

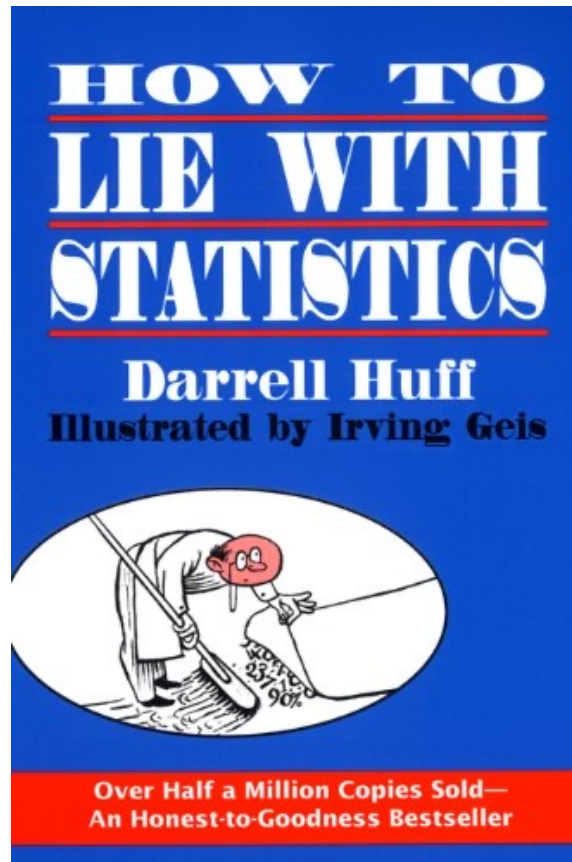
Statistics (I)

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 ”

- | | | |
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Simpson's paradox

Is UC Berkeley gender biased?

	Applicants	Admitted
Men	8442	44%
Women	4321	35%

~~YES!~~

Simpson's paradox

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

Outline

Statistical Thinking

Descriptive Statistics

Inferential Statistics

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Inferential Statistics

Statistical Thinking

1. Data is just a **sample**
2. Your 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 100 people

Without Statistical Thinking

Treat the 100 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% \pm 3%
Trump: 48% \pm 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

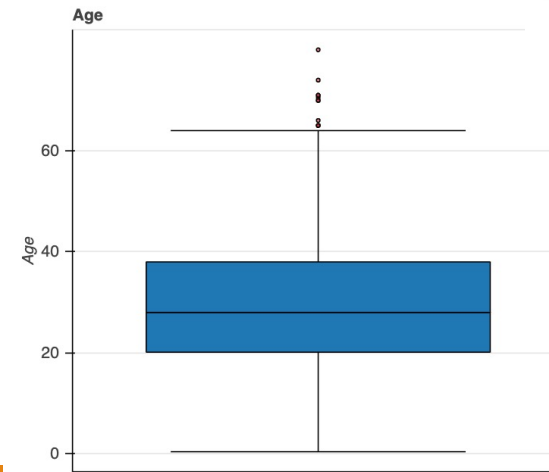
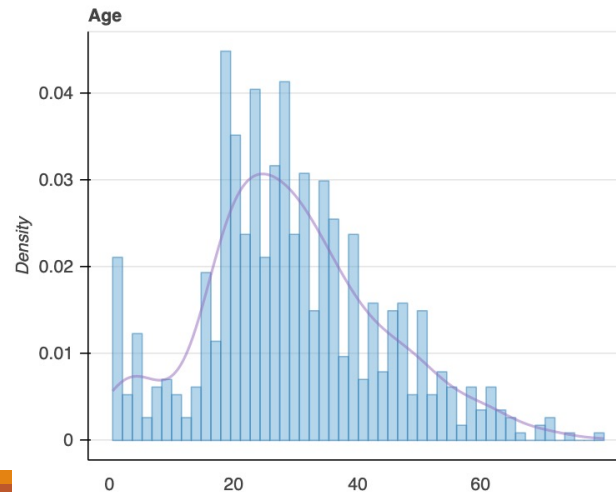
- Why? Aim to use the data (i.e., sample) to learn about a population
- How? Estimation, confidence intervals, hypotheses testing, etc.

