foundations of data science for everyone

I: what is data science and working environment

dr.federica bianco | *fbb.space* |  *fedhere* |  *fedhere*

1 what is data science

2 the scientific method

epistemology

- falsifiability
- probabilistic induction
- reproducibility

3 data science tools

- github
- python
- jupyter notebooks
- google colab
- stackoverflow

python™

stackoverflow

this slide deck

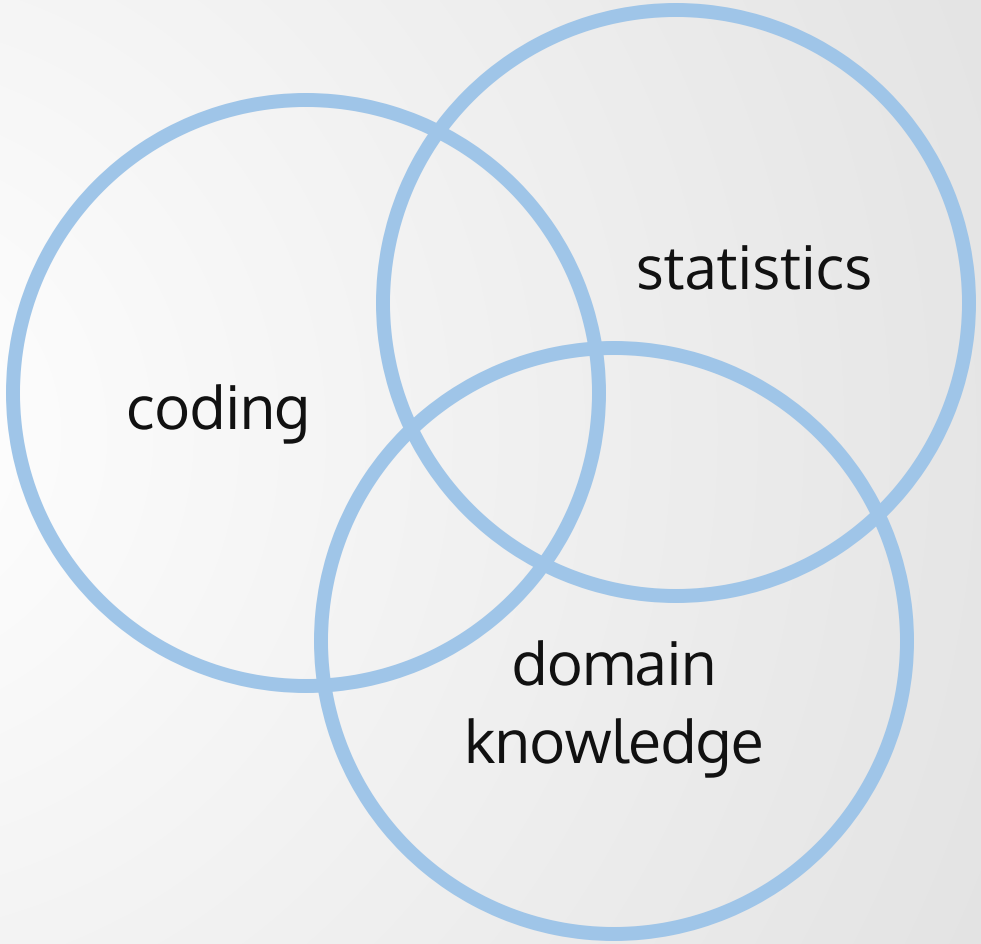
https://slides.com/federicabianco/fds_01

1 what is data science?

foundations of data science for everyone

Data Science: the field of studies that deals with the extraction of information from data within a domain context to enable interpretation and prediction of phenomena.

This includes development and application of statistical tools and machine learning and AI methods



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foundations of data science for everyone

