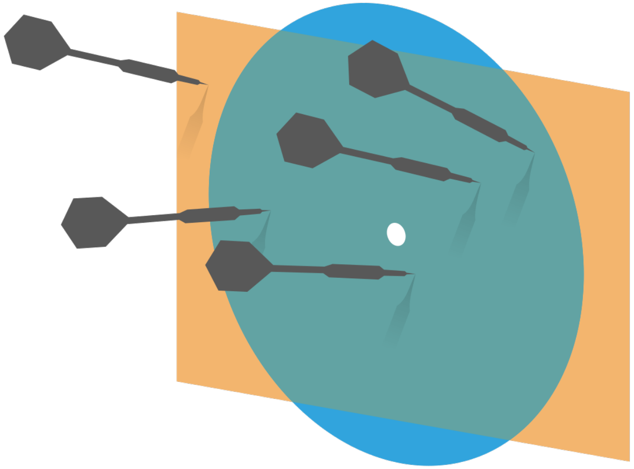
Probability and Statistics for Computer Science



Credit: wikipedia

"The eternal mystery of the world is its comprehensibility … The fact that it is comprehensible is a miracle."
– Albert Einstein

Hongye Liu, Teaching Assistant Prof, Course CS361, UIUC, 8.25.2020

How to Zoom in the lectures

- Students’ Video and Audio will be both muted during the lecture unless permitted by the instructor for questions.
- You can use the chatbox to ask questions or write comments.
- Questions will be collected by the assistant for answers or summary.

Test Poll1

- Have you read the syllabus on the course website?

  A. Yes.   B. No.

Test Poll2

- Have you done the survey on the course Compass website?

  A. Yes.   B. No.

Test Poll3

- Have you watched the welcome video in the Orientation module?

  A. Yes.   B. No.

Objectives

- Welcome/Orientation
- Big picture of the contents
- Lecture 1 - Data Visualization & Summary (I)

Vision

- Passion for learning
- Compassion for each other

How to succeed in this course?

- Factors that will hinder you from success
- Factors that will help you succeed

Avoid these that could cause failure

- Academic integrity infraction – by all means!
- Missing homeworks or project
- Late/Poor homeworks or project
- Insufficient viewing of the contents
- Poor time management
- Too many challenging classes at the same time
- Not motivated/not interested in the topic

Factors that will help you succeed

- Try your best to be engaged/motivated, learn from the course and from each other
- Be **Active** in class participation
- Do as much practice as possible, not just the homeworks and project.
- Read the textbook and other recommended books.
- Clear your doubts/misconceptions **asap (every lecture/discussion is important)**

Interactions are important!

- Try to go to office hours as much as possible
- Try to meet or talk to the instructor as least once personally
- You are encouraged to join the team work
- Show compassion via community service

We will try to customize for students in international locations for team work

- Please answer this poll:

Are you in an international location that has more than 3hrs time difference from Central USA?

A. Yes

B. No

Graded Team work

Extra Points

Quizzes

Course materials

- Compass Course Site

  Find it through Compass for CS361 Fall 2020 AL1

- Public Website

  https://courses.engr.illinois.edu/cs361/fa2020/

What are the contents?

- Probability and Statistics in action
- What does this course teach?

  Textbook: Forsyth, D. A. "Probability and Statistics for Computer Science," Springer (2018)

- Why are there 4 sections? How are they related?

This field really started with gaming

- We are familiar with flipping a coin or throwing a dice, the result is uncertain!

Head
Or Tail?

Which side
is front?

Life is uncertain so aim for long-term average

- We repeat a lot of experiments and see if there is regularity

Head
Or Tail?

Which side
is front?

Throwing a lot of “coins” for many times in one touch

- Galton board, the Bead Machine

https://www.youtube.com/watch?v=Kq7e6cj2nDw

Probability and Statistics Experiment in action

Simulation of random draw of a picture on computer

- It's the same as throwing a 4-sided die.

What does this course teach?

- Describing Datasets

  Summary & visualization

- Probability
- Inference – Statistical Inference
- Tools – Machine Learning tools

Describing datasets (Summary & visualization)

Descriptive & Graphical

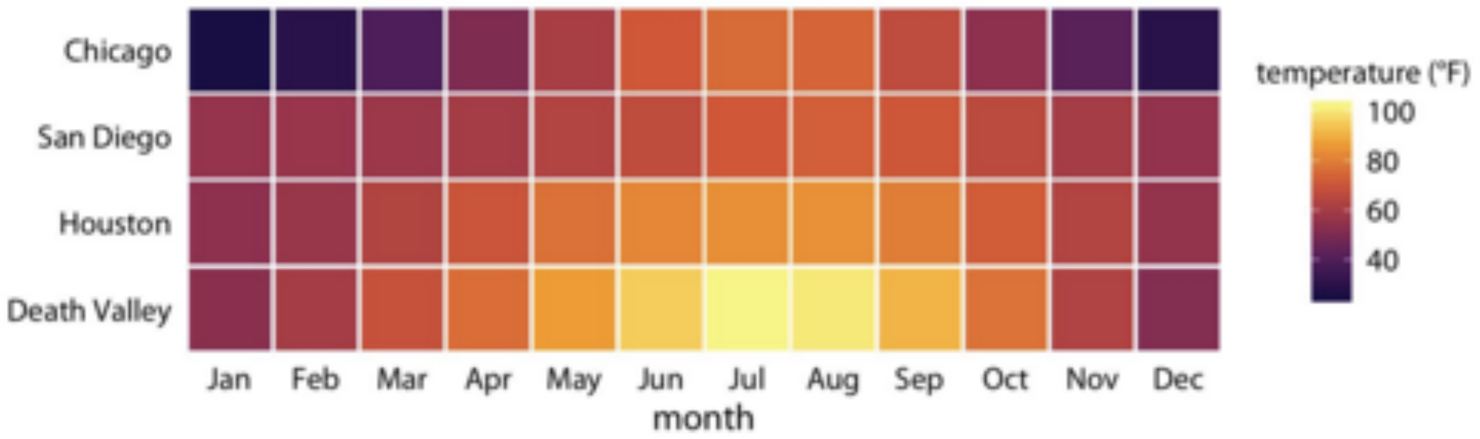


Figure 2-4. Monthly normal mean temperatures for four locations in the US. Data source: NOAA.

Summarization of 4 locations' annual mean temperature by month

Probability

- **Mathematical**

Romeo and Juliet have a date

Each arrives with a delay btw 0 and 1 hour. The first to arrive leaves after 1/4 hour. All pairs of delays are equally likely.

What's the probability that they will meet?

