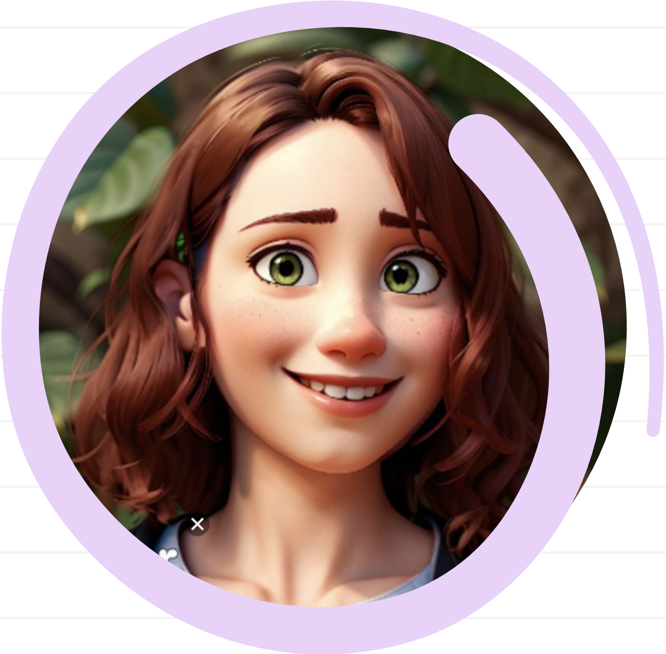
DSC 40B

Lecture 1 :

Intro/Review

Motivation

Mic!



Hello! I'm...

Marina Langlois.

I teach coding classes at HDSI :) and many of you have probably taken one, two, or even three classes!

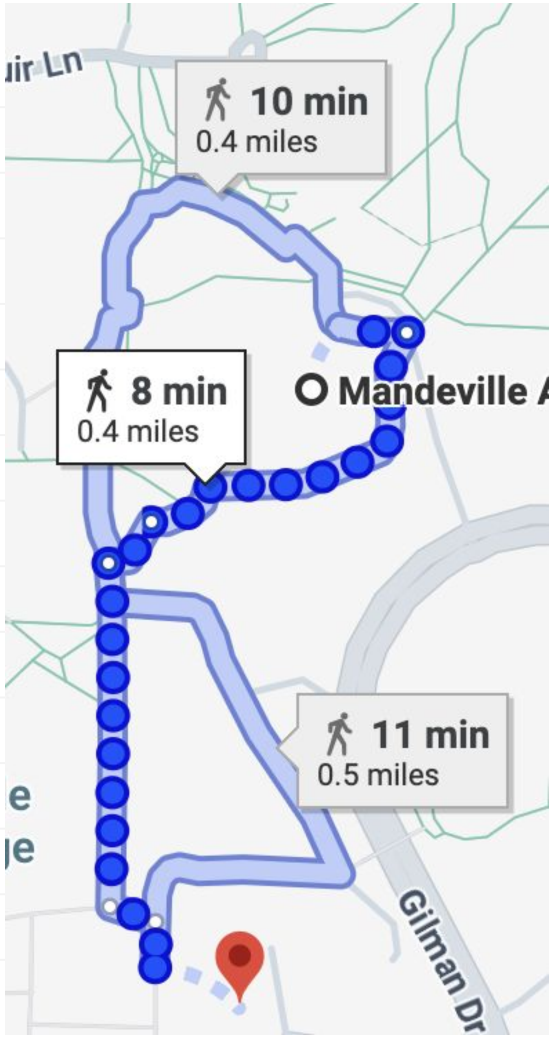
Fun fact: there was a student who took 6 (all different!) classes with me :)

Credits

- ***Most*** of the materials will be re-used from Justin Eldridge's offerings of this class.

I might be late for class because...

Section	Days	Time	Building & Room	
a Sci (4 Units)				P
A00	MWF	10:00a-10:50a	PETER	102
A01	M	4:00p-4:50p	WLH	2111
12/12/2025	F	8:00a-10:59a	TBA	TBA
(4 Units)				P
A00	MWF	12:00p-12:50p	MANDE	B-202
A01	M	4:00p-4:50p	MANDE	B-202
12/11/2025	Th	11:30a-2:29p	MANDE	B-202
nce (2 Units)				P
A00	M	11:00a-11:50a	YORK	4080A
A01		TBA		



Class Business

Syllabus

- All course materials, the syllabus, etc., can be found at dsc40b.com
  - 9 Labs, 8 homeworks (Due Monday + Wed)) + "super hw"
  - 2 exams (dates to be determined). Week 5 and 9.
  - Handwritten submissions, late policy, ChatGPT policy
  - One homework dropped, one lab dropped
  - Exam redemption

Participation

- This is one of the changes.
  - I need students to teach, not empty chairs :(
  - **Class Participation**: 2%
  - **Discussions**: 1%

https://webclicker.web.app/

ZNSOLY

Steps:

1. Go to a link above
2. Code: ZNSOLY
3. Make sure to use your UCSD email address (i.e., @ucsd.edu)
4. Use quest/public wifi please.
5. Answer the questions when I active the poll.
6. Do not worry if it does not work today. The first class does not count. We will figure it out eventually.

https://webclicker.web.app/ ZNSOLY

What is your DSC30 status? :)

A: Already took it

B: Took a similar class

C: Taking it this quarter

D: Still need to take it

E: Something else

Discussion on Monday?