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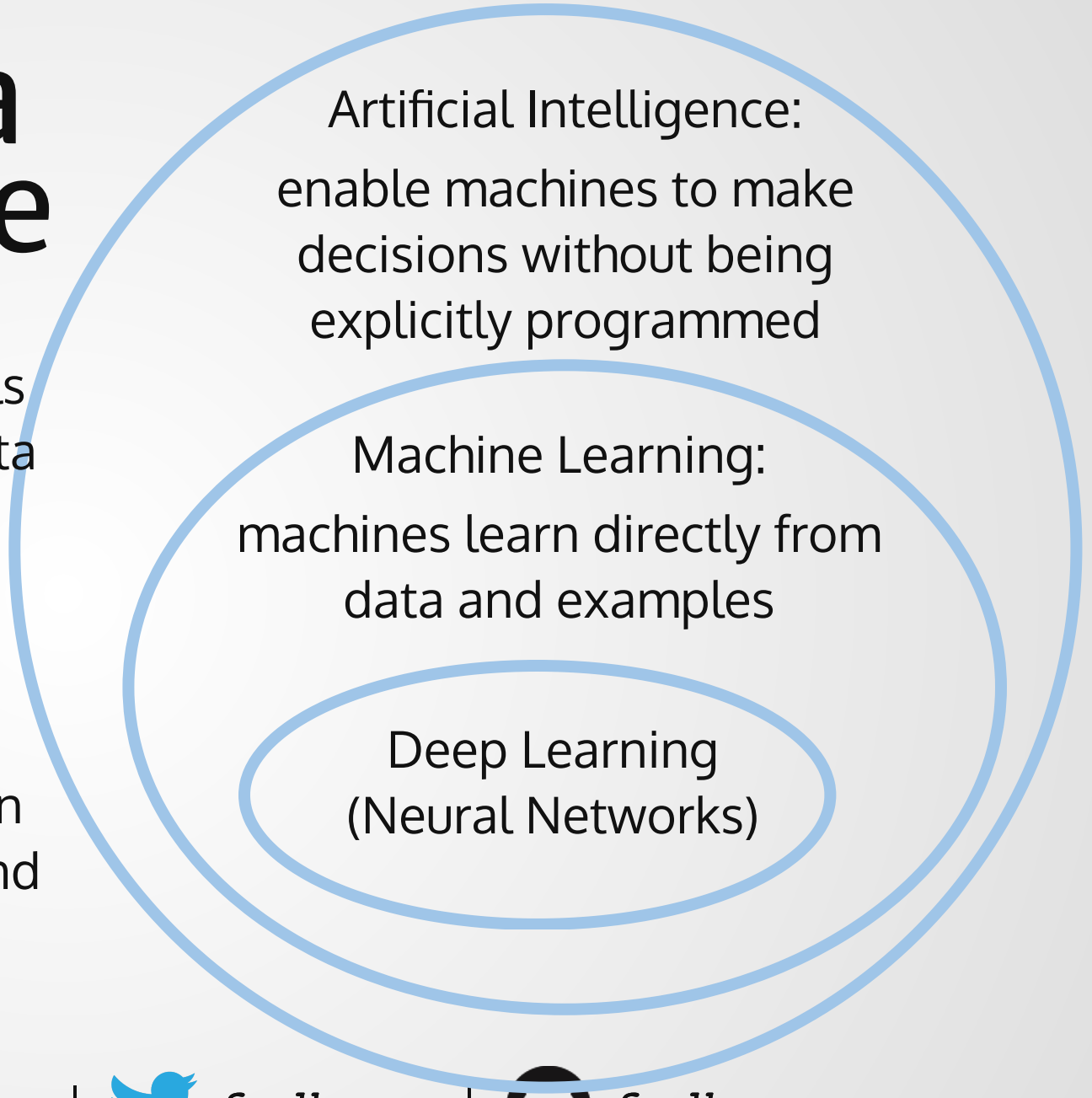