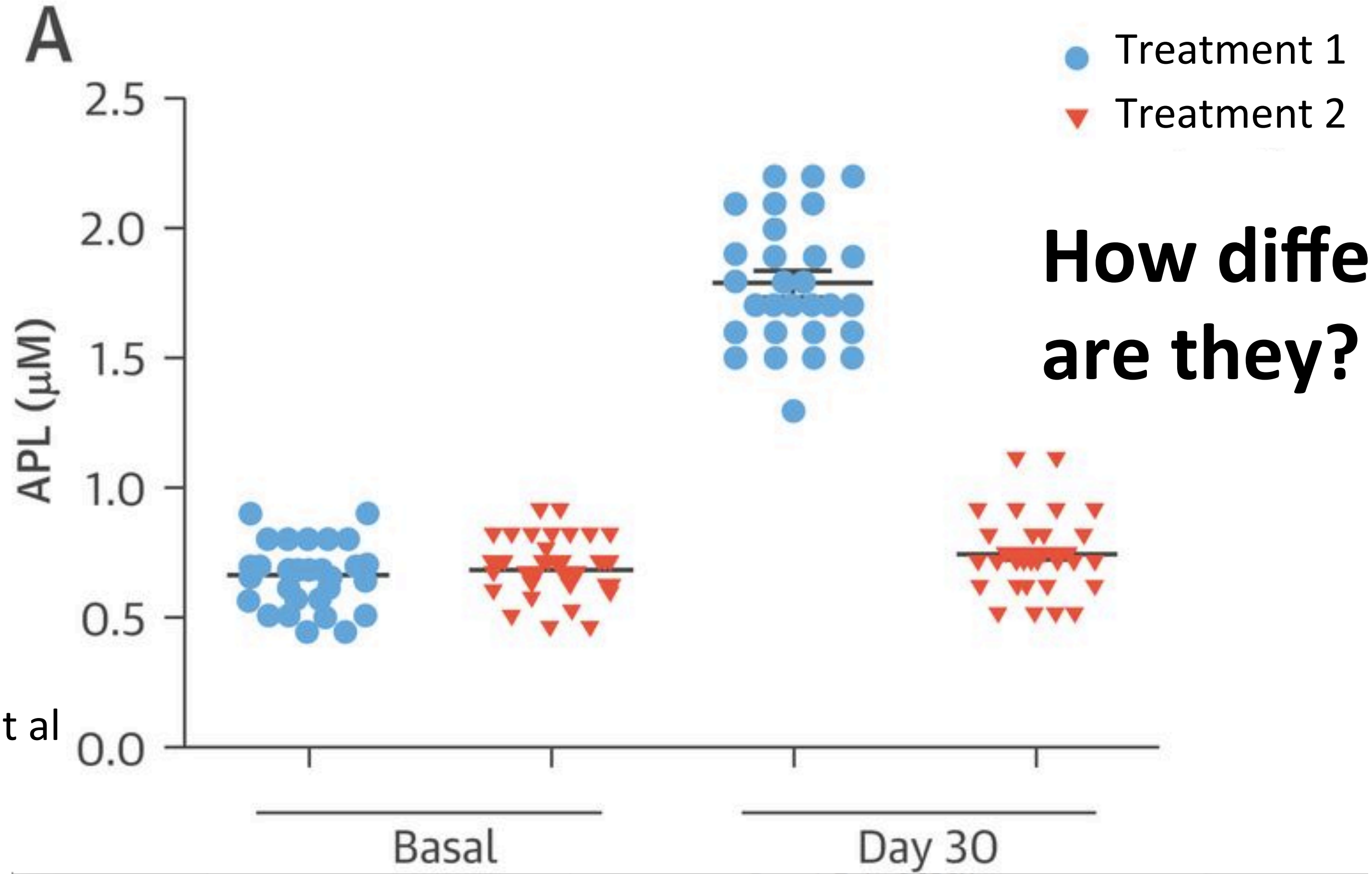
Probability

- **Mathematical**

How many slots are empty on average for a simple hashing table?

Inference

- **Analytical**

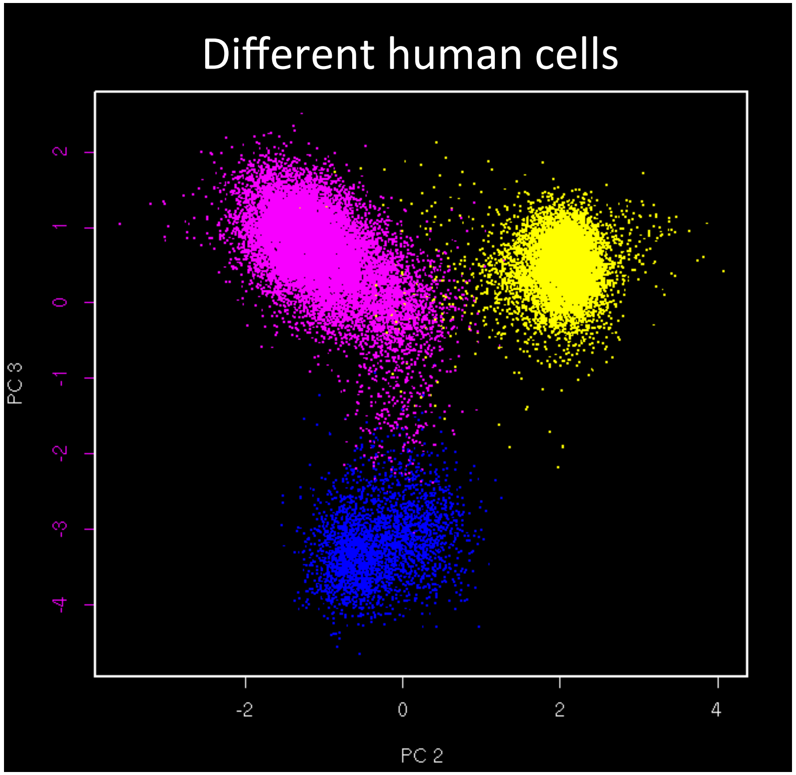


How different are they?

J Fromonot et al
JACC 2016

Tools (Machine learning)

- **Algorithmical**



High-dimensional or complex shaped data sets need tools! Humans are limited in 2-3D.

Machine learning is Highly desired!

Often depends on Statistics.

Why these 4 sections?

- Summary & visualization
  Graphical

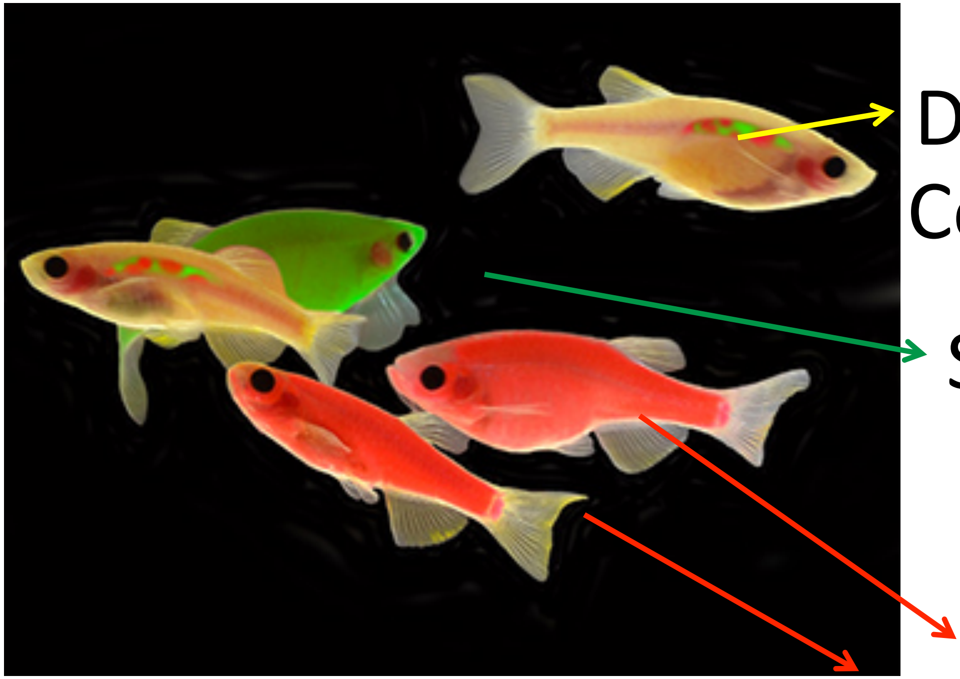
- Probability
  Mathematical

- Inference – Statistical Inference
  Analytical

- Tools – Machine Learning tools
  Algorithmical

Why these 4 sections?