Yes!


SOOOOO...
ANY QUESTIONS?

Let's jump back to DSC 40A...
Just for a bit

Big picture

- In what ways can we **define and represent** the process of **learning from data**?
    - **Learning from data**:
        - observing examples (like pictures of cats and dogs with labels, or past stock prices) and
        - figuring out a pattern or model that can make predictions about new, unseen examples.

Two questions

- In what ways can we **define and represent** the process of **learning** from data?
- How can we **translate** that representation into procedures a **computer** can execute?

Example 1: Minimize Absolute Error

- **Goal**: summarize a collection of numbers, x_1 , … , x_n :
- **Idea**: find number M minimizing the total absolute error:

$$\sum_{i=1}^{n} |M - x_i|$$

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- **Goal**: summarize a collection of numbers, $x_1, \ldots, x_n$:
- **Idea**: find number M minimizing the total absolute error:

$$\sum_{i=1}^{n} |M - x_i|$$

What is M?

A: Range

B: Mean

C: Standard deviation

D: Median

Example 1: Minimize Absolute Error

Solution: The **median** of $x_1, \ldots, x_n$.

The End for 40A

The End?

Minimize Absolute Error

- How do we actually **compute** the median?

Minimize Absolute Error

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Using **just** Python, no extra libraries. Imagine DSC20 Final :)

Please, talk to each other.

Minimize Absolute Error

- How do we actually **compute** the median?

1) Sort
2) Find the middle

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Time complexity?

A: n

B: n log n

C: n^2

D: Did not take DSC30 yet

Minimize Absolute Error

- How do we actually **compute** the median?

1) **Sort**
2) Find the middle

Is this the best (fastest) you can do?

Time complexity?

A: n

B: n log n

C: n^2

D: Did not take DSC30 yet

Key idea

- In this class, our work doesn't stop once we solve the math problem (like you did in DSC 40A).
- We still need to **compute** the answer.
- We need an **algorithm**.

