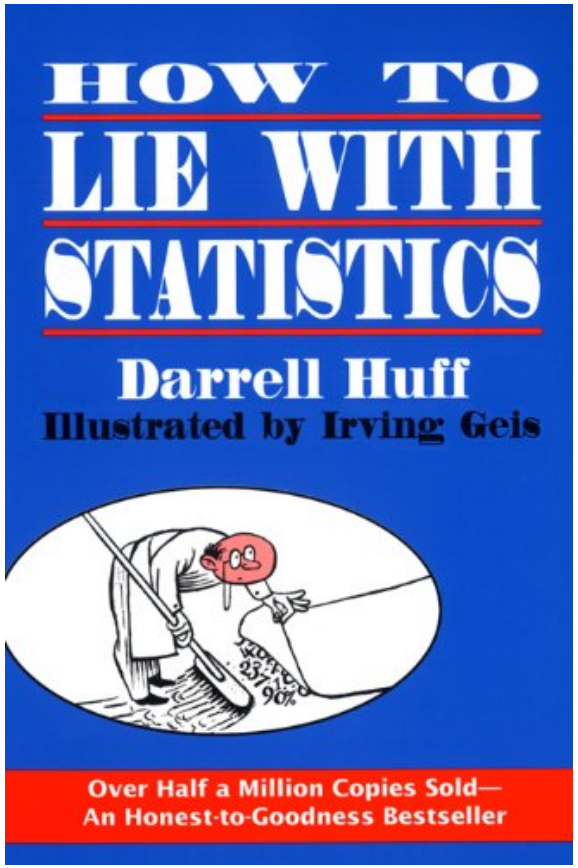
Statistics (basics)

SLIDES BY:

JIANNAN WANG

https://www.cs.sfu.ca/~jnwang/

Why Should you Care?



“ There are three kinds of lies:
lies, damned lies, and statistics ”

Would you like to be called a lying data scientist?

Outline

Statistical Thinking

Descriptive Statistics

Inferential Statistics

Outline

Statistical Thinking

Descriptive Statistics

Inferential Statistics

Statistical Thinking

1. Data is just a **sample**

2. You goal is to infer a **population**

3. Think about how to go "backwards" from the **sample** to the **population**

Example 1. Image Classification

Is it a dog or a cat?

Dataset: 1000 images collected from the Web

Without Statistical Thinking

Treat the 1000 images as the population

> Train a model on the data

> Evaluate a model on the same data

> Model accuracy: 95%

With Statistical Thinking

What is the population?

- All the images in the Web

What is your dataset?

- A sample of 1000 images drawn from the Web

What should you do?

- Split the dataset into a training dataset and a test dataset
- Train the model on the training dataset
- Evaluate the model on the test dataset

Example 2. Poll Prediction

Who will win the election?

Dataset: A survey of 1000 people

Without Statistical Thinking

Treat the 1000 people as the population

> Count the number of people who wants to vote for Hillary, e.g., 52

> Count the number of people who wants to vote for Trump, e.g., 48

> Hillary will win the election

With Statistical Thinking

What is the population?

- All the people who will vote in the election day

What is your dataset?

- A sample of 1000 people before the election day

Analysis result

Hillary: 52% ±3%
Trump: 48% ± 2%

Assumption: People have not changed their votes since the time of the poll

Summary

Statistical Thinking

- Sample, Population and Their Connection
- With vs. Without Statistical Thinking

Descriptive Statistics

Inferential Statistics

Outline

Statistical Thinking

Descriptive Statistics

Inferential Statistics

Descriptive vs. Inferential Statistics

Descriptive Statistics: e.g., Median

- *Why?* Aim to understand the data
- *How?* Data summarization, data visualization, etc.

Inferential Statistics: e.g., A/B Testing

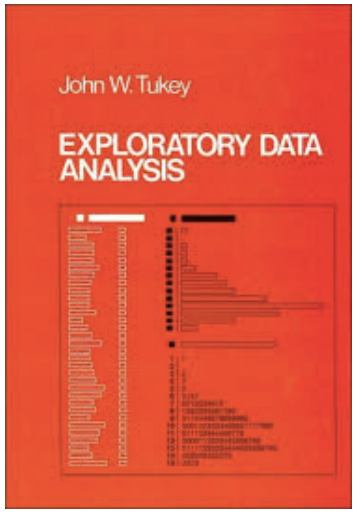
- *Why?* Aim to use the data (i.e., sample) to learn about a population
- *How?* Estimation, confidence intervals, hypotheses testing, etc.