- The common thread is **Data.**
- We are doing computer science and so are like these yellow fish



Data Science + Comp. Science

Statistics

Mathematics

What is special of Data? For Data?

Why these 4 sections?

- Real world data is often high dimensional and complex
- These 4 parts of knowledge or techniques are inseparably/ organically connected in many real world applications.

What do we emphasize?

- Mathematical principle
- Critical thinking
- Working with real world data

LECTURE 1

Q. What do you feel about it when we speak of data visualization?

Example 1: Black hole

Constructed image using data collected from many different telescopes' view of the same object

This project received a 3million-dollar award

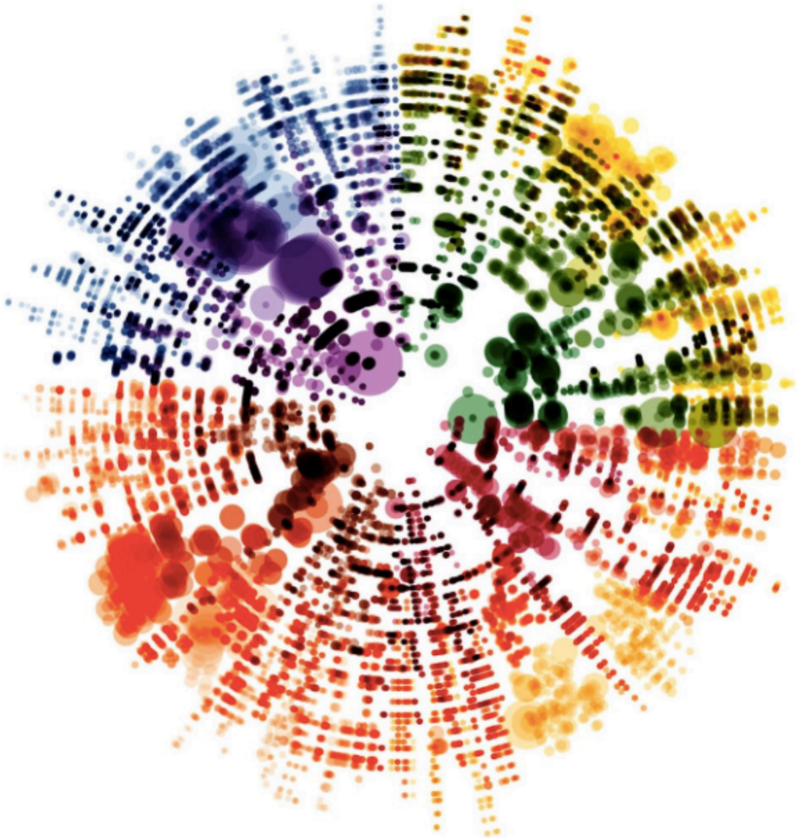
Credit: NASA

Example 2: Four seasons by Vivaldi

Pitch is shown by the distance from center;

Length of the note is the size of dot

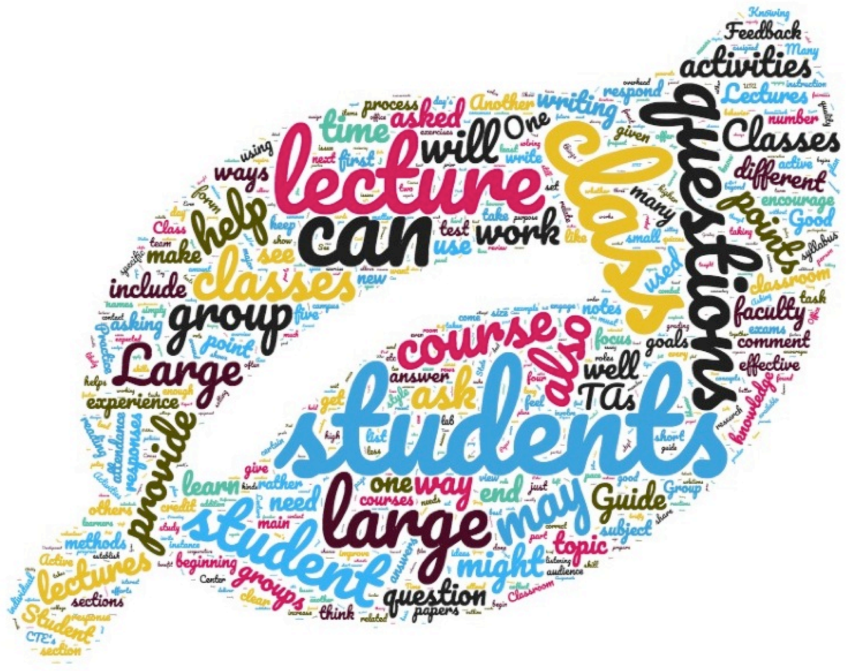
Instrument is shown by the color



https://medium.com/future-today/off-the-staff-an-experiment-in-visualizing-notes-from-music-scores-58f6ee9f0cef