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- In this class, our work doesn't stop once we solve the math problem (like you did in DSC 40A).
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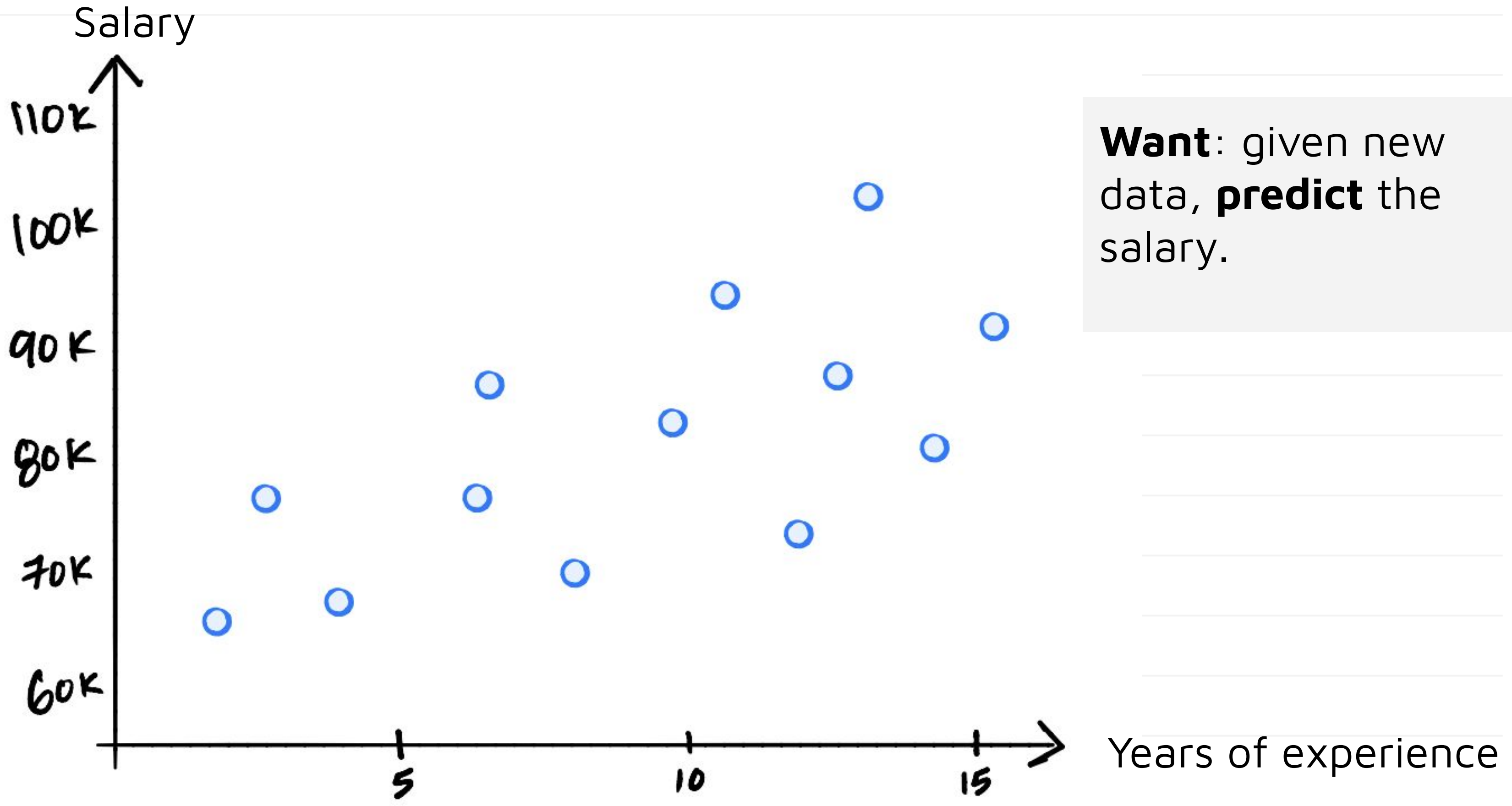
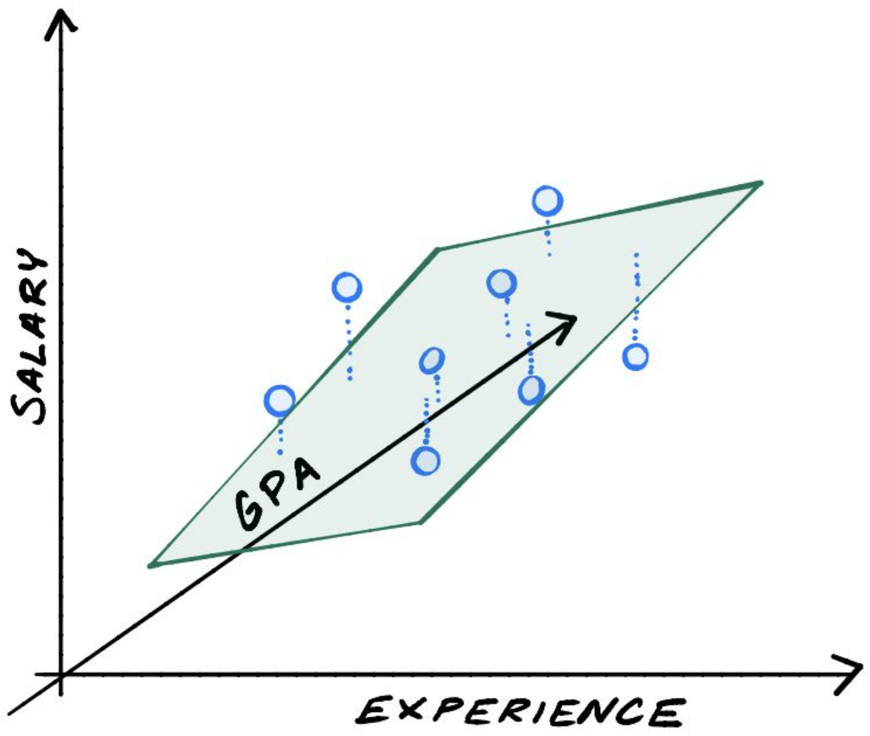
- We need an **algorithm**.
- More than that, we need an **implementation** of that algorithm (that is: **code**).

Example 2: Least Squares Regression



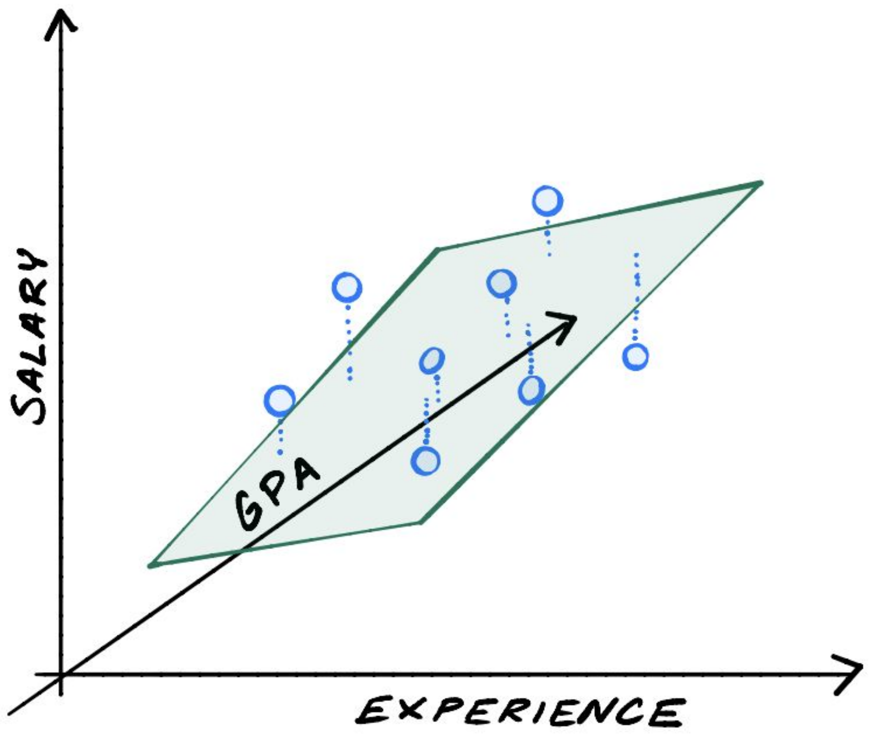
Want: given new data, **predict** the salary.