Exploratory Data Analysis (EDA)

The process of doing descriptive statistics

John W. Turkey

- Professor at Princeton University
- Founding chairman of the Princeton statistics department in 1965
- Worked on EDA at Bell Labs since 60's
- Wrote a book entitled "Exploratory Data Analysis" in 1977



EDA is like detective work

From John Turkey

> “ Exploratory data analysis is an attitude, a state of flexibility, a willingness to look for those things that we believe are not there, as well as those that we believe to be there ”

Case Study

Is UC Berkeley gender biased?

	Applicants	Admitted
Men	8442	44%
Women	4321	35%

Case Study

Is UC Berkeley gender biased?

Department	Men		Women	
	Applicants	Admitted	Applicants	Admitted
A	825	62%	108	**82%**
B	560	63%	25	**68%**
C	325	**37%**	593	34%
D	417	33%	375	**35%**
E	191	**28%**	393	24%
F	373	6%	341	**7%**

NO!

Women tended to apply to competitive departments with low rates of admission

Chart Types

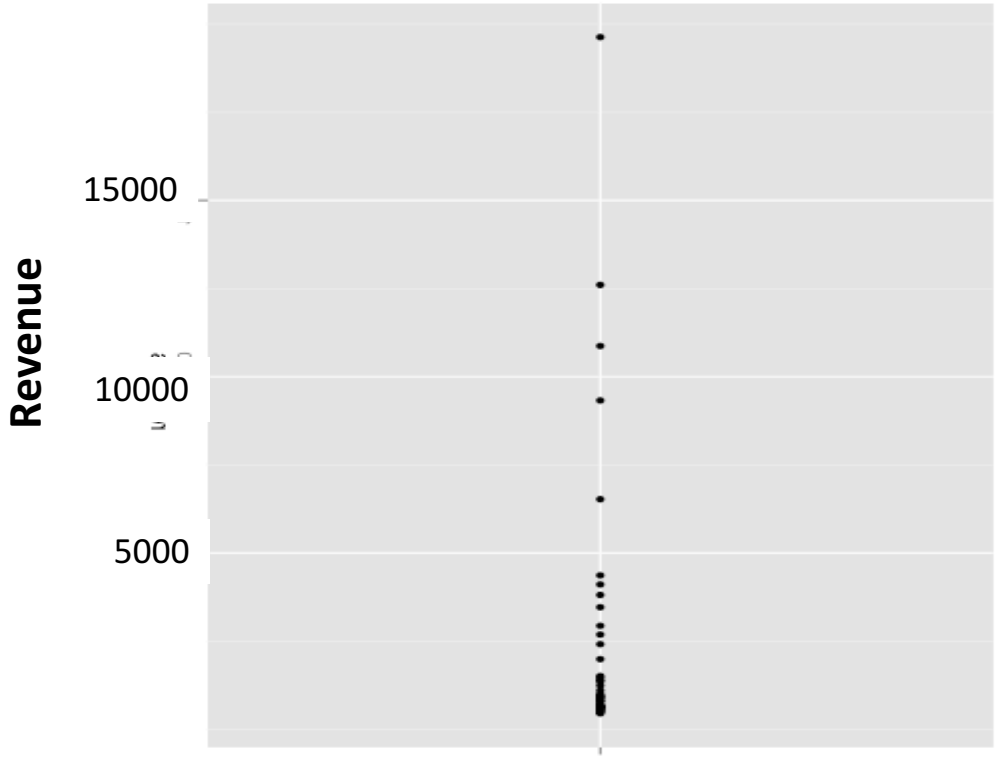
Single Variable

- Dot plot
- Jitter plot
- Error bar plot
- Box plot
- Histogram
- Kernel density estimate
- Cumulative distribution function

From UC Berkeley "Introduction to Data Science"