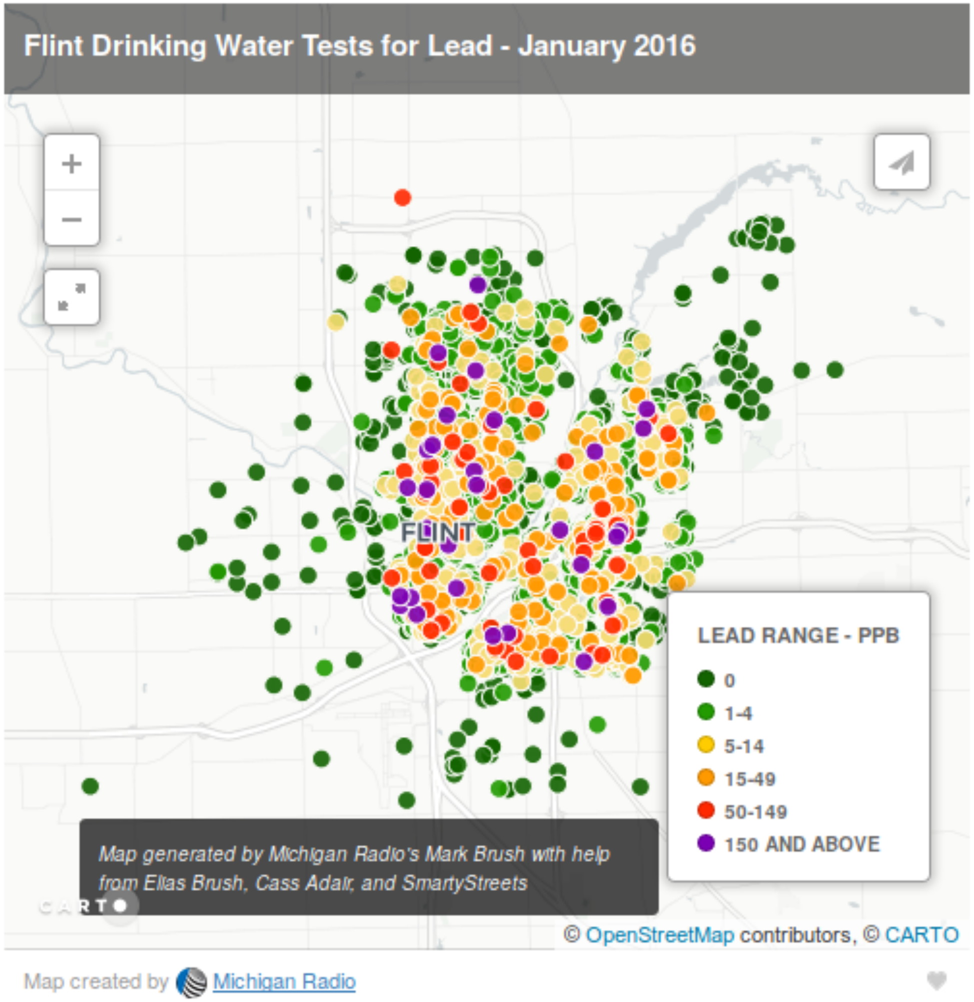
Example 3: Word cloud

Frequency of words of a document in novel visual presentation



Example 4: GIS map

Color scaled dots show the lead level in water in an area in Michigan

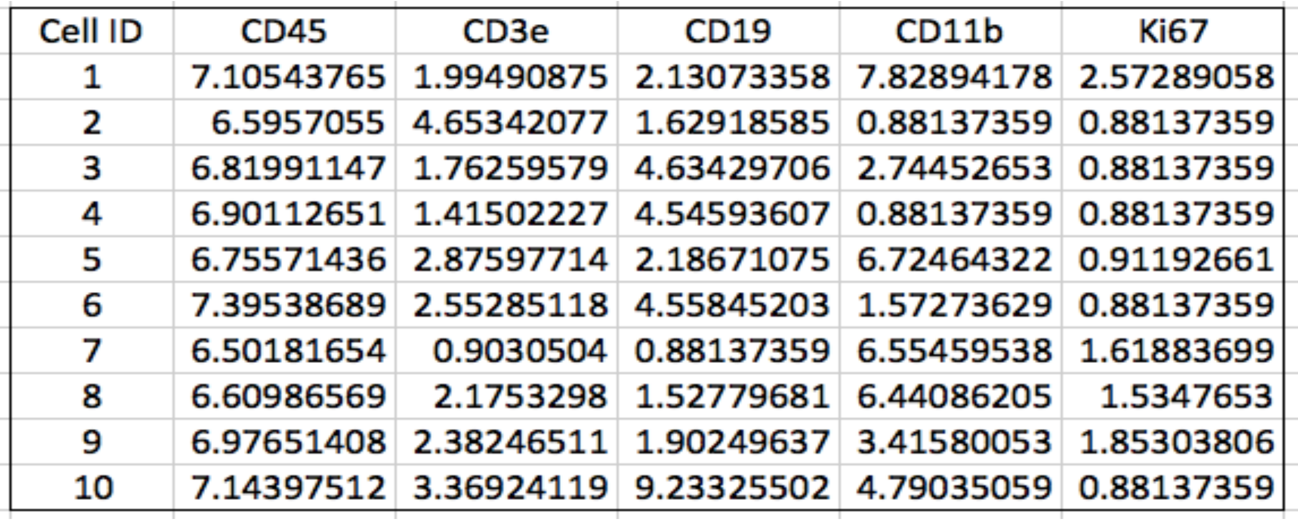

Flint Drinking Water Tests for Lead - January 2016
FLINT
LEAD RANGE - PPB
● 0
● 1-4
● 5-14
● 15-49
● 50-149
● 150 AND ABOVE
Map generated by Michigan Radio's Mark Brush with help from Elias Brush, Cass Adair, and SmartyStreets
CARTO
© OpenStreetMap contributors, © CARTO
Map created by Michigan Radio

Lecture I: Data Visualization &Summary

- Datasets {x} – a set of N items x_i, i=1…N, each of which is a tuple

Proteins →

Cells ↓



Cell ID	CD45	CD3e	CD19	CD11b	Ki67
1	7.10543765	1.99490875	2.13073358	7.82894178	2.57289058
2	6.5957055	4.65342077	1.62918585	0.88137359	0.88137359
3	6.81991147	1.76259579	4.63429706	2.74452653	0.88137359
4	6.90112651	1.41502227	4.54593607	0.88137359	0.88137359
5	6.75571436	2.87597714	2.18671075	6.72464322	0.91192661
6	7.39538689	2.55285118	4.55845203	1.57273629	0.88137359
7	6.50181654	0.9030504	0.88137359	6.55459538	1.61883699
8	6.60986569	2.1753298	1.52779681	6.44086205	1.5347653
9	6.97651408	2.38246511	1.90249637	3.41580053	1.85303806
10	7.14397512	3.36924119	9.23325502	4.79035059	0.88137359

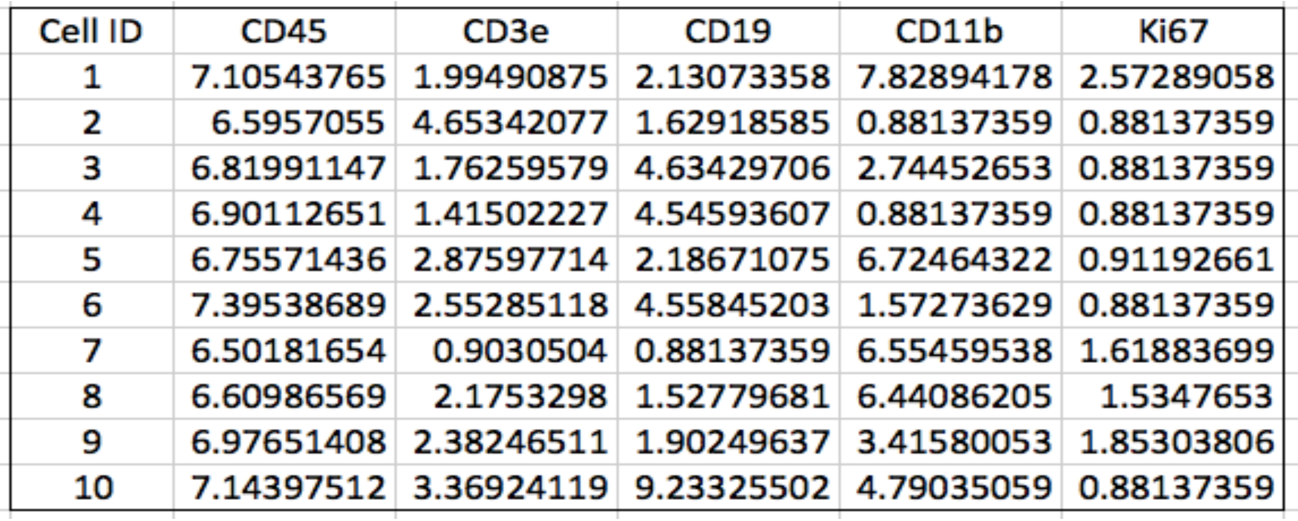
Each row is a tuple

Lecture I: Data Visualization &Summary

- Convention: columns are the ***features***; the number of features is ***dimension.***

Proteins →

Cells ↓



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Each row is a tuple with dimension =5

Data types

- Categorical
- Ordinal
- Continuous

Q. Which of the following data is not categorical?

A. Number of enrolled students in a class
B. Weight of apples in a grocery store
C. Instruments played by an orchestra
D. Type of chemical reagents in a lab
E. A & B

Simple Visualization of Data

- General principles
- Bar chart
- Histogram
- Conditional histogram

Simple Visualization of Data

- General principles

  Must not mislead or distort;