Example 2: Least Squares Regression



- Formulation (**linear regression**):
  - Find the best (hyper) plane *fitting* these points with **least total error** (sum-square distances).

Example 2: Least Squares Regression



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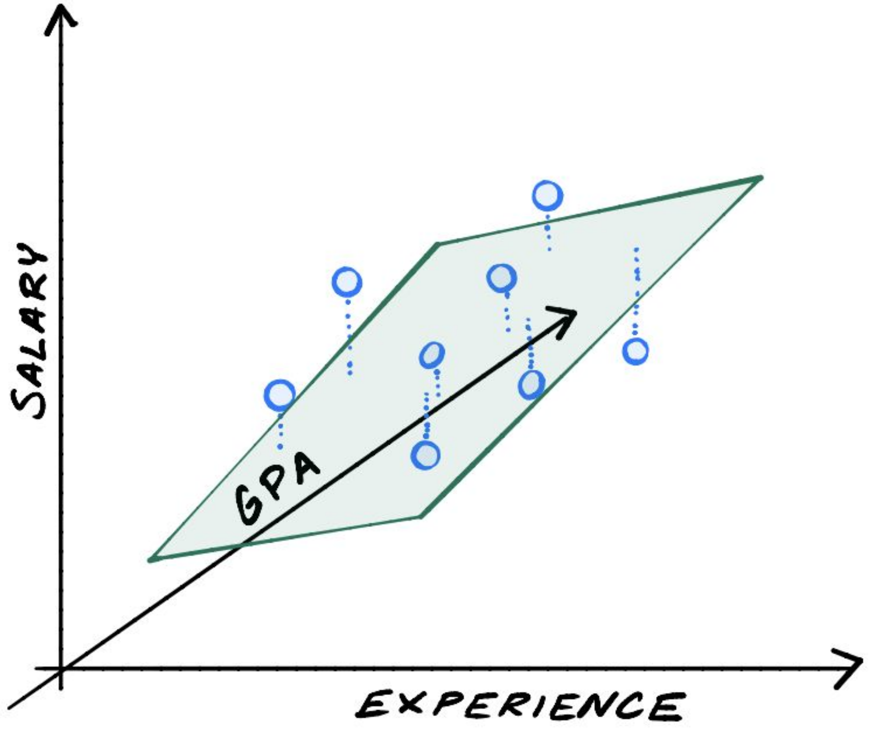

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- **Answer**:

$$(X^T X)\vec{w} = X^T \vec{b}$$

- **The END**

Wait...

- How do we **really** compute it?
- How do we ask a computer to **compute it for us**?
- We need an **algorithm**.

An Algorithm?

- Let's say we have `numpy` installed.
- It provides an implementation of an algorithm:
  - *Solves normal equations and does regression.*

```
>>> import numpy as np
>>> w = np.linalg.solve(X.T @ X, X.T @ b)
```

But ...is it even good?

- How fast does it run on 1,000 points?
- How does it scale on 1,000,000 points?
- What if the feature dimension increase to 100,000?
- Can we come up with the ***better*** algorithm for this problem?

Key idea

- Having an algorithm **isn't enough** – we need to know about its performance.
- Otherwise, it may be **useless** for our particular problem.

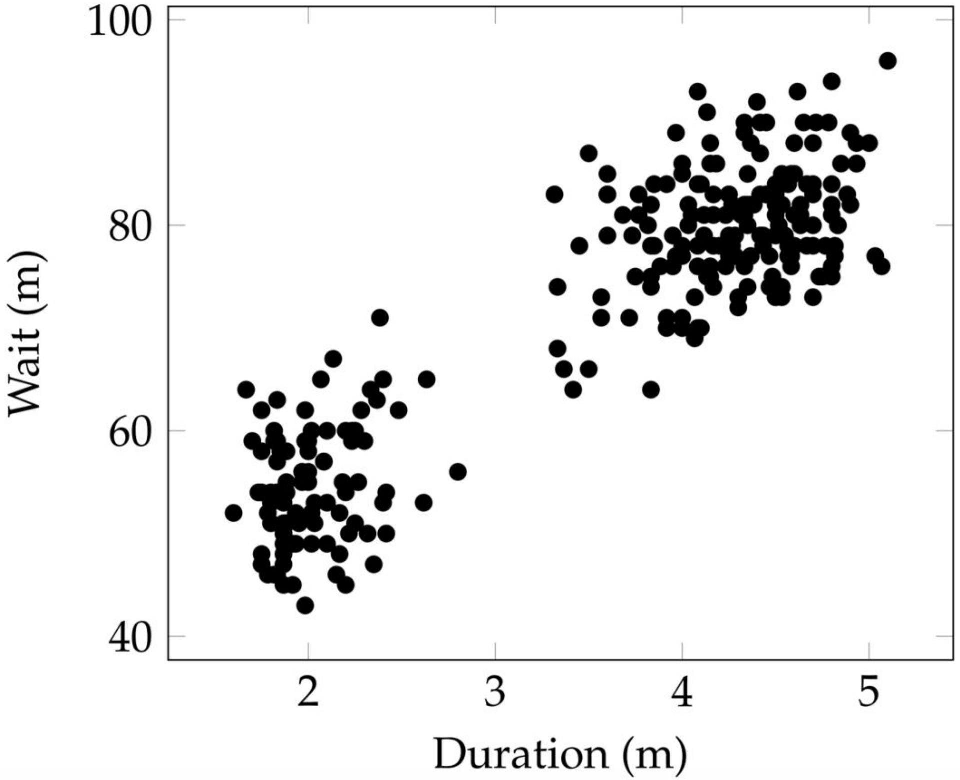
Not convinced? Another example: Clustering