Exploratory Data Analysis (EDA)

Understand data and discover insights
via data visualization, data summarization, etc.

Understand “Age” column

Minimum	0.42
5-th Percentile	4
Q1	20.125
Median	28
Q3	38
95-th Percentile	56
Maximum	80
Range	79.58
IQR	17.875

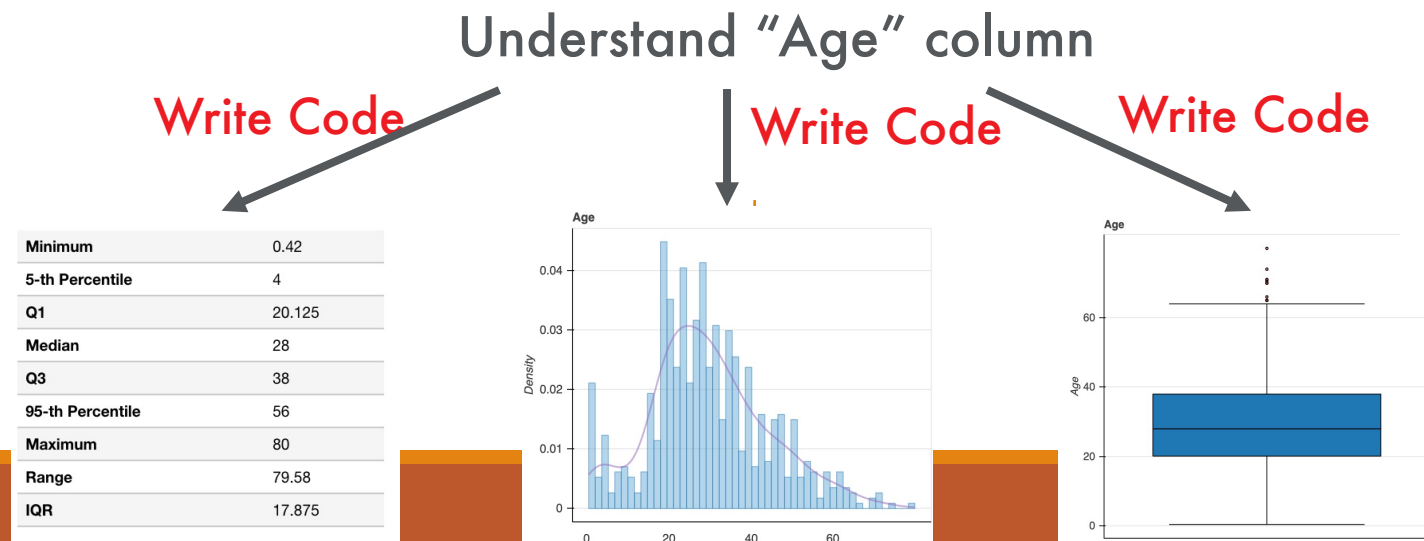


Current EDA Solutions in Python

Solution 1: Pandas + Matplotlib

☹ Hard to Use

- Beginner: Need to know how to write plotting code
- Expert: Need to write lengthy and repetitive code