  Aesthetically pleasing;

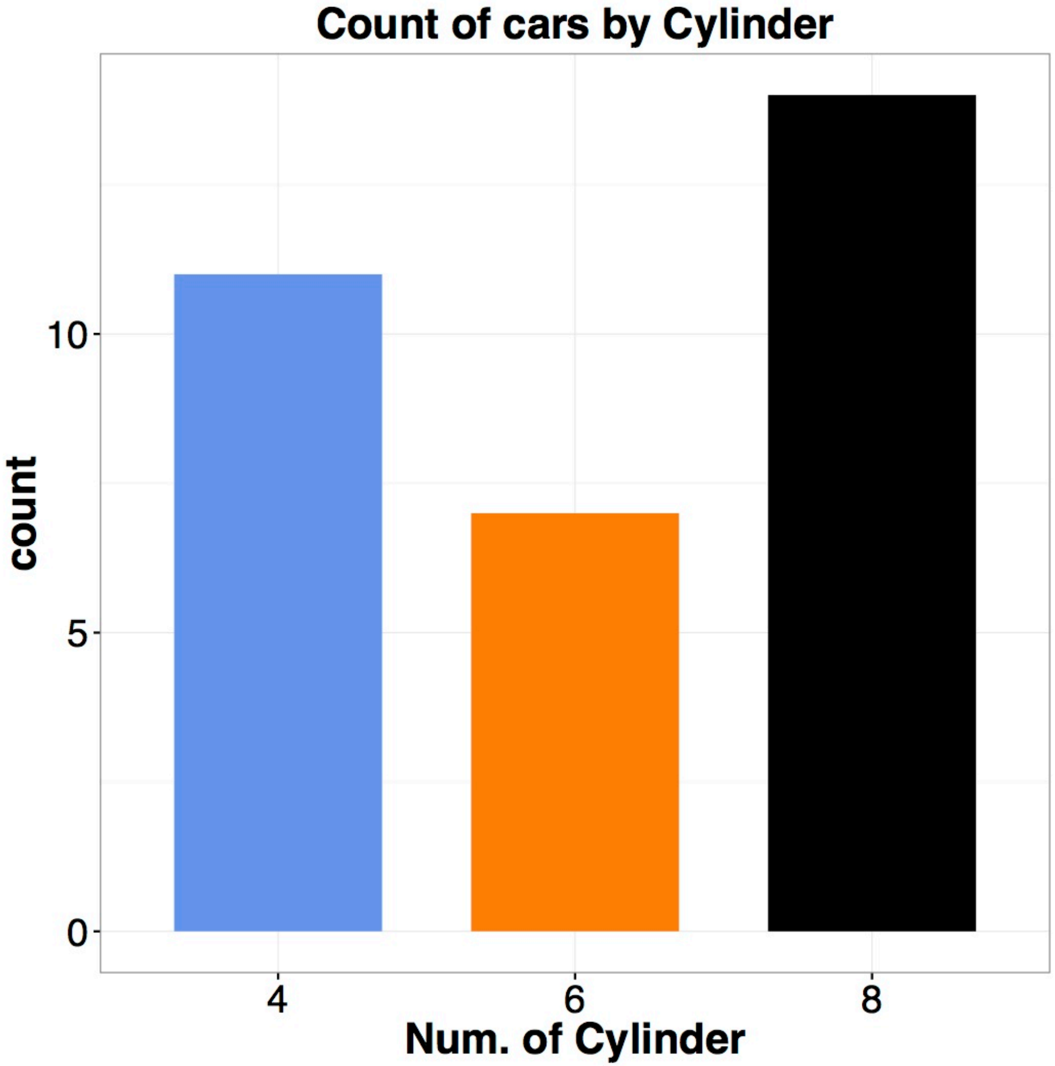
  Clear, Attractive, Convincing;

  Show message/significance.

Simple Visualization of Data

- Bar chart

A set of bars that are organized by categorical or ordinal feature



Data: “mtcars”

An example of good, ugly, bad, wrong

Dr. Wilke illustrated the difference between ***good*, *ugly, bad and wrong visualization***

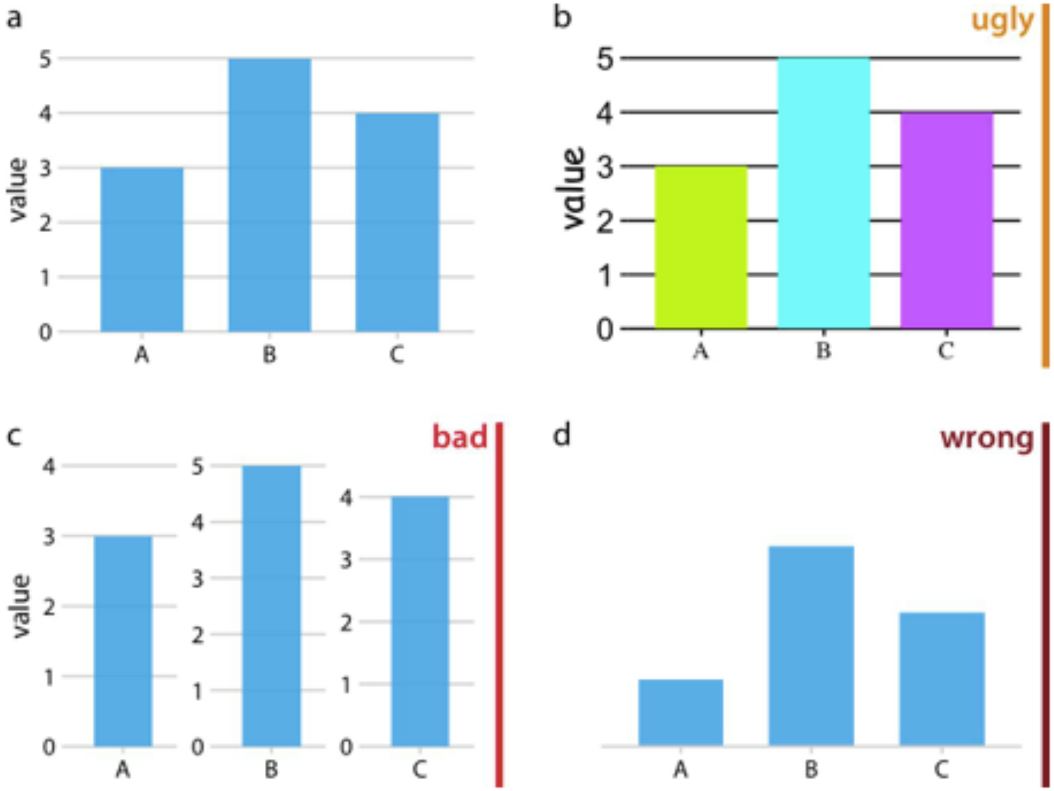
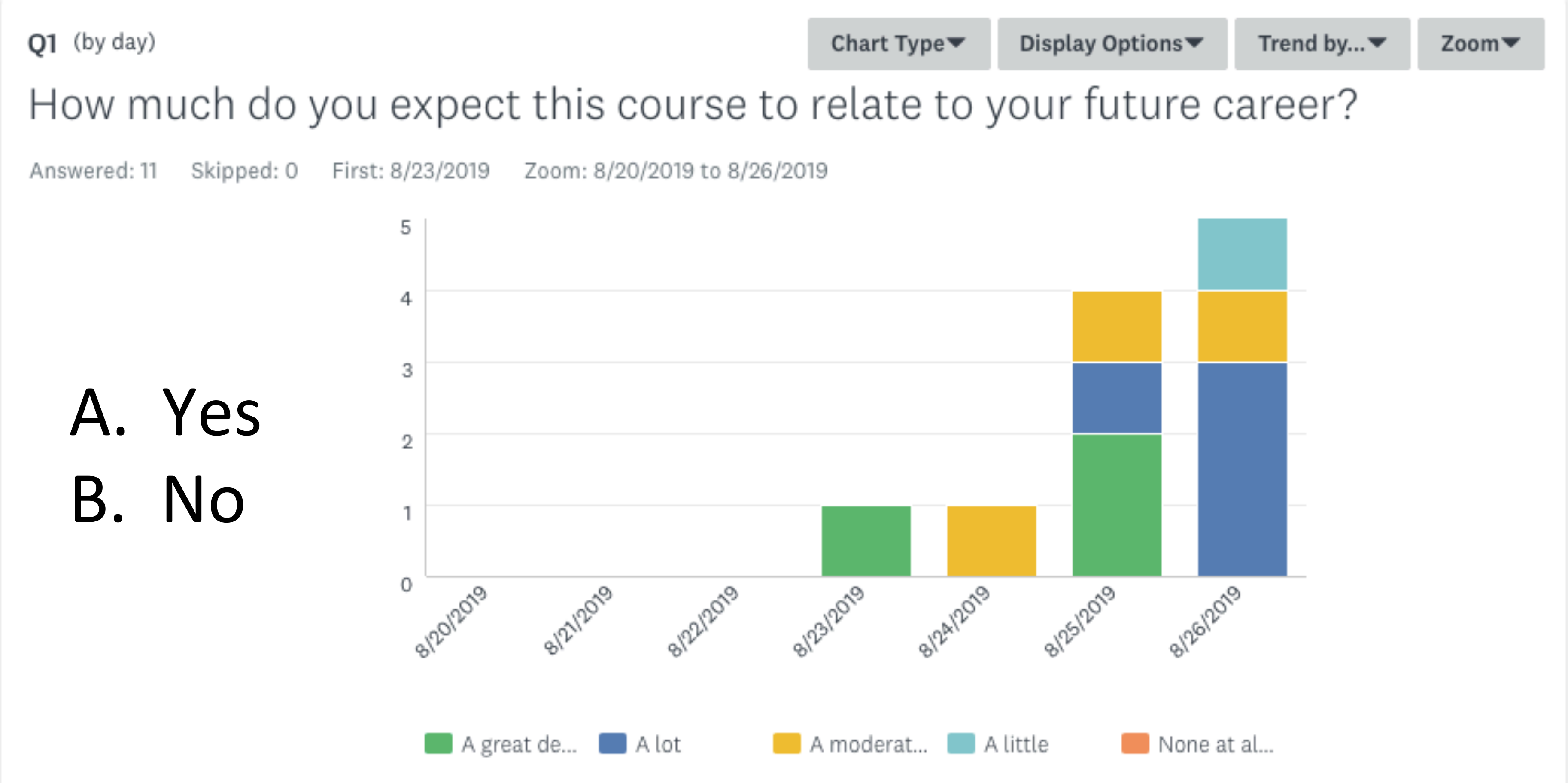