- Given a pile of data, discover *similar* groups.
- **Examples**:
  - Find political groups within social network data.
  - Given data on COVID-19 symptoms, discover groups that are affected differently.
  - Find the similar regions of an image (segmentation).
- Most useful when data is high dimensional…

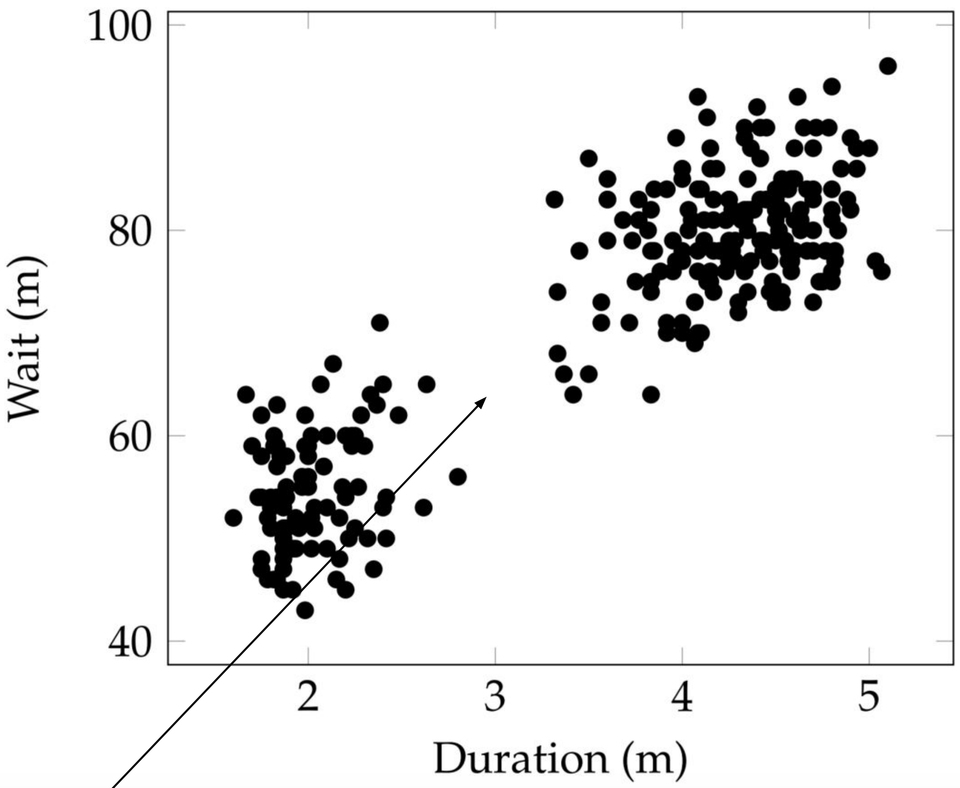
Example: Old Faithful geyser in Yellowstone

Example: Old Faithful in action

What is the pattern behind its eruption?