Dot plot

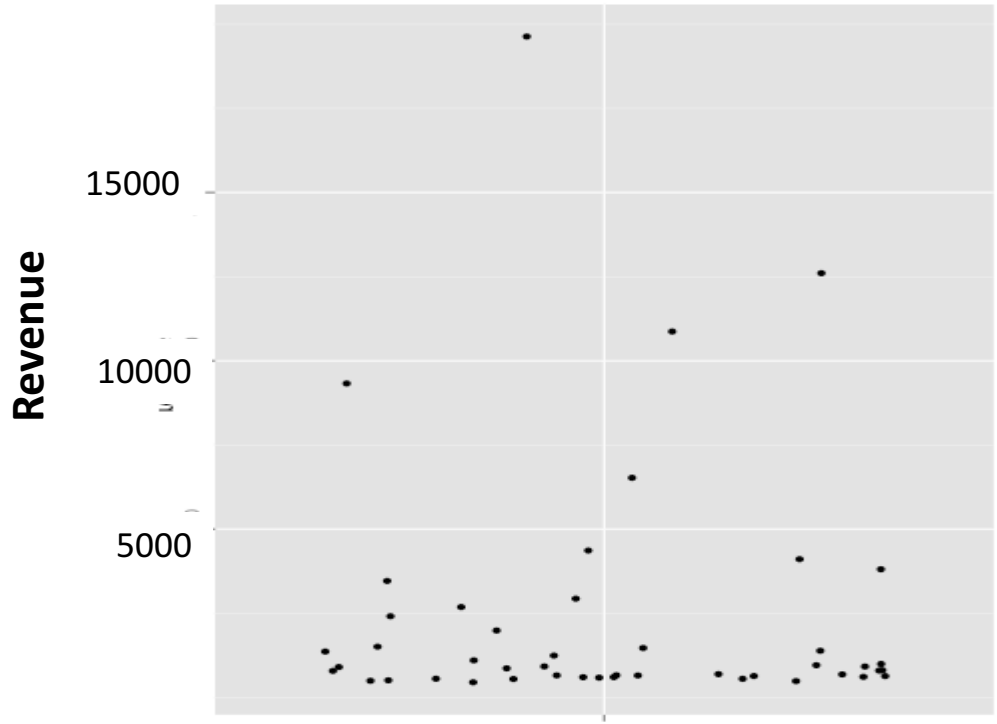
Revenue
2000
11000
5400
204944
32244
1232
…



Jitter plot

Noise added to the x-axis to spread the points

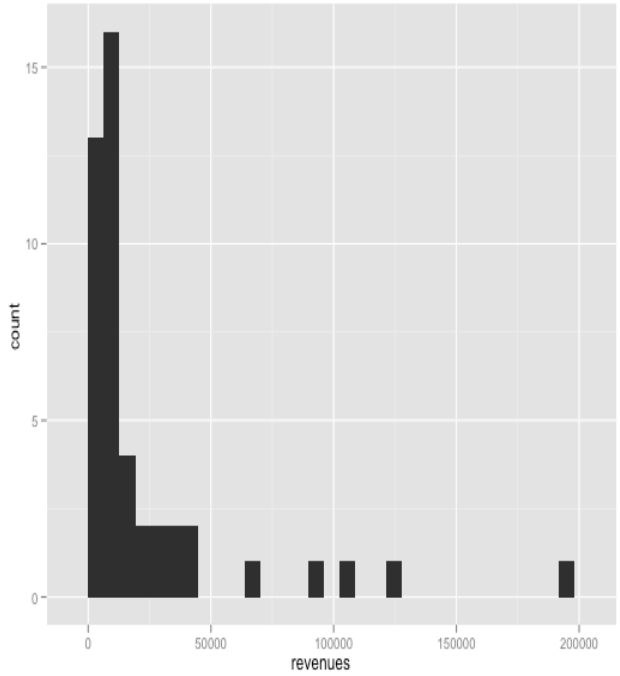
Revenue
2000
10000
5400
204944
32244
1232
…