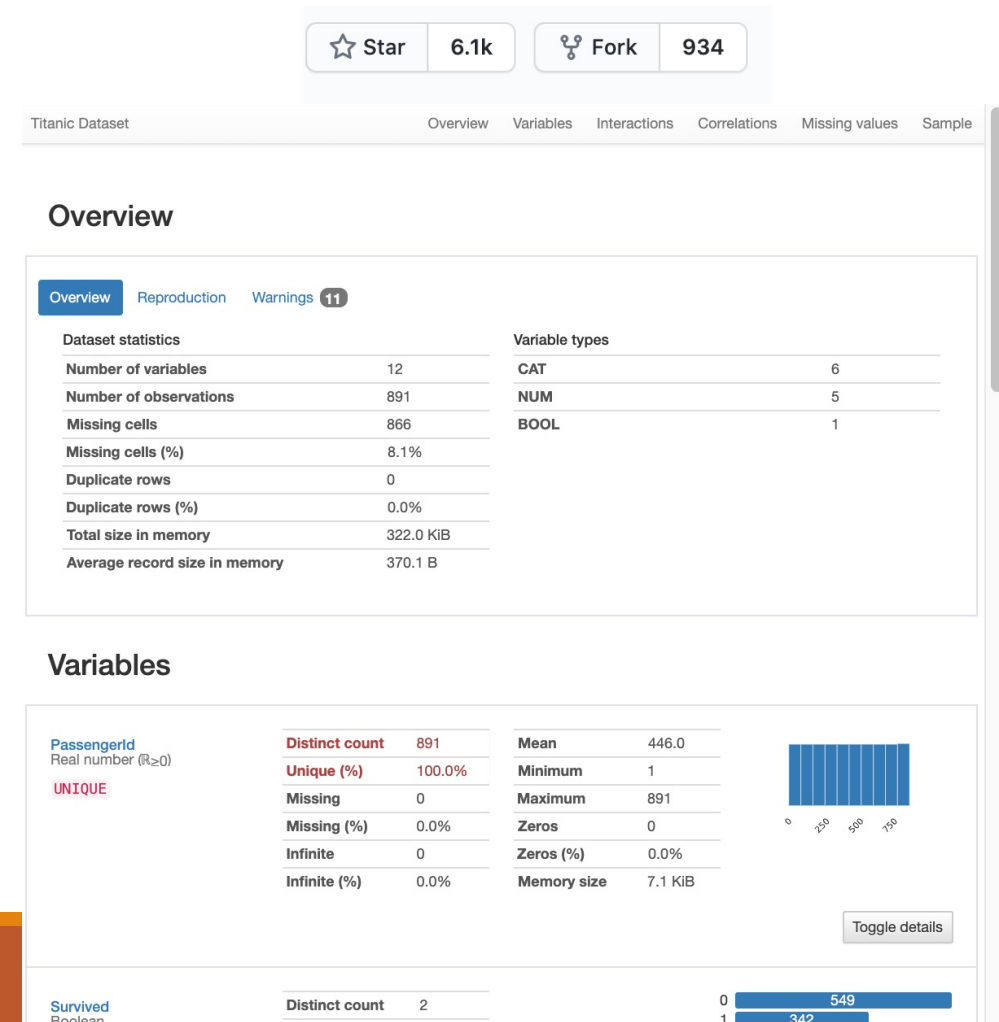
Current EDA Solutions in Python

Solution 2: Pandas-profiling










☹️ Slow

☹️ Hard to Customize

```
profile = ProfileReport(df, title="Pandas Profiling Report")
```



DataPrep.EDA Design Goals

EDA Solutions	Easy to Use	Interactive Speed	Easy to Customize
1. Pandas + Matplotlib			
2. Pandas-profiling			
3. DataPrep.EDA			

Key Idea


Task-Centric API Design

- Declarative
- Support both coarse-grained and fine-grained EDA tasks












Example

- `plot(df)`: "I want to see an overview of the dataset"
- `plot_missing(df)`: "I want to understand the missing values of the dataset"
- `plot(df, x)`: "I want to understand the column x"
- `plot(df, x, y)`: "I want to understand the relationship between x and y"
- ...

DataPrep.EDA (Demo)

jupyter DataPrep.EDA Demo Last Checkpoint: a minute ago (unsaved changes)  [Logout](#)

File Edit View Insert Cell Kernel Widgets Help Trusted Python 3

          Code 

```
In [2]: from dataprep.eda import plot, plot_missing, plot_correlation, create_report
```

```
In [ ]: import pandas as pd
```

```
In [ ]: df = pd.read_csv("titanic.csv")
```

I want an overview of the dataset

```
In [ ]: plot(df)
```

Understand Missing Value

```
In [ ]: plot_missing(df)
```

Understand Correlation

```
In [ ]: plot_correlation(df)
```

Understand Numerical Column

```
In [ ]: plot(df, "Age")
```

Understand Text Column

```
In [ ]: plot(df, "Name")
```

Understand Column Relationship

Correlation Analysis

Correlation

- It is a measure of relationship between two variables

Why is correlation analysis useful?