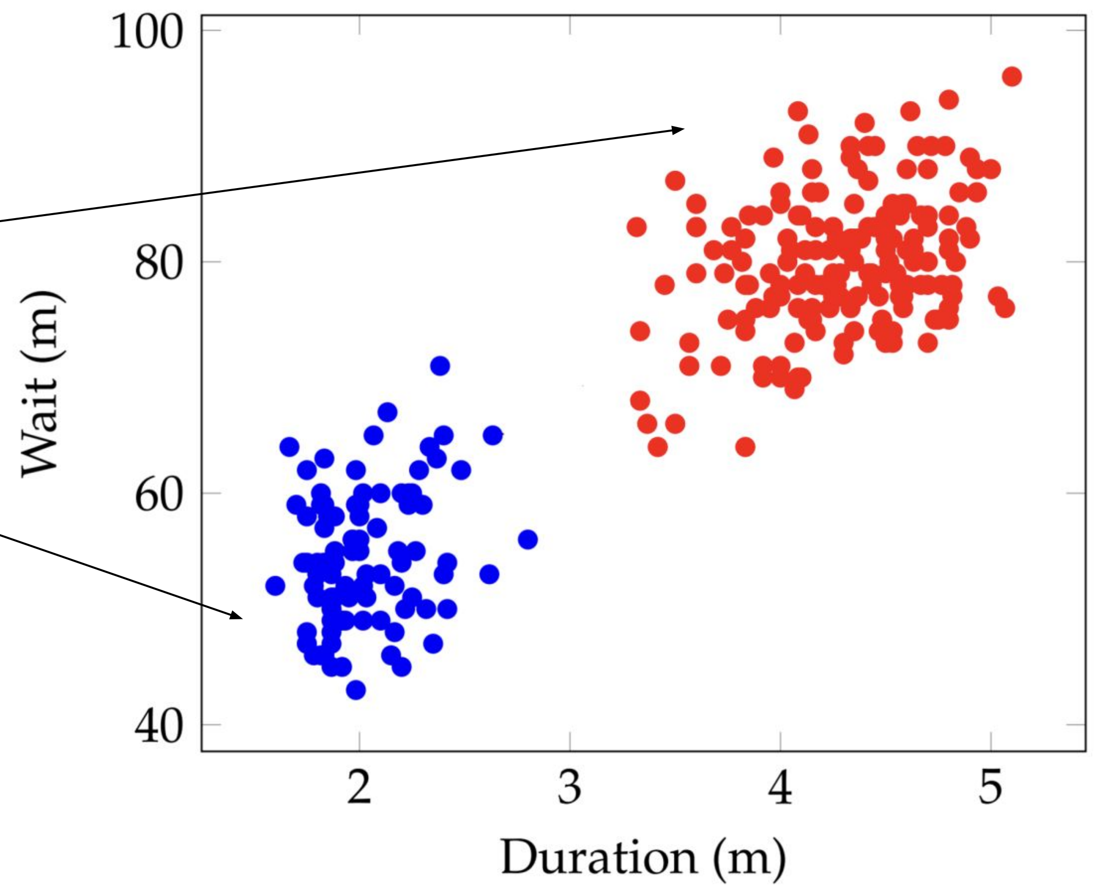
What is the pattern behind its eruption?



Interesting observation for geophysicists

Example: Old Faithful

Goal: Invent an algorithm that finds these clusters automatically.



Clustering

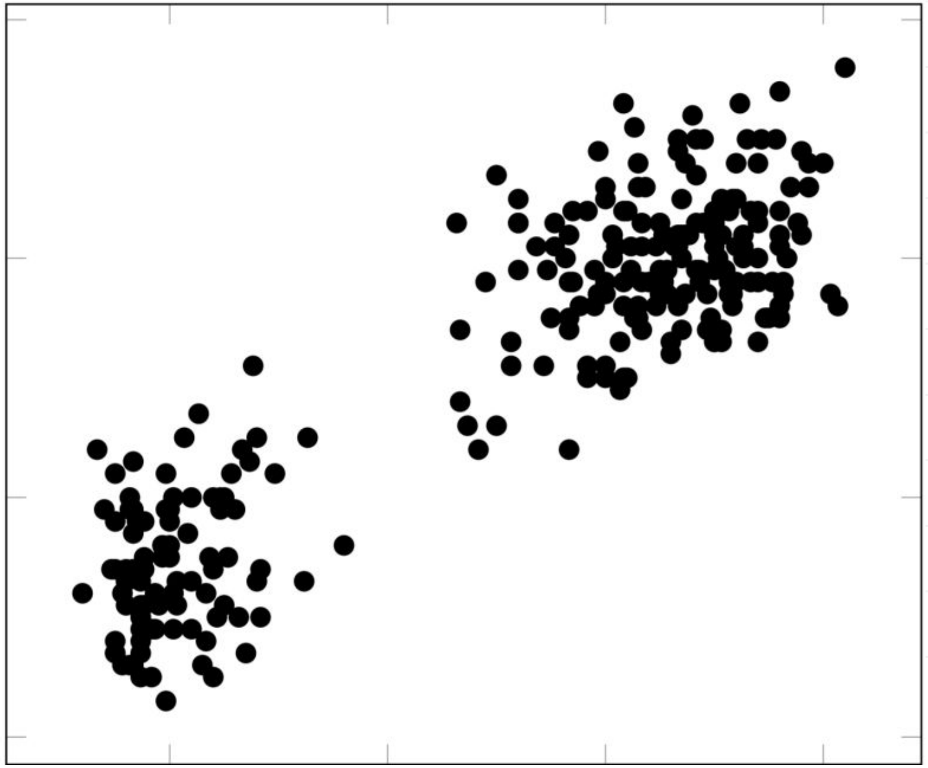
- **Goal**: for computer to identify the two groups in the data.
- **A clustering** is an assignment of a color to each data point.
- There are **many** possible clusterings.