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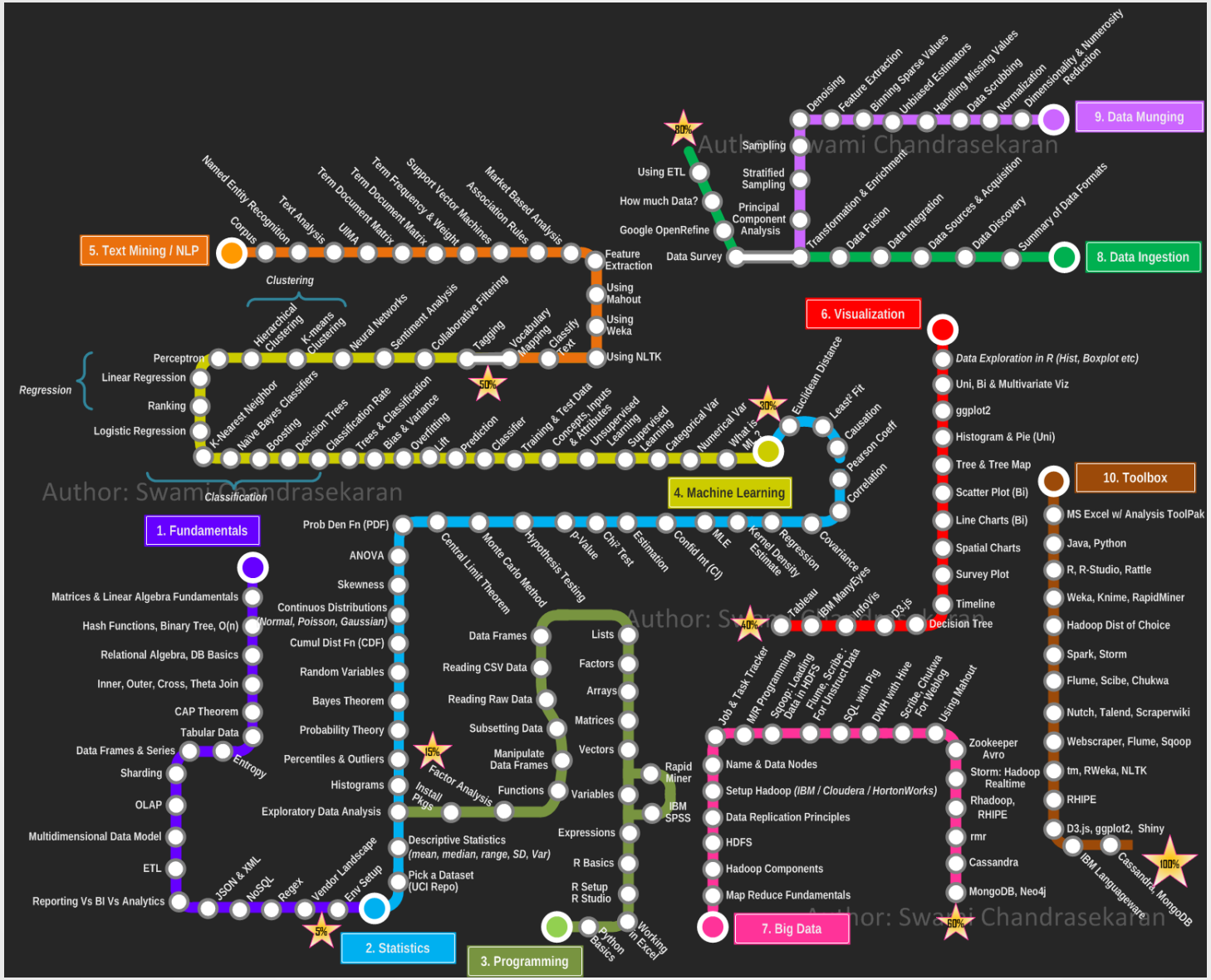
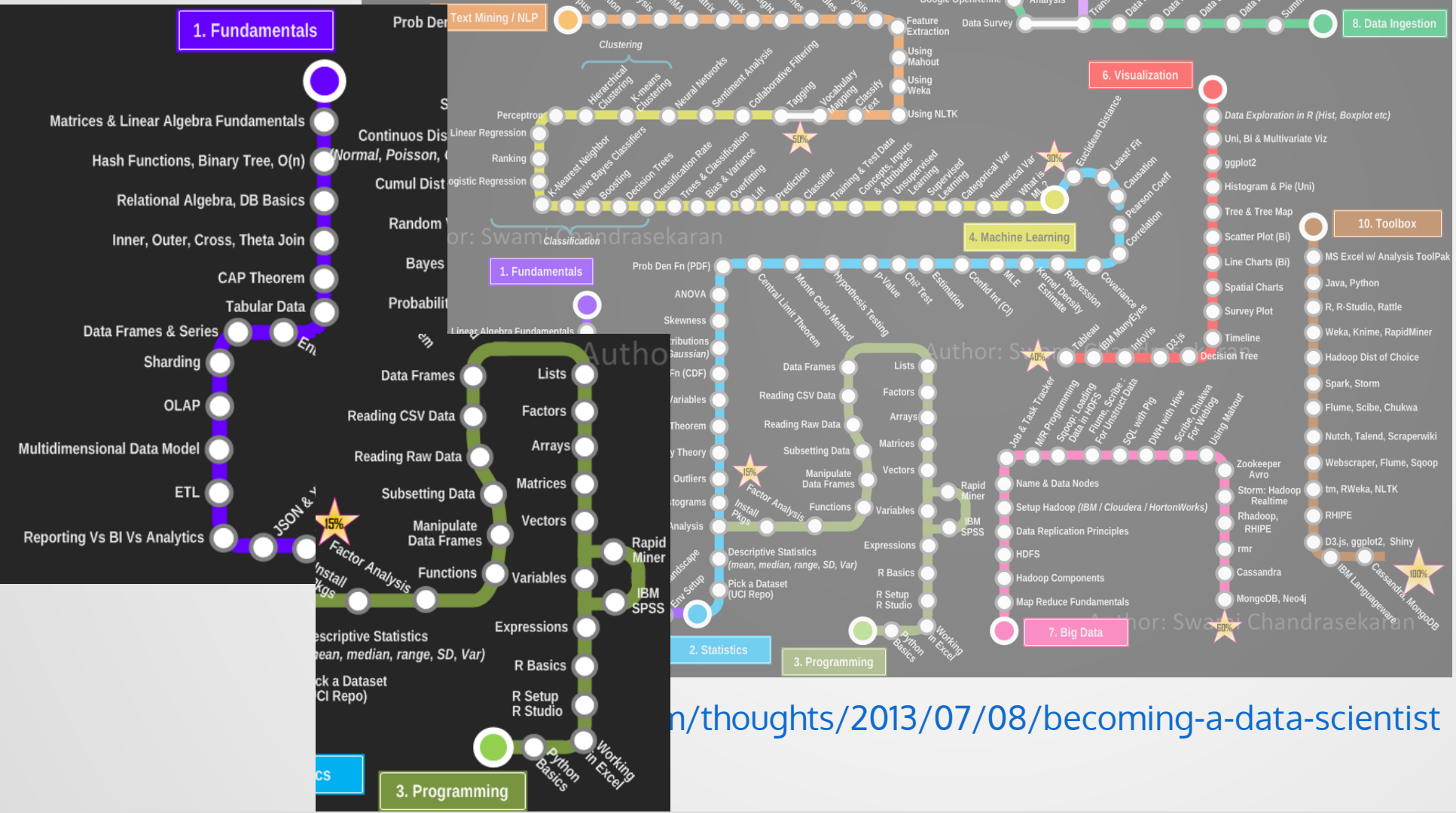


http://nirvacana.com/thoughts/2013/07/08/becoming-a-data-scientist

PROGRAMMING

STATISTICS

we will refer to this as needed



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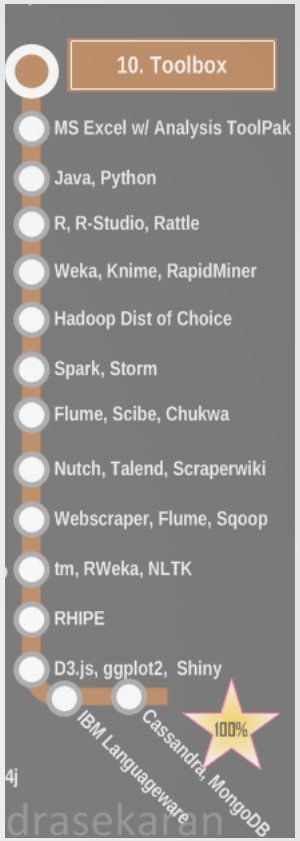