- For understanding data better
- For making predictions better

Case Study: How to do correlation analysis

Height and weight are correlated

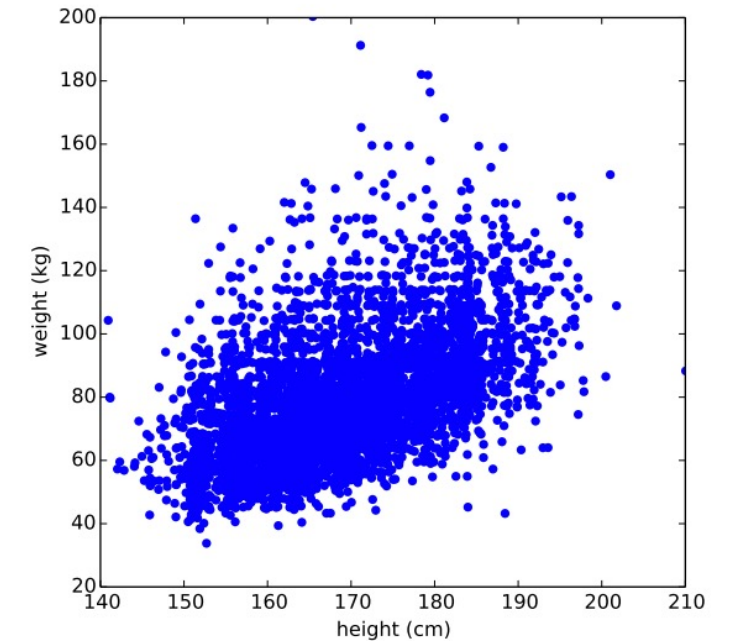
1	height	weight	age	male
2	151.765	47.8256065	63	1
3	139.7	36.4858065	63	0
4	136.525	31.864838	65	0
5	156.845	53.0419145	41	1
6	145.415	41.276872	51	0
7	163.83	62.992589	35	1
8	149.225	38.2434755	32	0

Source: *Think Stats -- Exploratory Data Analysis in Python*

Idea 1. Visualization

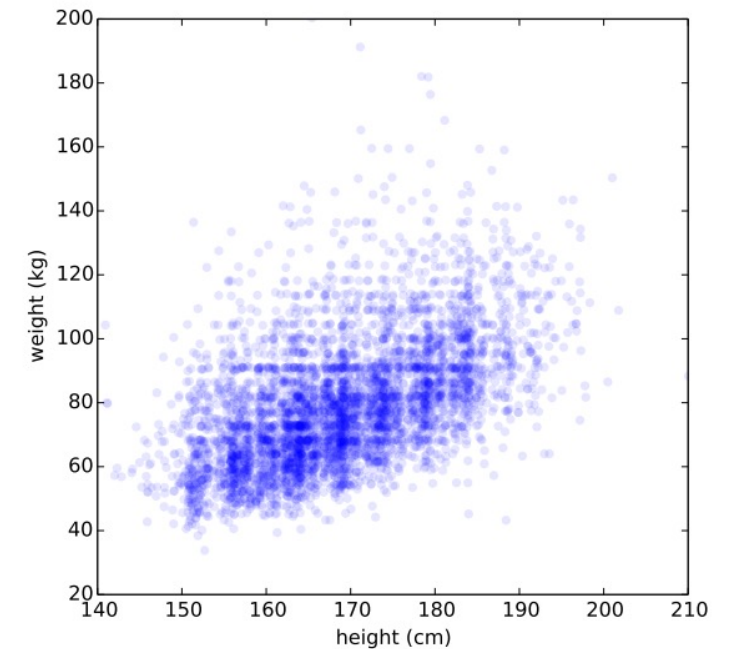
Scatter Plot

1	height	weight	age	male
2	151.765	47.8256065	63	1
3	139.7	36.4858065	63	0
4	136.525	31.864838	65	0
5	156.845	53.0419145	41	1
6	145.415	41.276872	51	0
7	163.83	62.992589	35	1
8	149.225	38.2434755	32	0



