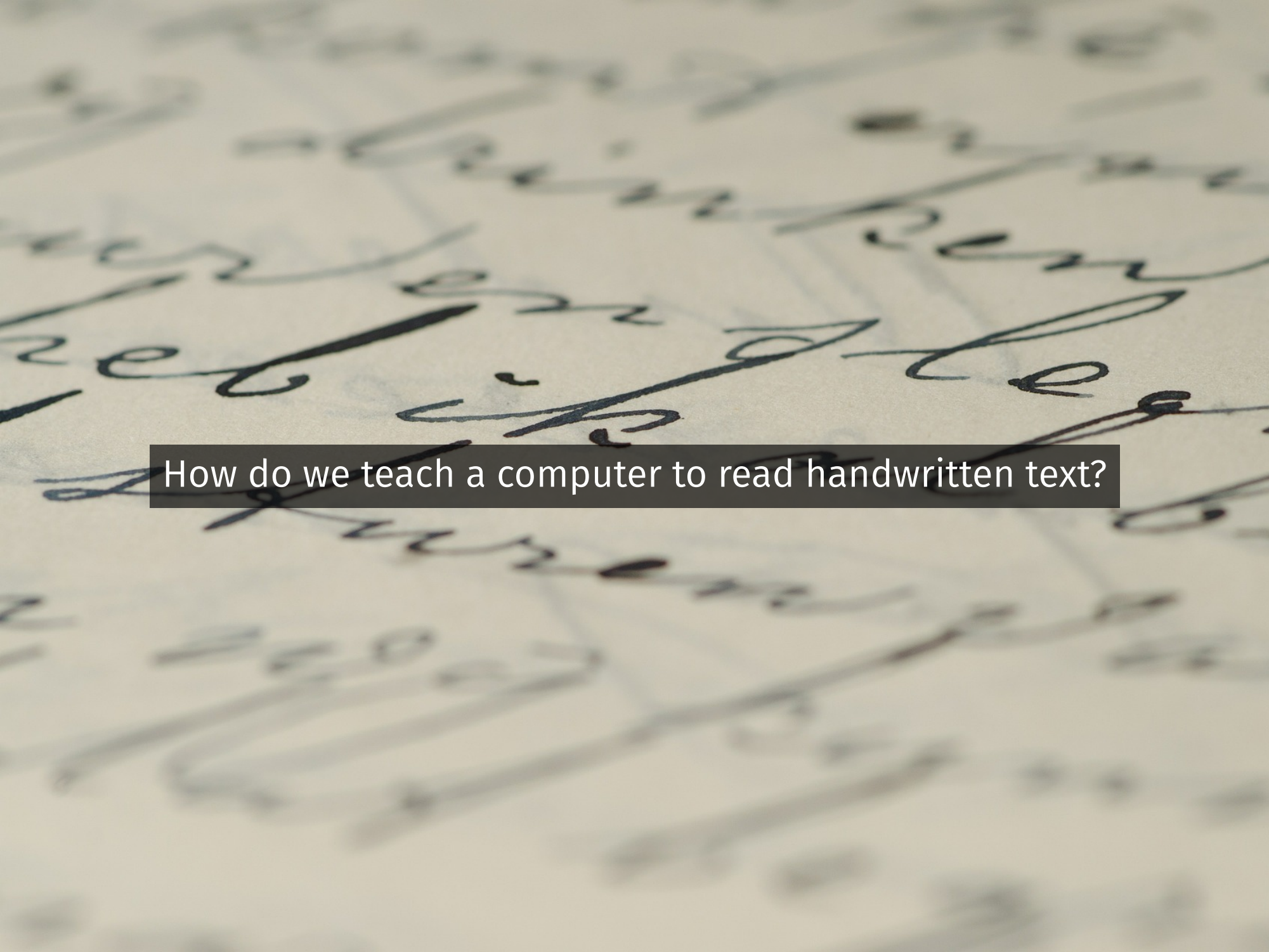
DSC 40A

Theoretical Foundations of Data Science I


How do we decide who needs the most help before a hurricane hits?


How do we teach a computer to read handwritten text?


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

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



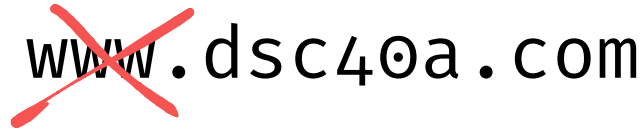
How do we learn from data?

The fundamental approach:
1) Turn learning into a math problem.
2) Solve that problem.

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.

Theoretical Foundations of Data Science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No discussion tonight!

DSC 40A

Lecture 01

Learning via Optimization, pt I.

Lecture Format

- Lecture slides will be posted before class.
- Suggestion: don't write everything down!
- I'll write definitions, proofs, etc. on the slides.

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- Value of lecture: **interaction** and **discussion**.

Today's Question

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

Recommended Reading

Chapter 01, Section 01


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

Learning from Data

- Idea: ask a few data scientists about their salary.
- StackOverflow survey.
- 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?

The Mean and the Median

- The **mean**:

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

- The **median**:

$$90{,}000 \quad 94{,}000 \quad \underbrace{96{,}000}_{\uparrow} \quad 120{,}000 \quad 160{,}000$$

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

Quantifying goodness/badness of a prediction

- The **error**: distance from prediction to the right answer.

  error = |prediction – (actual future salary)|

- Find prediction with smallest possible error.

- There's a problem with this:

We don't know actual salary.