Figure 1-1. Examples of ugly, bad, and wrong

C. Wilke “Fundamentals of Data Visualization”

Q: Is this a good bar chart?



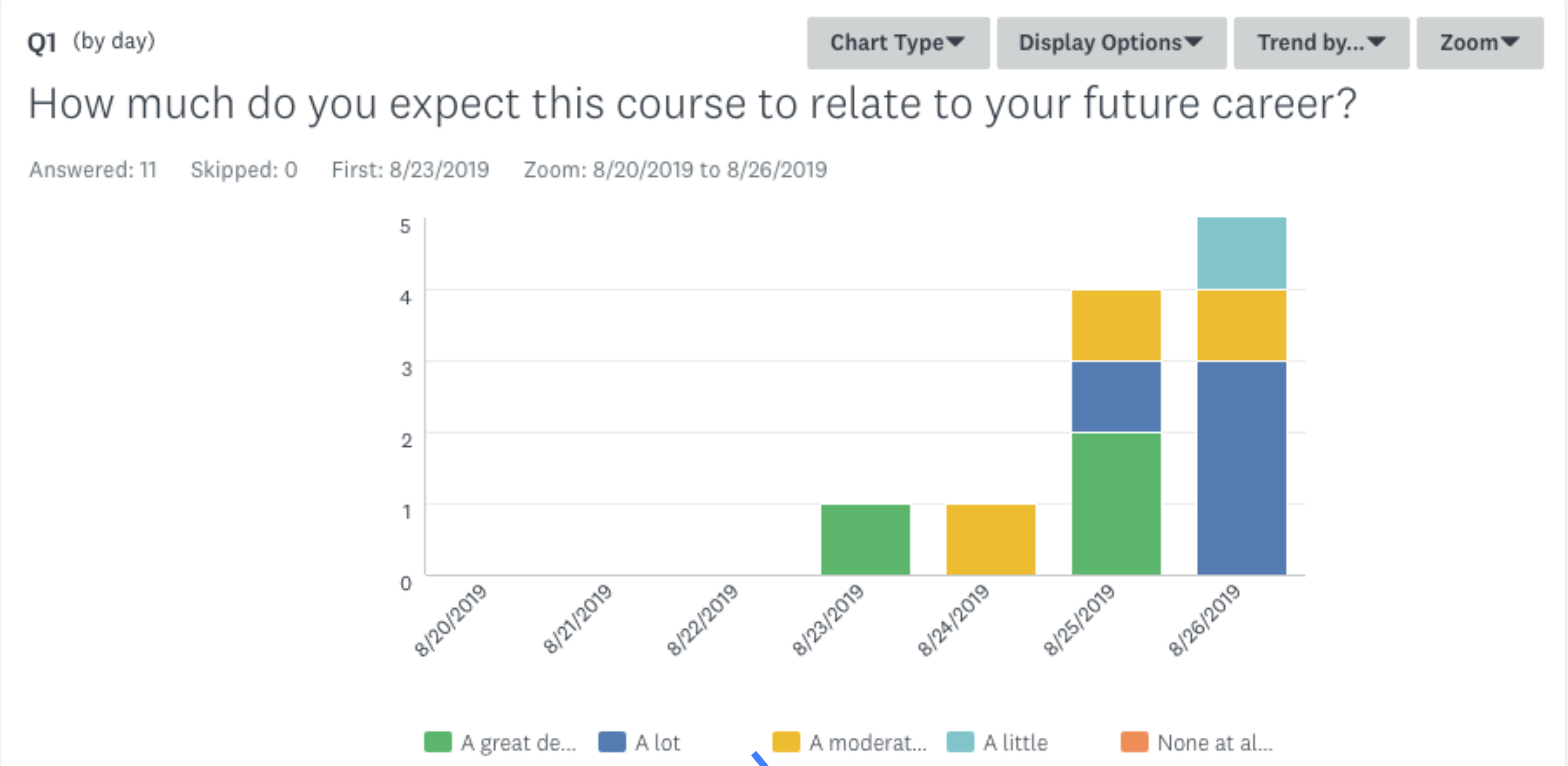
Q1 (by day)

How much do you expect this course to relate to your future career?