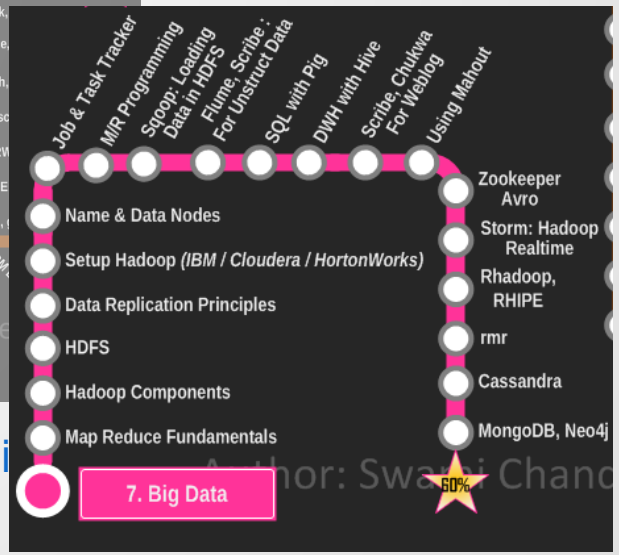

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PROGRAMMING

STATISTICS

DATA INGESTION

DATA MUNGING

NLP

MACHINE LEARNING

VISUALIZATION

http://nirvacana.com/thoughts/2013/07/08/becoming-a-data-scientist

PROGRAMMING

STATISTICS

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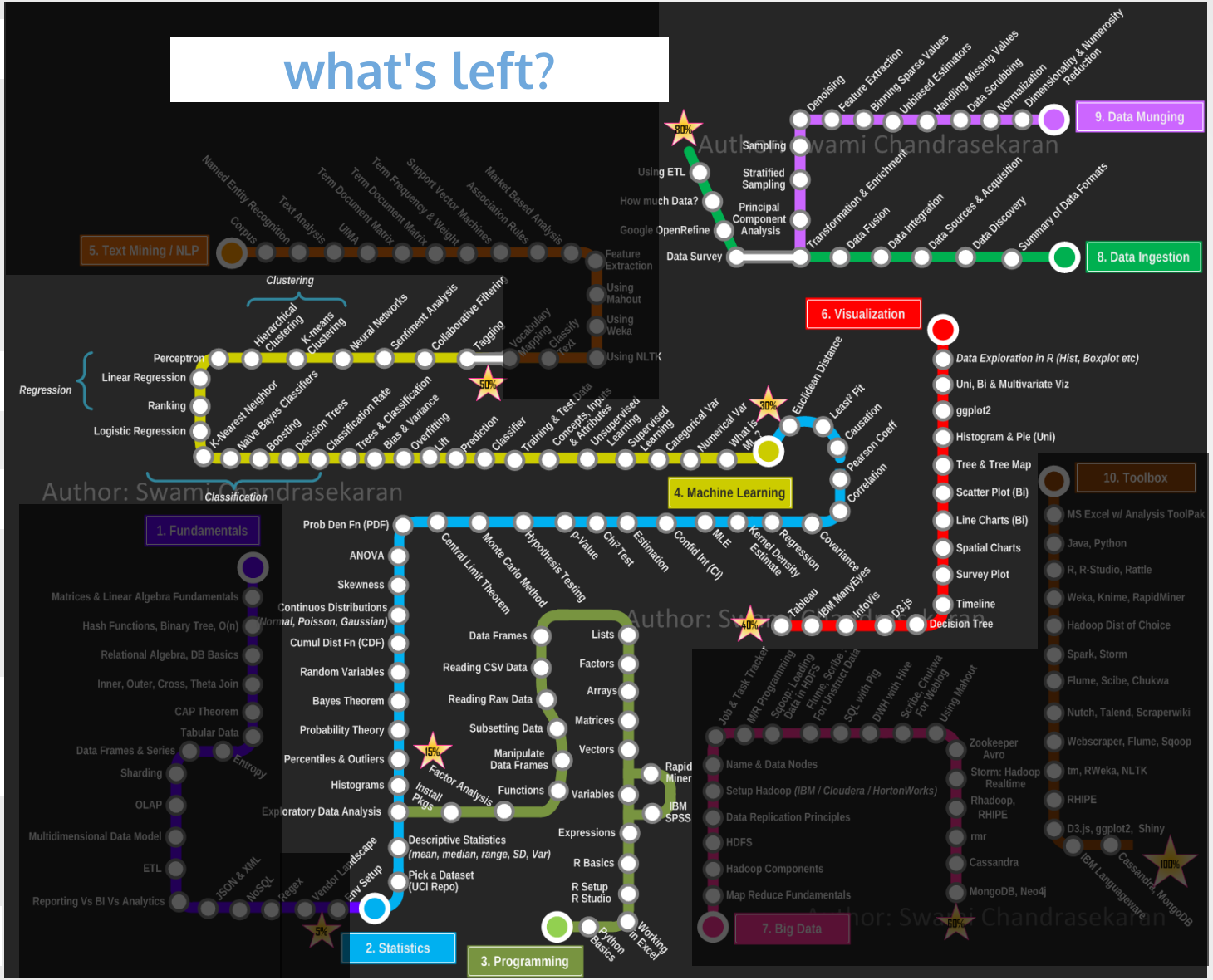