Histogram

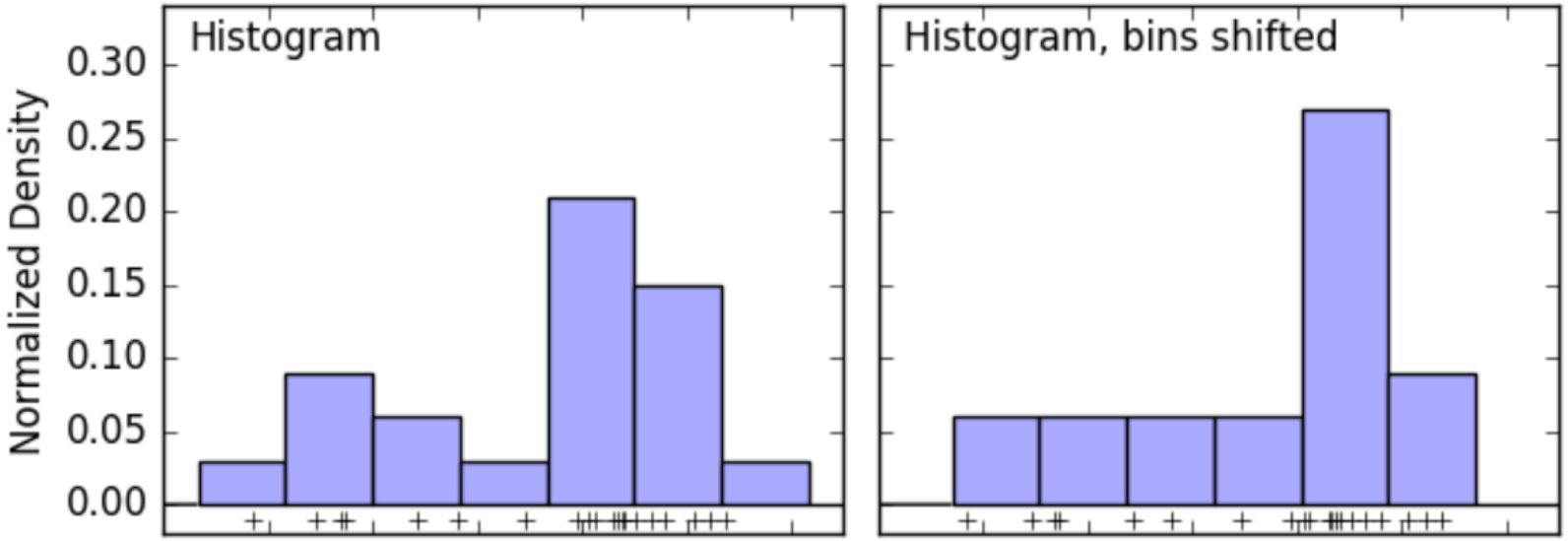
Probability Density Functions

Revenue
2000
100000
5400
204944
32244
1232
…



Limitation of Histogram

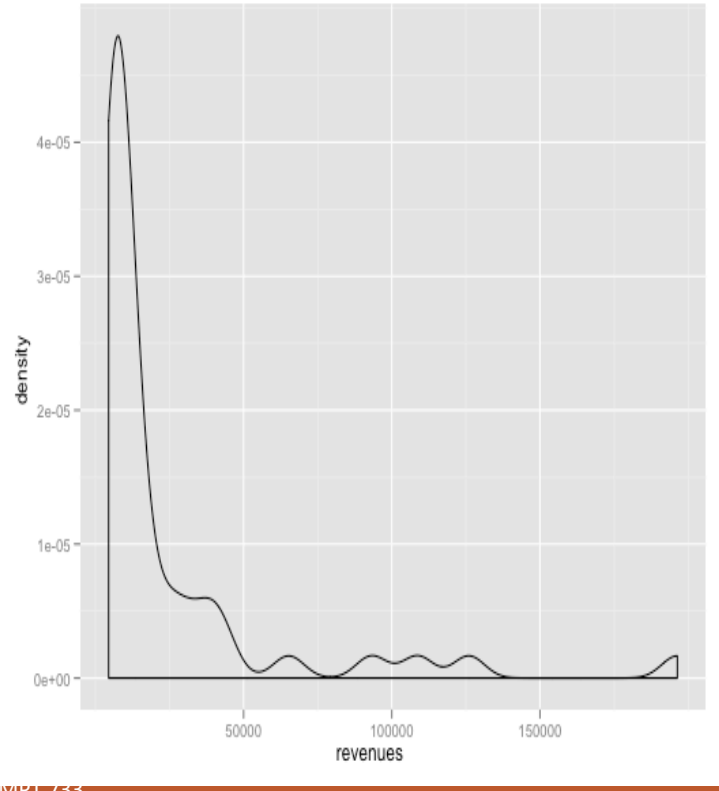
The choice of binning can have a big effect on the resulting visualization