Answered: 11 Skipped: 0 First: 8/23/2019 Zoom: 8/20/2019 to 8/26/2019

A. Yes
B. No

How about using a color scale



Q1 (by day)

How much do you expect this course to relate to your future career?

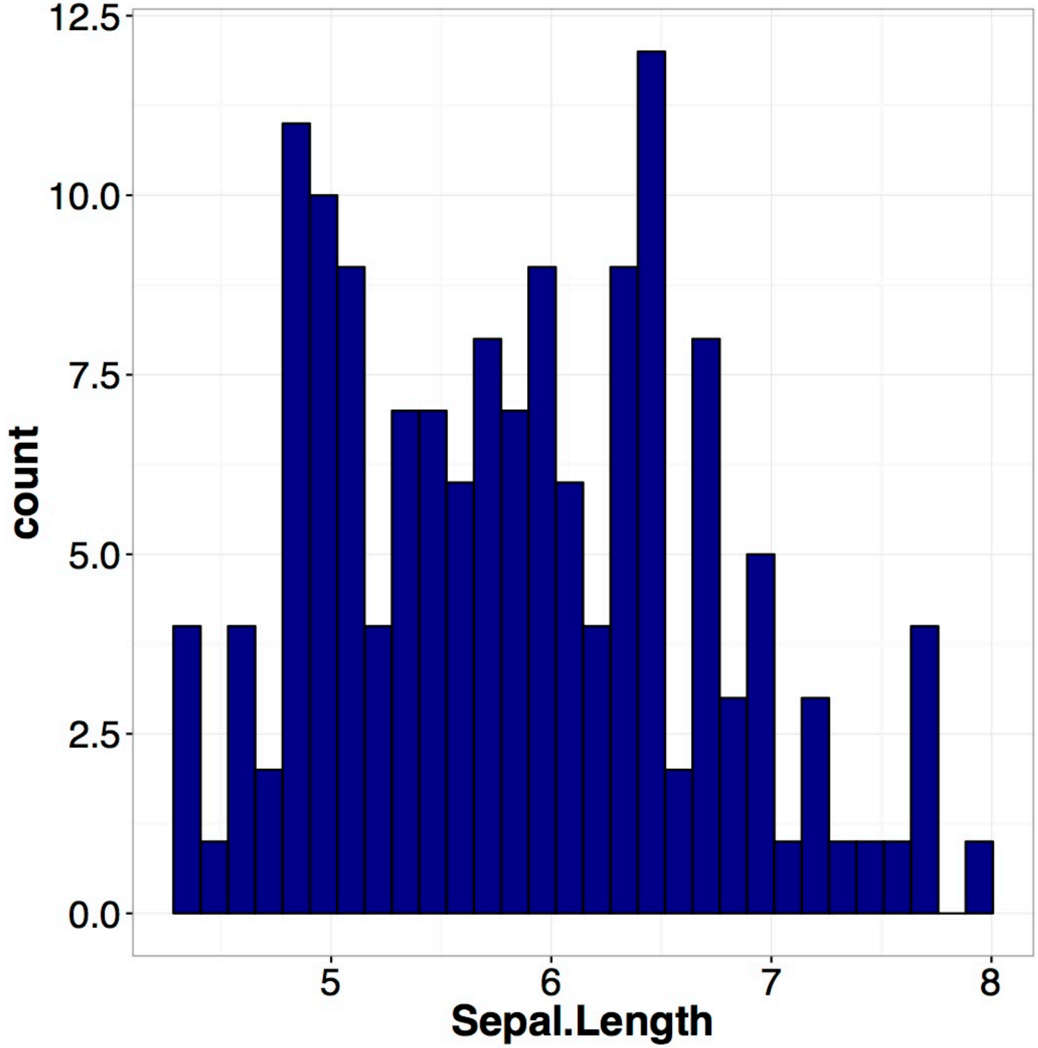
Answered: 11 Skipped: 0 First: 8/23/2019 Zoom: 8/20/2019 to 8/26/2019

Visualizing Data with Histogram

- Histogram

A set of bars that are organized by bins that contains numerical data (discrete or continuous)

Data: "iris"

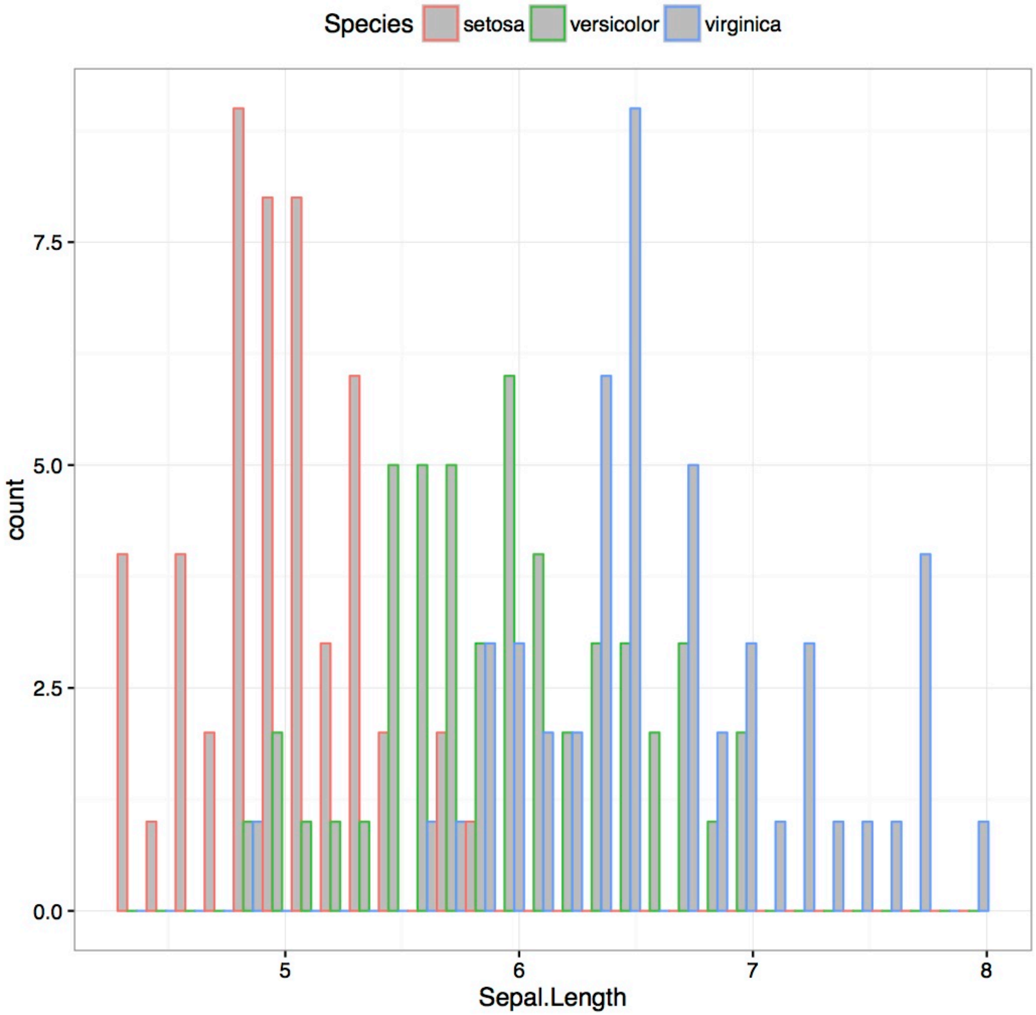


Visualizing Data with Histogram (II)