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python

probability distributions

p-values

uncertainties

PROGRAMMING

STATISTICS

DATA INGESTION

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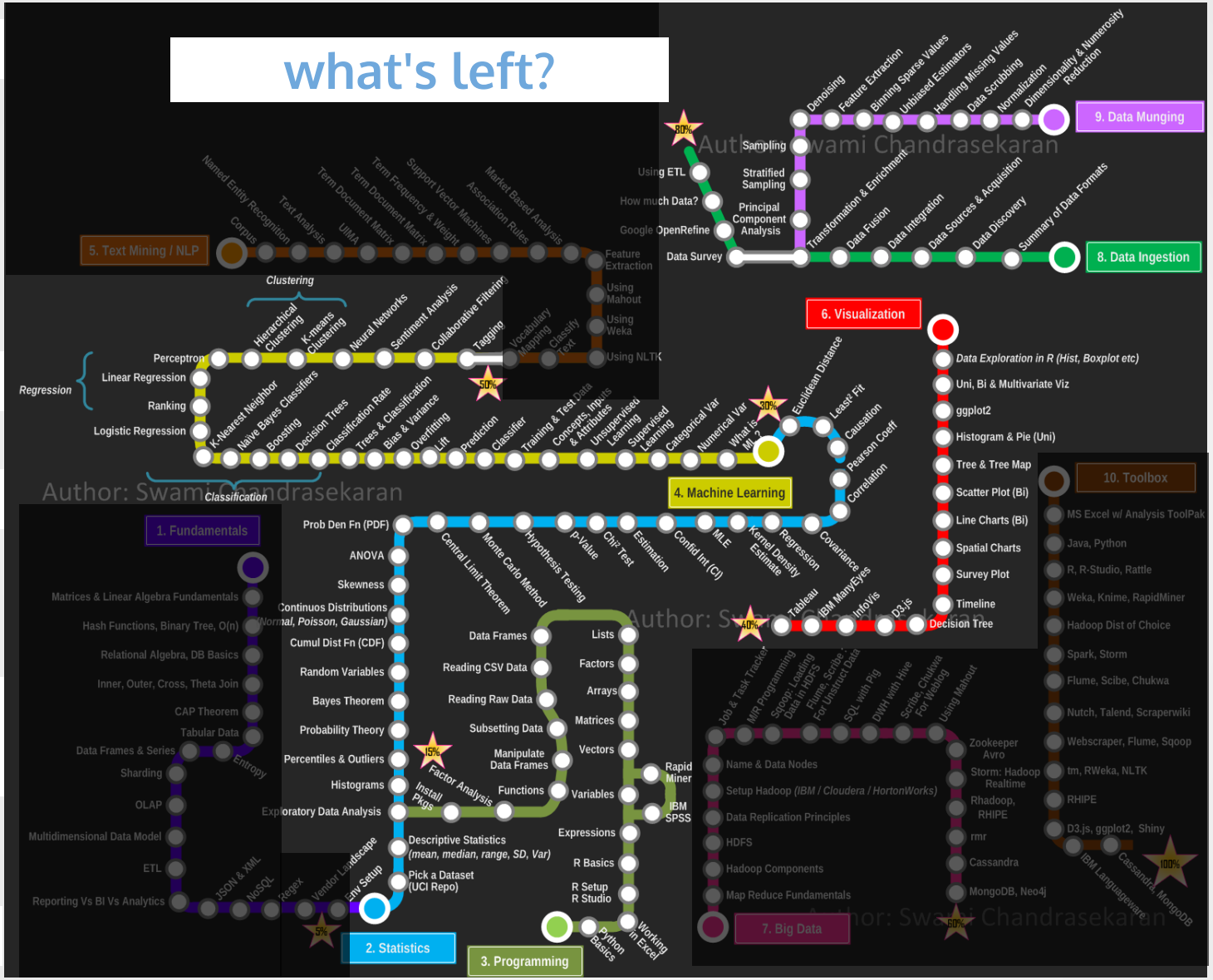
MACHINE LEARNING

VISUALIZATION



http://nirvacana.com/thoughts/2013/07/08/becoming-a-data-scientist

python

probability
distributions
p-values
uncertainties

regression
(linear, template)
classification
(trees, neural
networks)
clustering

2 some administrative stuff

Syllabus

syllabus

Learning Outcomes

By the end of this class you should be able to formulate an appropriate analysis plan for a research question, select, gather, and prepare data for analysis, and choose and apply machine learning methods to the data.

Syllabus

syllabus

- 5% pre-class questions
- 15% class participation (ask questions, contribute in breakouts!!)
- 25% homework
- 15% midterm
- 30% final

Syllabus

syllabus

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from beginning of class to 5 minutes past (be on time!)

questions on previous class material and reading assignments

Syllabus

syllabus

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- 30% final

ask questions

answer questions

get up and code

extra credit assignments

homework

- 5% pre-class questions
- 15% class participation
- **25% homework**
- **15% midterm**
- **30% final**

Please work in groups of up to 3-5 people on homework as a collaborative projects.

All members of the group are responsible for the assignment.