Solution 1: Kernel density estimate

Like a smooth histogram

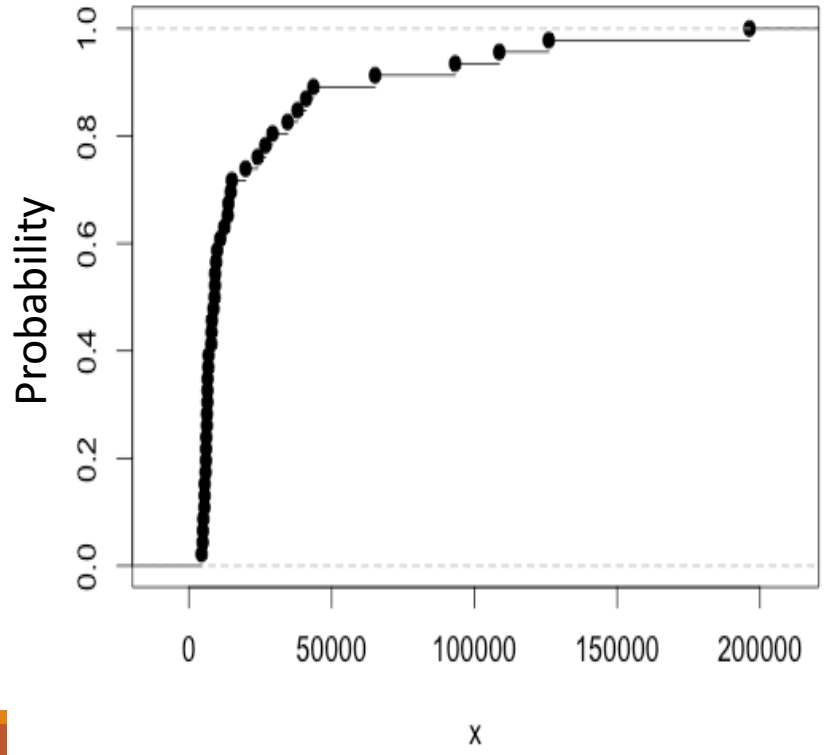
Revenue
2000
10000
5400
204944
32244
1232
…



Solution 2: Cumulative distribution function

Integral of the histogram

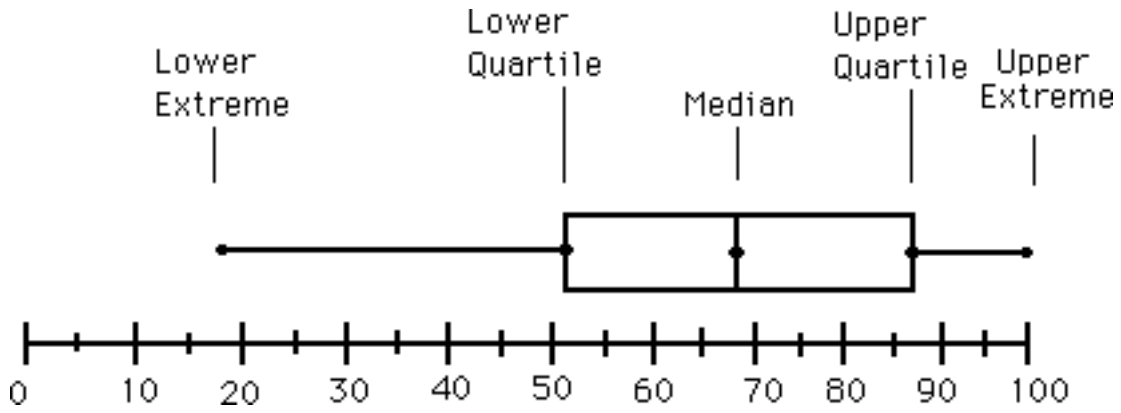
Revenue
2000
10000
5400
204944
32244
1232
…



Box Plot

A graphical form of 5-number summary

- Min, 25% Quartile, Median, 75% Quartile, Max

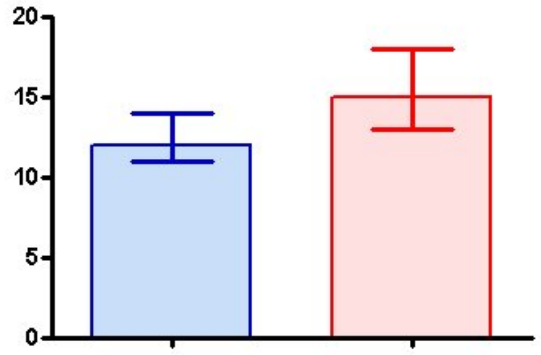


Error Bars

Usually based on confidence intervals (CI).