- Conditional histogram

Histogram generated by subsets of the data

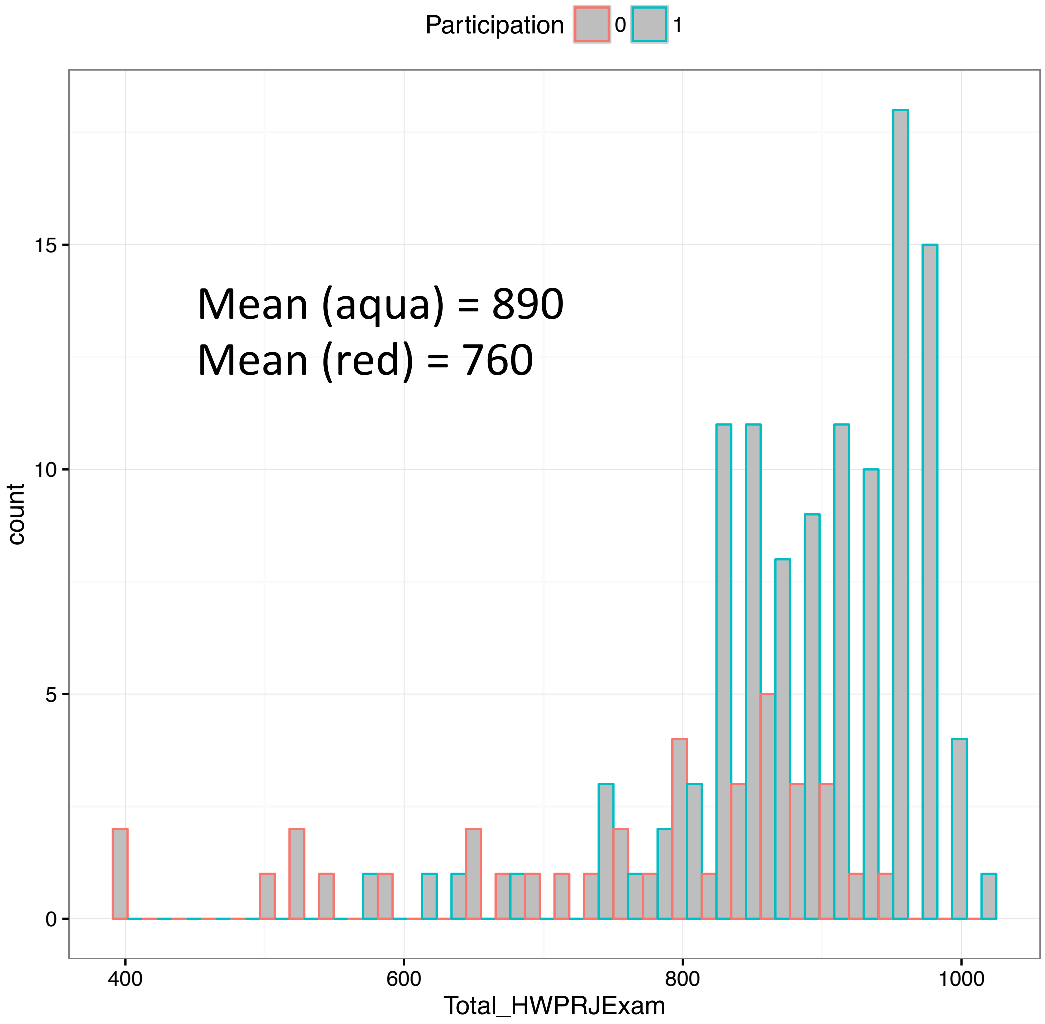
Data: “iris”



Visualizing Data with Histogram (III)

- Conditional histogram

Data: Combined Score (HWs, Prj and Exams) grouped by students with full participation or **not full** in CS361 fall 2019



Summarizing 1D continuous data

- Location Parameters
  - Mean
  - Median
  - Mode
- Scale parameters
  - Standard deviation and variance
  - Interquartile range

Summarizing 1D continuous data

- Mean

$$mean(x_i) = \frac{1}{N}\sum_{i=1}^{N} x_i$$

It’s the centroid of the data geometrically, by identifying the data set at that point, you find the center of balance.

Properties of the mean

- Scaling data scales the mean

$$mean(\{k \cdot x_i\}) = k \cdot mean(\{x_i\})$$

- Translating the data translates the mean

$$mean(\{x_i + c\}) = mean(\{x_i\}) + c$$

Less obvious properties of the mean

- The signed distances from the mean

  sum to 0

$$\sum_{i=1}^{N}(x_i - mean(\{x_i\})) = 0$$

- The mean minimizes the sum of the squared distance from the mean

$$\underset{\mu}{argmin} \sum_{i=1}^{N}(x_i - \mu)^2 = mean(\{x_i\})$$

Qs:

- What is the answer for

  $\mathit{mean}(\mathit{mean}(\{x_i\}))$?

  A. $\mathit{mean}(\{x_i\})$ B. unsure C. 0

- Recall in which application did we compare the means of experiments?

Standard Deviation

- The standard deviation

$$std(\{x_i\}) = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(x_i - mean(\{x_i\}))^2}$$

$$= \sqrt{mean(\{x_i - mean(\{x_i\}))^2\})}$$

Can a standard deviation of a dataset be -1?

A. YES
B. NO

Properties of the standard deviation

- Scaling data scales the standard deviation

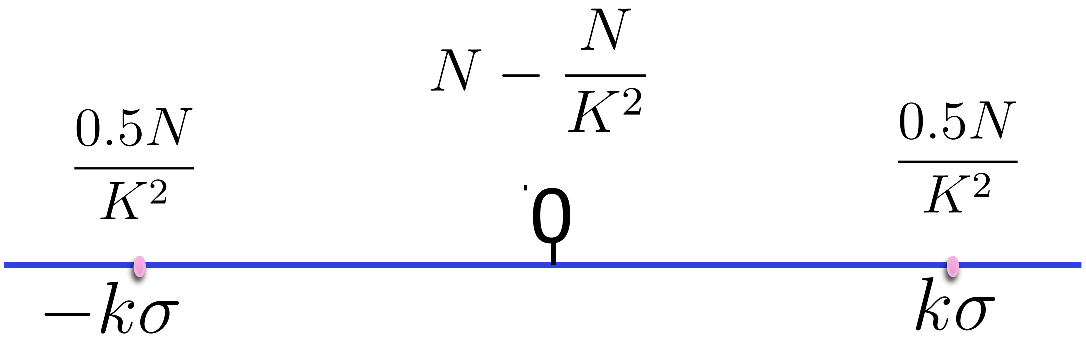
$$std(\{k \cdot x_i\}) = |k| \cdot std(\{x_i\})$$

- Translating the data does **NOT** change the standard deviation

$$std(\{x_i + c\}) = std(\{x_i\})$$

Standard deviation: Chebyshev's inequality

- At most $\frac{N}{k^2}$ items are k standard deviations (σ) away from the mean
- Rough justification: Assume mean =0



$$std = \sqrt{\frac{1}{N}[(N - \frac{N}{k})0^2 + \frac{N}{k^2}(k\sigma)^2]} = \sigma$$

Question:

Assignments

- Register for Compass and Gradescope
- Finish the orientation quiz
- Submit HW0 to Gradescope to test it
- Start week1 module on Compass

Additional References

- Charles M. Grinstead and J. Laurie Snell "Introduction to Probability”
- Morris H. Degroot and Mark J. Schervish "Probability and Statistics”