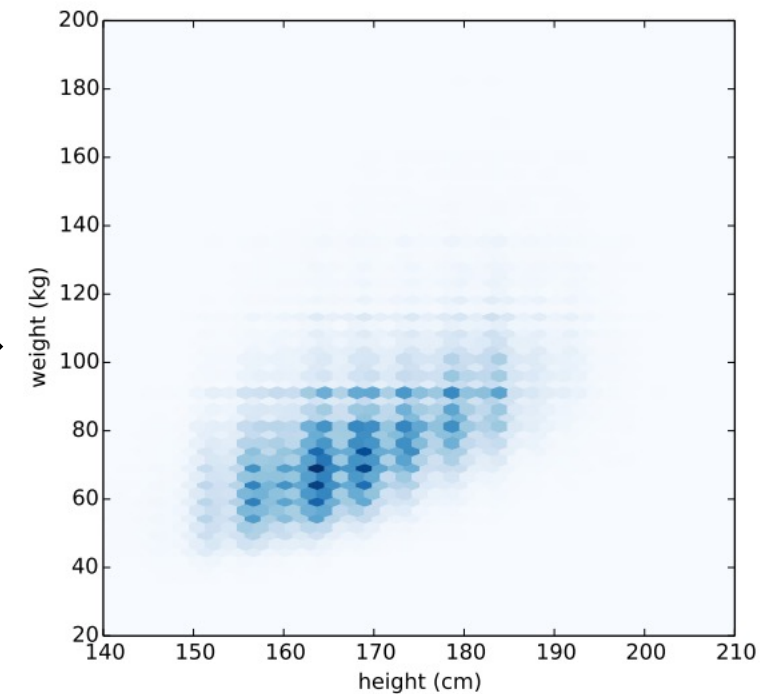
Scatter Plot (with transparency)

1	height	weight	age	male
2	151.765	47.8256065	63	1
3	139.7	36.4858065	63	0
4	136.525	31.864838	65	0
5	156.845	53.0419145	41	1
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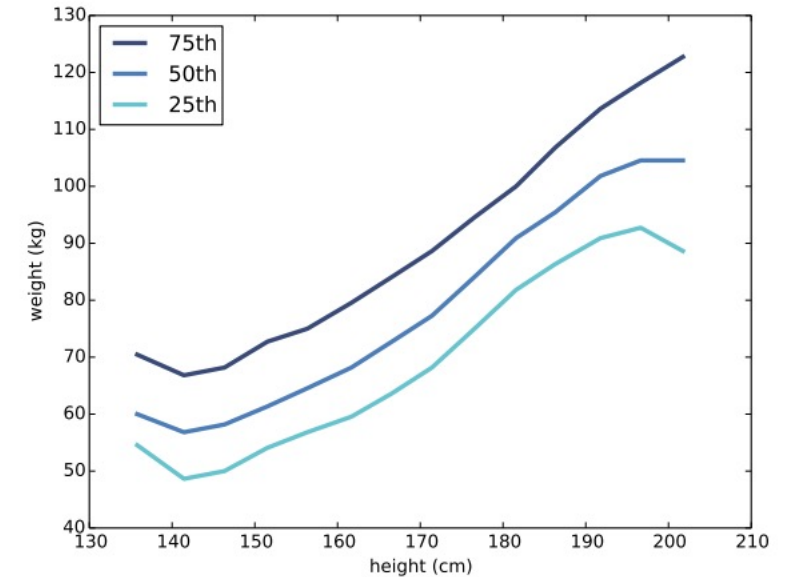
Hexbin Plot

1	height	weight	age	male
2	151.765	47.8256065	63	1
3	139.7	36.4858065	63	0
4	136.525	31.864838	65	0
5	156.845	53.0419145	41	1
6	145.415	41.276872	51	0
7	163.83	62.992589	35	1
8	149.225	38.2434755	32	0



Characterizing relationships

1	height	weight	age	male
2	151.765	47.8256065	63	1
3	139.7	36.4858065	63	0
4	136.525	31.864838	65	0
5	156.845	53.0419145	41	1
6	145.415	41.276872	51	0
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8	149.225	38.2434755	32	0



Idea 2. Correlation Coefficient

Covariance

Covariance is a measure of the **tendency** of two variables to vary together.