The assignment must be uploaded in every student's repository. Does not have to be identical for all group members, but it has to be just as complete as the one turned in

Code of Conduct

to ensure a healthy and safe collaborative environment

Code of Conduct: Diversity is considered a resource that enriches us culturally and intellectually in this class. No instances of harassment or attempts to marginalize students will be tolerated in my class. Be respectful and collaborate instead of competing. If you have concerns please come talk to me.

1) Read this: bit.ly/fdsfe_coc

2) Answer questions here: https://bit.ly/fdsfe_cocform

3) join the slack with the link you receive after finishing the form

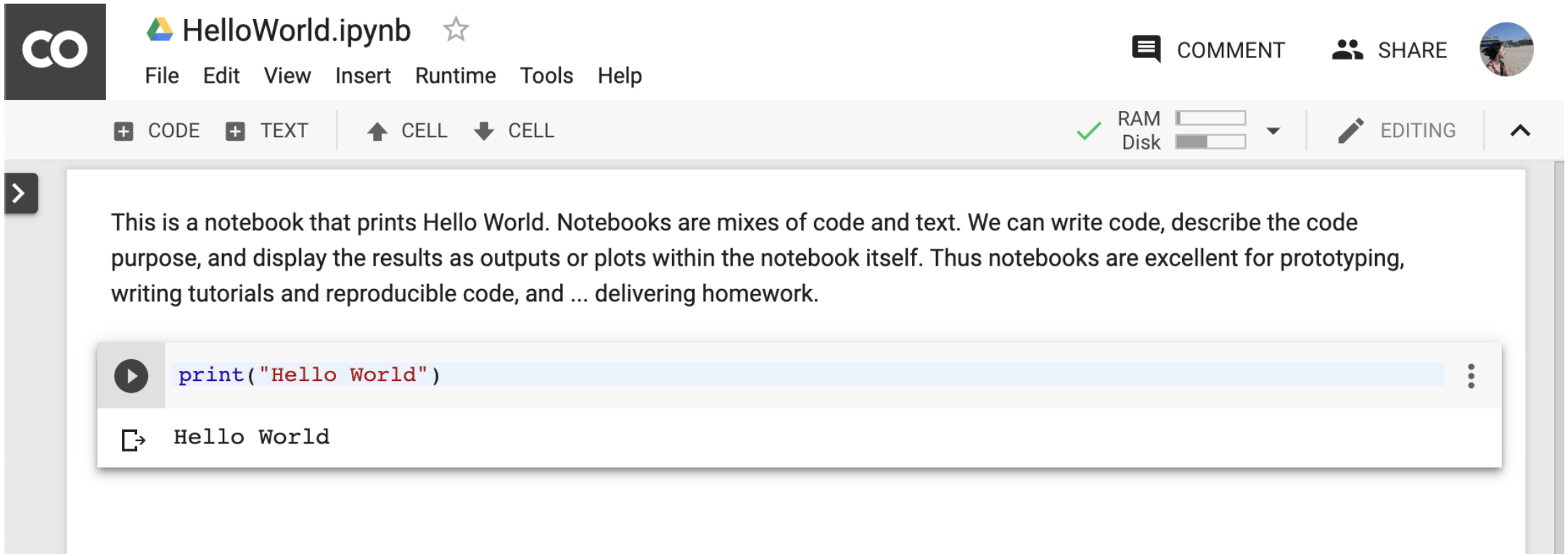
slack

3 the tools

Jupyter Notebook
Google Colaboratory

https://colab.research.google.com

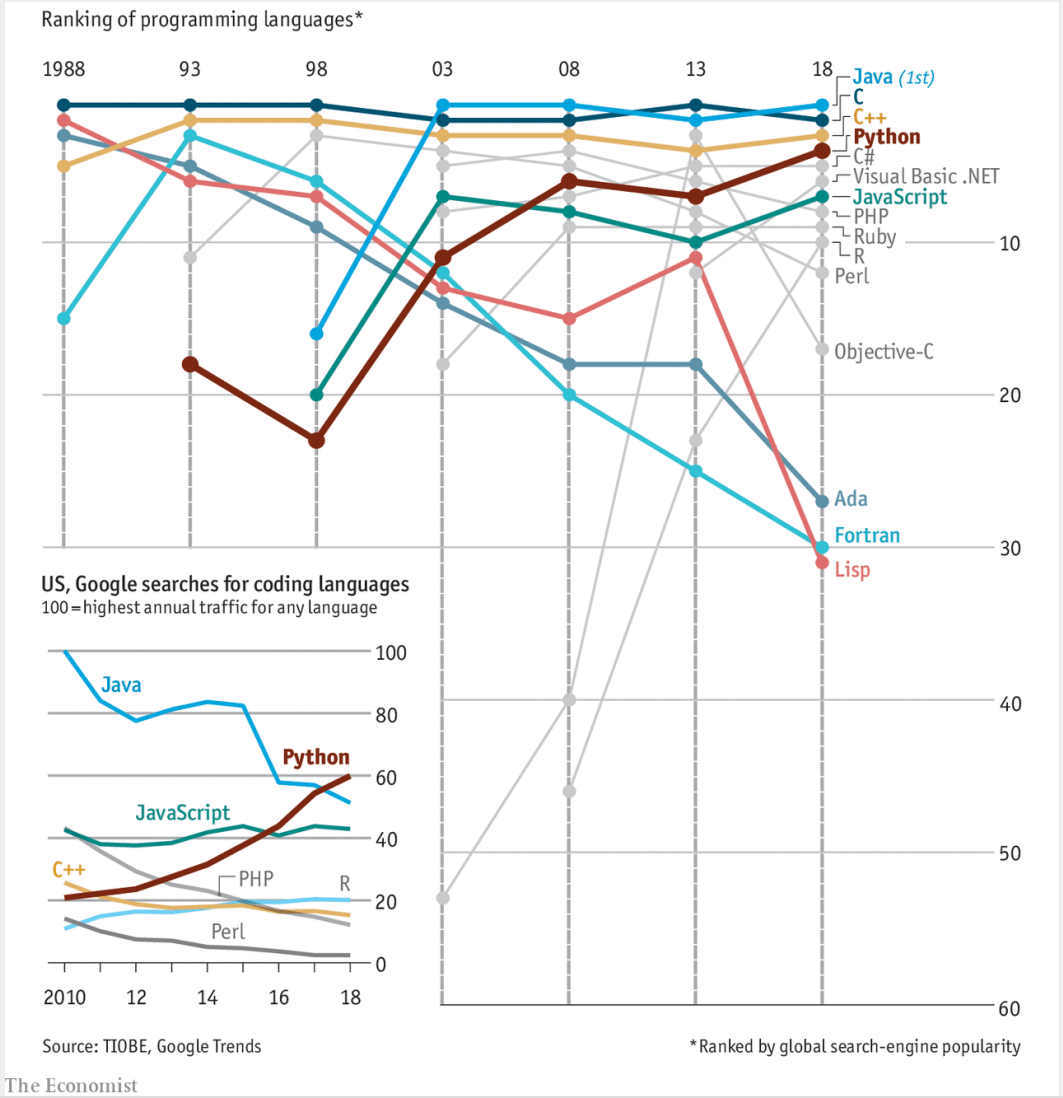
A collaborative platform for python coding