95% CI means 95% *of points are in the range*

Not necessarily symmetric



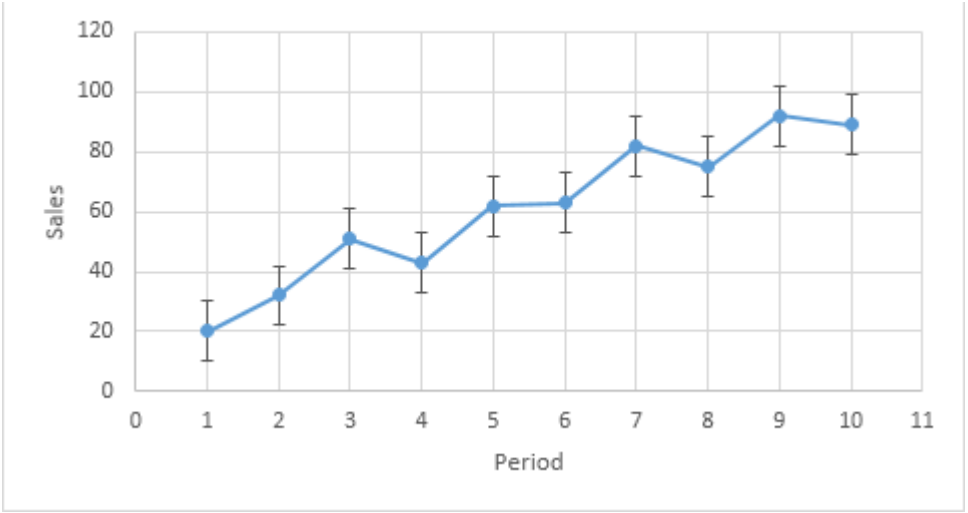


Chart Types

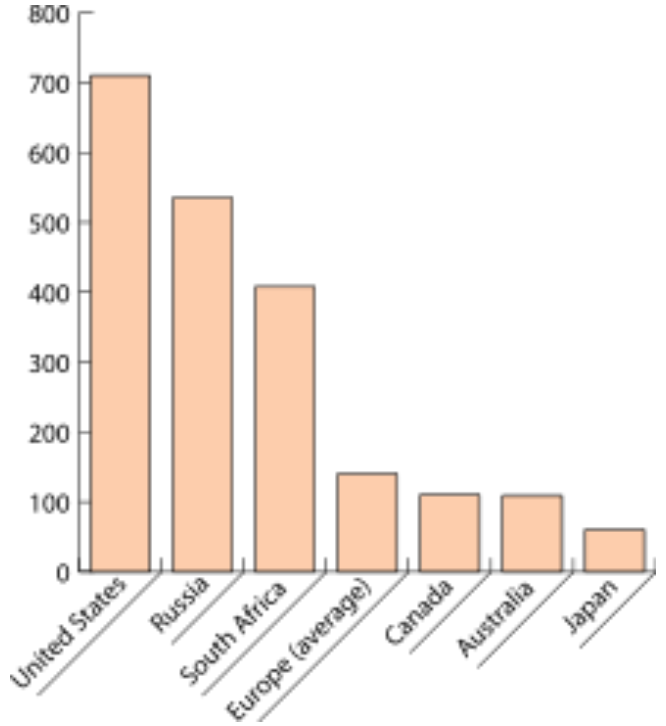
Two or more variables

- Bar chart
- Scatter plot
- Line plot
- See more at https://pandas.pydata.org/pandas-docs/stable/visualization.html#plotting-tools