$$\text{cov}(X, Y) = \text{E} [(X - \text{E}[X])(Y - \text{E}[Y])]$$

$$\text{cov}(X, Y) = \text{E}[XY] - \text{E}[X] \text{E}[Y]$$

Hard to interpret
113 kilogram-centimeters

Pearson's correlation



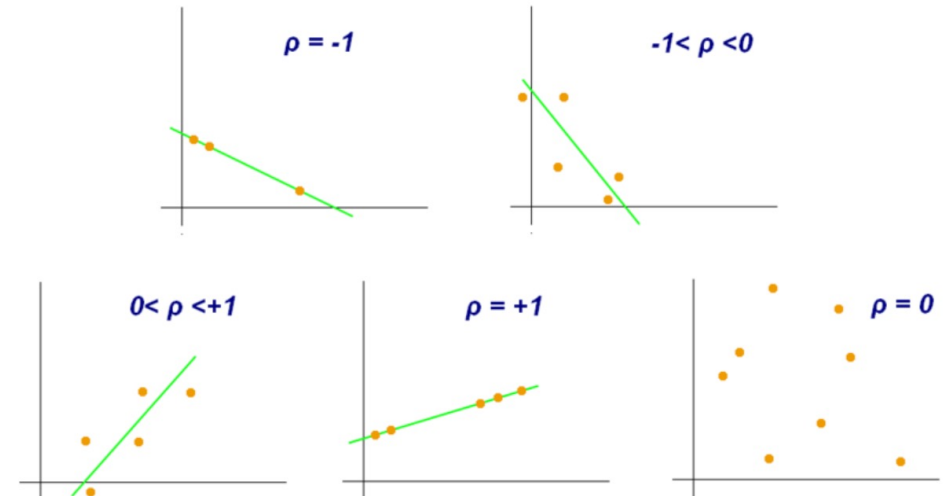
What about non-linear relationship?

Pearson's correlation is a measure of the linear relationship between two variables

$$\rho_{X,Y} = \frac{\text{cov}(X, Y)}{\sigma_X \sigma_Y}$$

Easy to Interpret

- $[-1, 0) \rightarrow$ Negative Correlated
- $(0, +1] \rightarrow$ Positive Correlated
- -1 or $+1 \rightarrow$ Perfectly Correlated



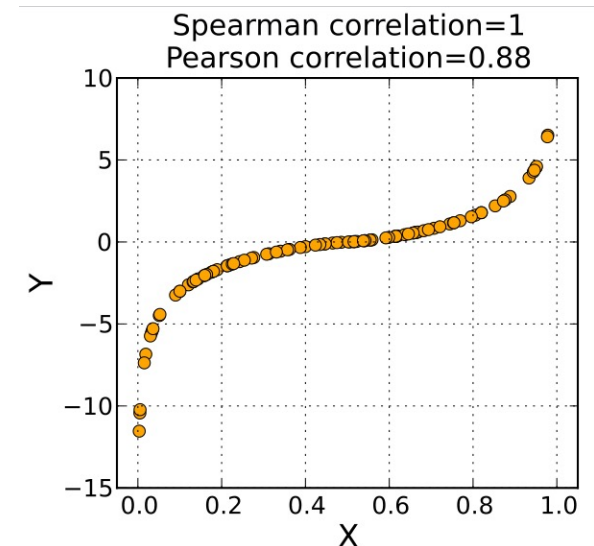
Spearman's rank correlation

Spearman's rank correlation is a measure of monotonic relationship between two variables

$$r_s = \rho_{r_X, r_Y} = \frac{\text{cov}(r_X, r_Y)}{\sigma_{r_X} \sigma_{r_Y}}$$

Advantages

- Mitigate the effect of outliers
- Mitigate the effect of skewed distributions



Summary

Statistical Thinking

Descriptive Statistics

- Descriptive vs. Inferential Statistics
- Exploratory Data Analysis with DataPrep
- Correlation Analysis

Inferential Statistics

Outline

Statistical Thinking

Descriptive Statistics

Inferential Statistics

- Estimation

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 Biden
- 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 \pm 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
- EDA with DataPrep.eda
- Correlation Analysis

Inferential Statistics

- Estimation and Bootstrapping