Clustering

- How do we turn this into something a **computer** can do?
- DSC 40A says: “Turn it into an optimization problem”.
- **Idea**: **design** a way of quantifying the “goodness” of a clustering; find the **best**.
  - Design a **loss function**.
  - There are many possibilities, tradeoffs!

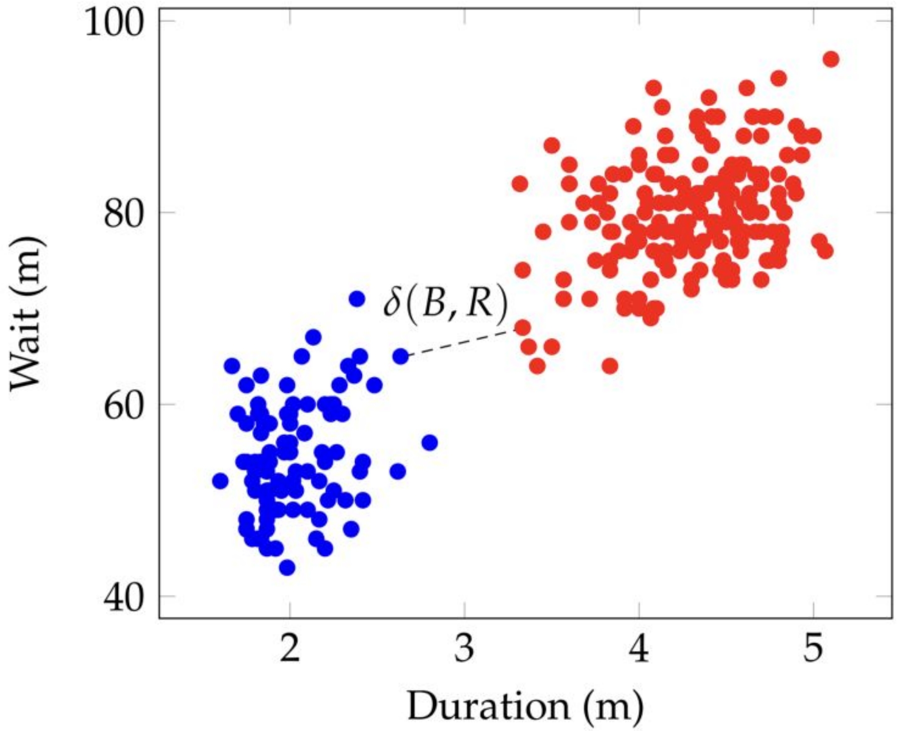
Think!

What's a **good** loss function for this problem? It should assign small loss to a **good** clustering.



Quantifying Separation

Idea: Define the "separation" $\delta(B, R)$ to be the **smallest** distance between a blue point and red point.



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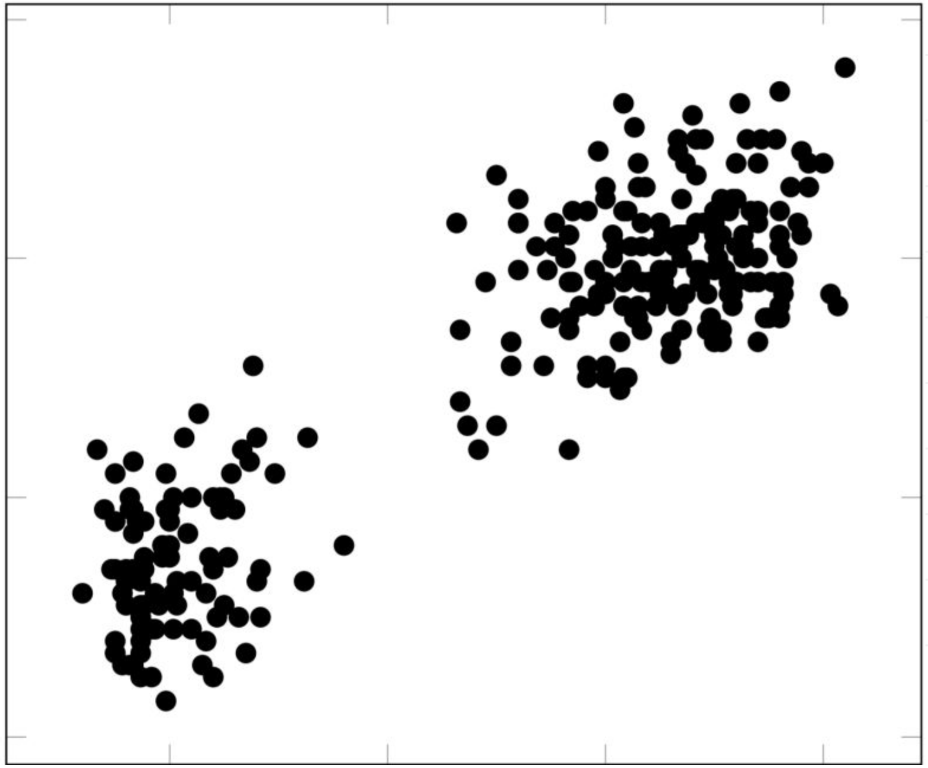

The Problem

- Given n points $\vec{x}^{(1)}, \ldots, \vec{x}^{(n)}$.