python

- intuitive and readable
- open source
- support **C** integration for performance
- packages designed for science:
  - scipy
  - statsmodels
  - numpy (computation)
  - sklearn (machine learning)

https://www.economist.com/graphic-detail/2018/07/26/python-is-becoming-the-worlds-most-popular-coding-language



python

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  - numpy (computation)
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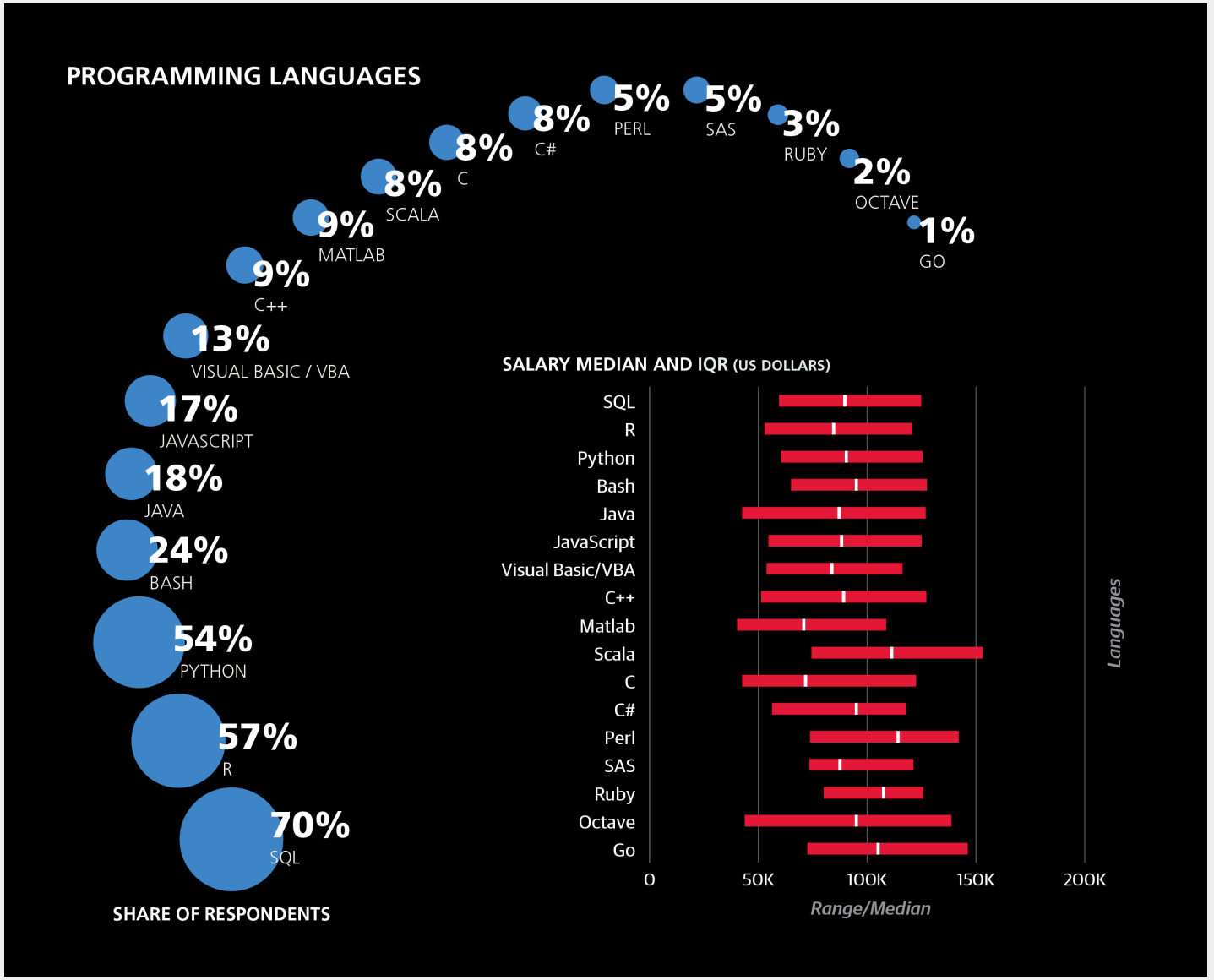
https://www.oreilly.com/ideas/2016-data-science-salary-survey-results