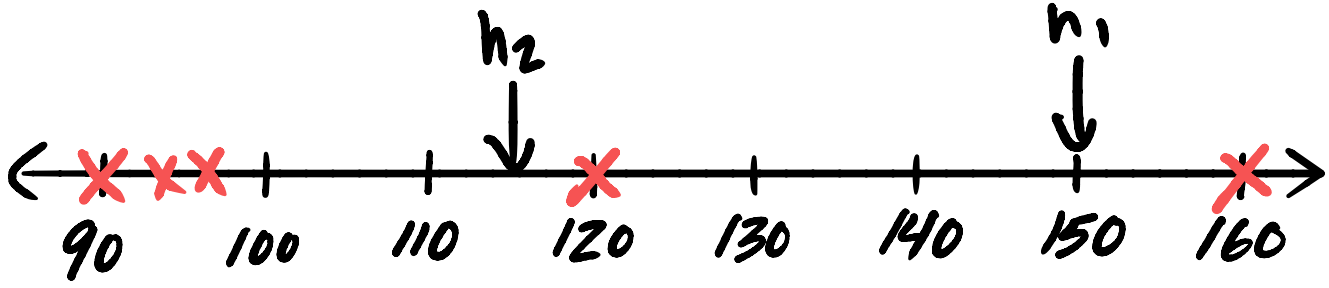
What is good/bad, intuitively?

- The data:

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

- Consider these hypotheses:

h_1 = 150,000 h_2 = 115,000



Discussion Question

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

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.

salary	error of h_1
90,000	60,000
94,000	56,000
96,000	54,000
120,000	30,000
160,000	10,000
	total error: 210,000
	mean error: 42,000

Quantifying our intuition

- Now suppose we had predicted $h_2 = 115{,}000$.

salary	error of h_2
90,000	25,000
94,000	21,000
96,000	19,000
120,000	5,000
160,000	45,000
	total error: 115,000
	mean error: 23,000

Mean Errors

- Mean error on data:

$$h_1 : 42{,}000 \qquad h_2 : 23{,}000$$

- Conclusion: h_2 is the better prediction.
- In general: pick prediction with the smaller mean 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?

Which better: the mean or median?

- Recall:

mean = 112,000 median = 96,000

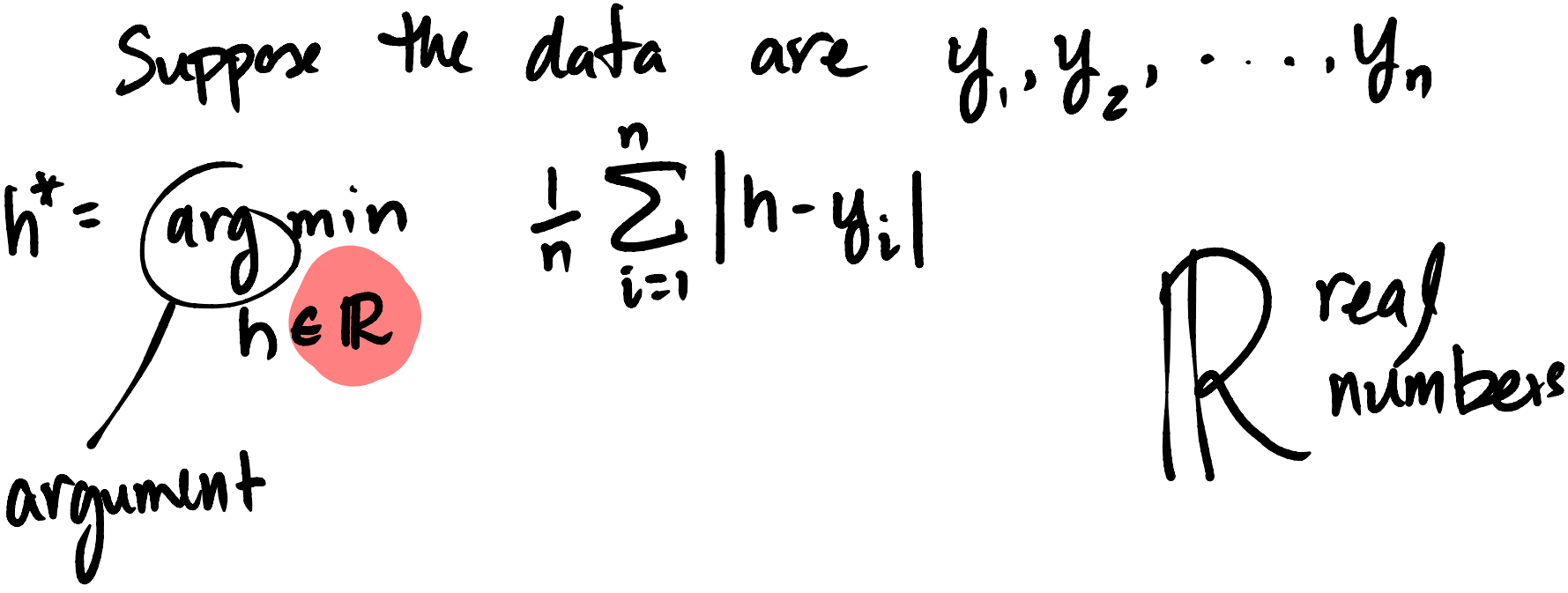
- We can calculate the average error of each:

mean : 22,400 median : 19,200

- 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 error.
- This is an **optimization problem**.



Status Update

- 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 error on the data.*

- We have turned the problem of learning into a specific type of math problem: an **optimization problem**.

What's Left

- We need to solve this math problem.
- Next time: math.