Bar Plot

One variable is categorical

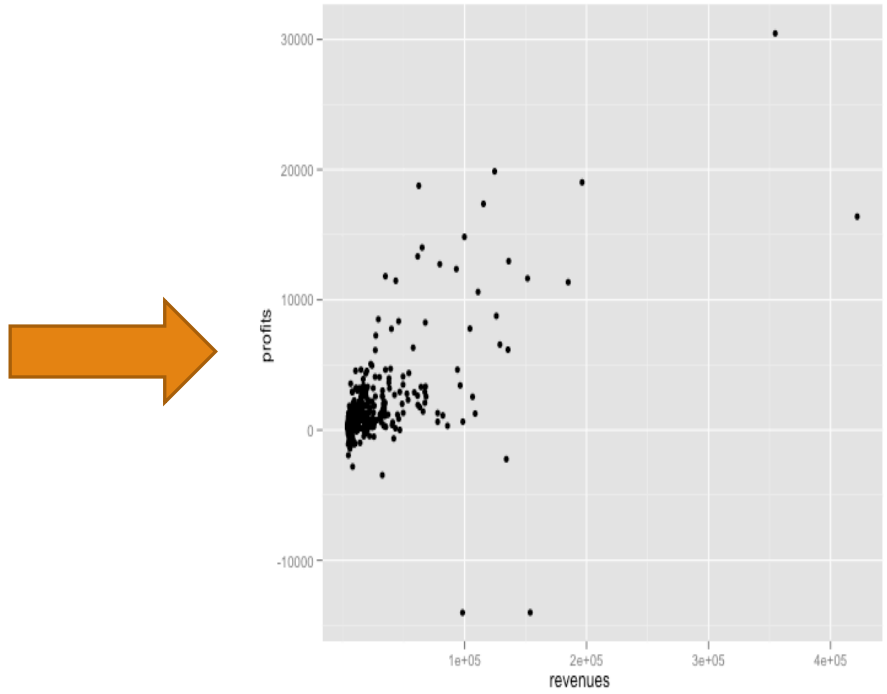
Region	Revenue
US	720
Russian	540
South Africa	400
Canada	120
	…



Scatter Plot

Variables are both numerical

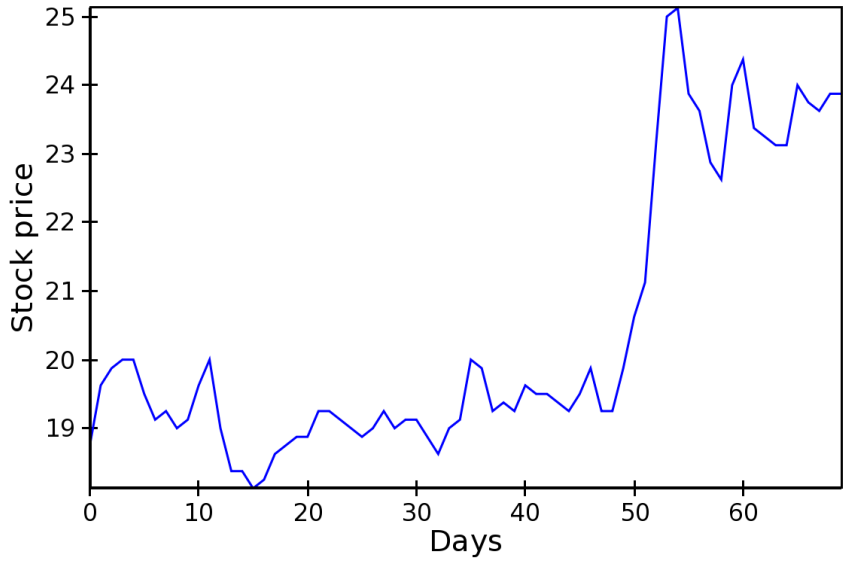
Revenue	Profit
20000	1000
45000	450
50234	-200
34522	900
	…



Line Plot

One variable is ordinal

Days	Price
1	15.34
2	17.12
3	18.56
4	19.21
…	…



Summary

Statistical Thinking

Descriptive Statistics

- Descriptive vs. Inferential Statistics
- Exploratory Data Analysis
- Chart types

Inferential Statistics

Outline

Statistical Thinking

Descriptive Statistics

Inferential Statistics

- Estimation (this lecture)
- Hypothesis Testing (next lecture)
- Regression (next lecture)

Estimation

Problem statement

- Estimate a numerical value associated with a population

Examples

- Estimate the percentage of the people in the US who will vote for Trump
- Estimate the median annual income of all households in the US

Example: Median Annual Income

How to estimate the median annual income of all households in the US?