- **Find**: an assignment of points to clusters **R** and **B** so as to **maximize** $\delta(B, R)$.

DSC 40A: “The End”

DSC 40A: “The End”

DSC 40B: “The Beginning”

The "Brute Force" Algorithm

- There are finitely-many possible clusterings.
- **Algorithm**: Try **each possible** clustering, return that with largest separation, $\delta(\boldsymbol{B}, \boldsymbol{R})$.
- This is called a brute force algorithm.

Code

```
best_separation = -float('inf') # Python for "infinity"
best_clustering = None

for clustering in all_clusterings(data):

    sep = calculate_separation(clustering)

    if sep > best_separation:

        best_separation = sep

        best_clustering = clustering

print(best_clustering)
```

The Algorithm

- We have an algorithm!
- But how long will this take to run if there are n points?
- How many clusterings of n things are there?

Exercise

How many ways are there of assigning **R** or **B** to n points?

Solution

- **Two** choices for each object: 2 x 2 x … x 2 = 2^n
    - Small nitpick: actual color doesn't matter, 2^{n-1}

Time

- Suppose it takes at least 1 *nanosecond* to check a single clustering.
  - One *billionth* of a second.
  - Time it takes for light to travel 1 foot.
- If there are n points, it will take at *least* 2^n nanoseconds to check all clusterings.
- This is an *extremely* optimistic estimate. It's actually much slower, and scales with n.

Time Needed

n	Time
1	1 nanosecond

Time Needed

n	Time
1	1 nanosecond
10	1 microsecond

1 millionth of a second

Time Needed

n	Time
1	1 nanosecond
10	1 microsecond
20	1 millisecond

1 thousandth of a second

Time Needed

n	Time
1	1 nanosecond
10	1 microsecond
20	1 millisecond
30	1 second

Time Needed

n	Time
1	1 nanosecond
10	1 microsecond
20	1 millisecond
30	1 second
40	18 minutes

Time Needed

n	Time
1	1 nanosecond
10	1 microsecond
20	1 millisecond
30	1 second
40	18 minutes
50	

Check your intuition:

A: In minutes

B: In hours

C: In days

D: In weeks

E: In years

Time Needed

n	Time
1	1 nanosecond
10	1 microsecond
20	1 millisecond
30	1 second
40	18 minutes
50	13 days

Time Needed

n	Time
1	1 nanosecond
10	1 microsecond
20	1 millisecond
30	1 second
40	18 minutes
50	13 days
60	36 years

Time Needed

n	Time
1	1 nanosecond
10	1 microsecond
20	1 millisecond
30	1 second
40	18 minutes
50	13 days
60	36 years
70	37,000 years

Example: Old Faithful

- The Old Faithful data set has **270** points.
- Brute force algorithm will finish in **6×10^{64} years.**

Algorithm Design

- Often, most obvious algorithm is **unusably slow.**

Algorithm Design

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- Does this mean our problem is too hard?
    - Direct result of our choice of loss function.

Algorithm Design

- Often, most obvious algorithm is **unusably slow**.
- Does this mean our problem is too hard?
  - Direct result of our choice of loss function.
- We'll see an efficient solution by the end of the quarter.

Main Idea

- Just having an algorithm isn’t enough – it must also be reasonably **efficient**. Otherwise, it might be **useless** for our particular problem.

DSC 40B is about:

- Assess the efficiency of algorithms.
- Understand why and how common algorithms work.
- Develop faster algorithms using design strategies and data structures.

Measuring Efficiency by Timing

Efficiency

- Speed matters, especially with large data sets.
- An algorithm is only useful if it runs **fast enough.**
  - That depends on the size of your data set.
- How do we measure the efficiency of code?
- How do we know if a method will be fast enough?

Scenario

- You’re building a least squares regression model to predict a patient’s blood oxygen level.
- You’ve trained it on 1,000 people.
- You have a full data set of 100,000 people.
- How long will it take? How does it **scale**?

Example: Scaling

- Your code takes 5 seconds on 1,000 points.
- How long will it take on 100,000 data points?
- 5 seconds × 100 = 500 seconds?
- More? Less?

Coming Up

- We'll answer this in coming lectures.
- Today: start with simpler algorithms for the mean, median.

Approach #1: Timing

- How do we measure the efficiency of code?
- Simple: time it!
- Useful Jupyter tools: `time` and `timeit`
    - Magic functions

[4]:
```
numbers = range(1000)
```

[5]:
```
%%time
sum (numbers)
```

```
CPU times: user 30 µs, sys: 0 ns, total: 30 µs
Wall time: 34.3 µs
```

[5]: 499500

[6]:
```
%%timeit
sum(numbers)
```

```
9.96 µs ± 3.79 ns per loop (mean ± std. dev. of 7 runs, 100,000 loops each)
```

Disadvantages of Timing

1. Time depends on the computer.

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2. Depends on the particular input, too.

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1. Time depends on the computer.
2. Depends on the particular input, too.
3. One timing doesn’t tell us how algorithm **scales**.

Thank you!

Do you have any questions?

CampusWire!