prediction h^ which has smallest mean absolute error on the data.*

- ▶ We have turned the problem of learning from data into a specific type of math problem: an **optimization problem**.
- ▶ **Next time:** we solve this math problem.