- Randomly select 10,000 households from the US
- Report their median annual income: 50,000USD

- **BUT, we need to report something like**

50,000 ±500 USD

A Naïve Solution

- Randomly select 10,000 households from the US
- Report their median annual income

Repeat this process for 100 times

50,000 49,600 50,200 … 49,200

You have to survey 1,000,000 million households in total ☹

A Smart Solution: Bootstrapping

Key Idea: Resampling

- Sample with replacement from the original data sample

Population: 1, 1, 8, 2, … 3, 3

Sample: 3, 8, 1, 8, 3

Resample: 8, 3, 3, 3, 1

A Smart Solution: Bootstrapping

- Randomly select 10,000 households from the US
- Draw a resample from the 10,000 households
- Report the median annual income of the resample

Repeat this process for 100 times

You do NOT need to survey any new household. ☺

Notes on Bootstrapping

Start with a large random sample (at least 30)

Replicate the resampling procedure as many times as possible (more than 1000 times)

Does not work for min/max

Conclusion

Statistical Thinking

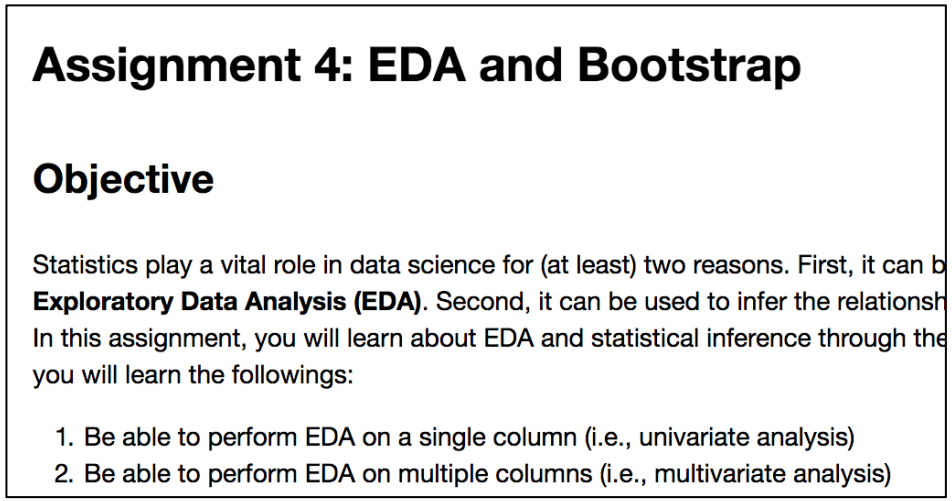
- Sample, Population and Their Connection
- With vs. Without Statistical Thinking

Descriptive Statistics

- Descriptive vs. Inferential Statistics
- Exploratory Data Analysis
- Chart types

Inferential Statistics

- Estimation and Bootstrapping



Assignment 4: EDA and Bootstrap

Objective

Statistics play a vital role in data science for (at least) two reasons. First, it can b
Exploratory Data Analysis (EDA). Second, it can be used to infer the relationsh
In this assignment, you will learn about EDA and statistical inference through the
you will learn the followings:

1. Be able to perform EDA on a single column (i.e., univariate analysis)
2. Be able to perform EDA on multiple columns (i.e., multivariate analysis)

Due next Monday

Plan for a 1–year Data Strategy

Team 1. SFU President Office

Team 2. BC Government

Team 3. Justin Trudeau Campaign Team

Team 4. Vancouver Hockey Team

Team 5. BC Children's Hospital

Team 6. Data Science Startup

Final Project

Companies

- Vancity. Property value prediction with market data
- WeRobotics. Automated Feature Detection of Aerial Imagery from South Pacific

SFU Profs

- Department of Linguistics. Topic modeling and visualization of news comments
- School of Business. Machine learning to detect misstated financial statements
- Department of Earth Sciences. A prototype Canadian Natural Hazards Database

Previous Cohorts

- Samsung Electronics Canada. Predictive Maintenance on IOT devices
- Terramera. Fall Detection using wearable sensor data
- Best Buy Canada. Predicting Soccer games and tournaments