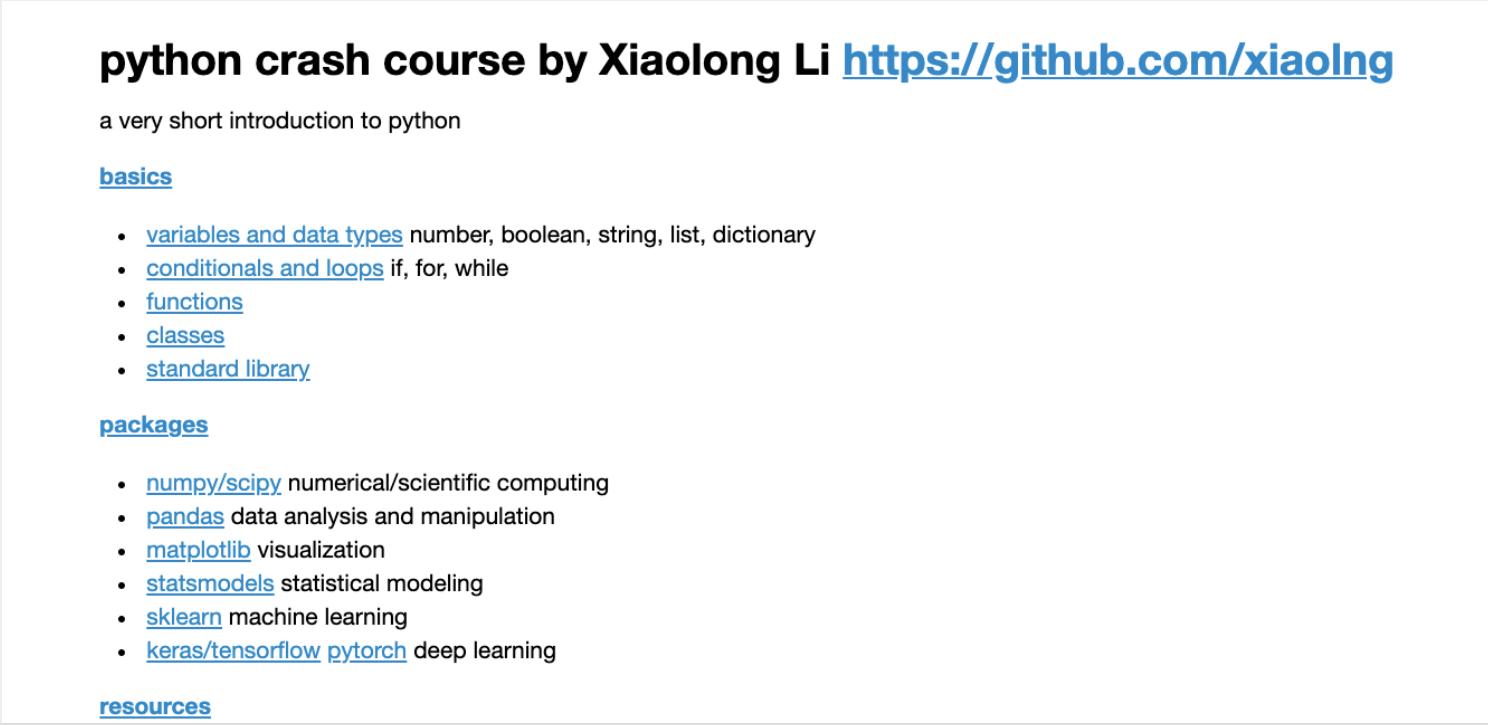
python

Resources: Notebook based

https://github.com/fedhere/FDSFE_FBianco/blob/main/pythoncrashcourse.ipynb

Most compact and rapid:

Xiaolong Li crash course



python crash course by Xiaolong Li https://github.com/xiaolng

a very short introduction to python

basics

- variables and data types number, boolean, string, list, dictionary
- conditionals and loops if, for, while
- functions
- classes
- standard library

packages

- numpy/scipy numerical/scientific computing
- pandas data analysis and manipulation
- matplotlib visualization
- statsmodels statistical modeling
- sklearn machine learning
- keras/tensorflow pytorch deep learning

resources

python

Resources: Notebook based

Slightly more comprehensive - python bootcamp

If there is demand in a couple of weeks

I will run a live session going over this bootcamp

https://github.com/fedhere/PyBOOT

Table of Contents

python

https://sharmamohit.com/work/courses/ucsl/

Resources: Notebook based

series of notebooks designed for Urban Science students by Dr. Mohit Sharma (in consultation with me)

recommanded if you are brand new to python and coding or are serious about cleaning up your foundamentals

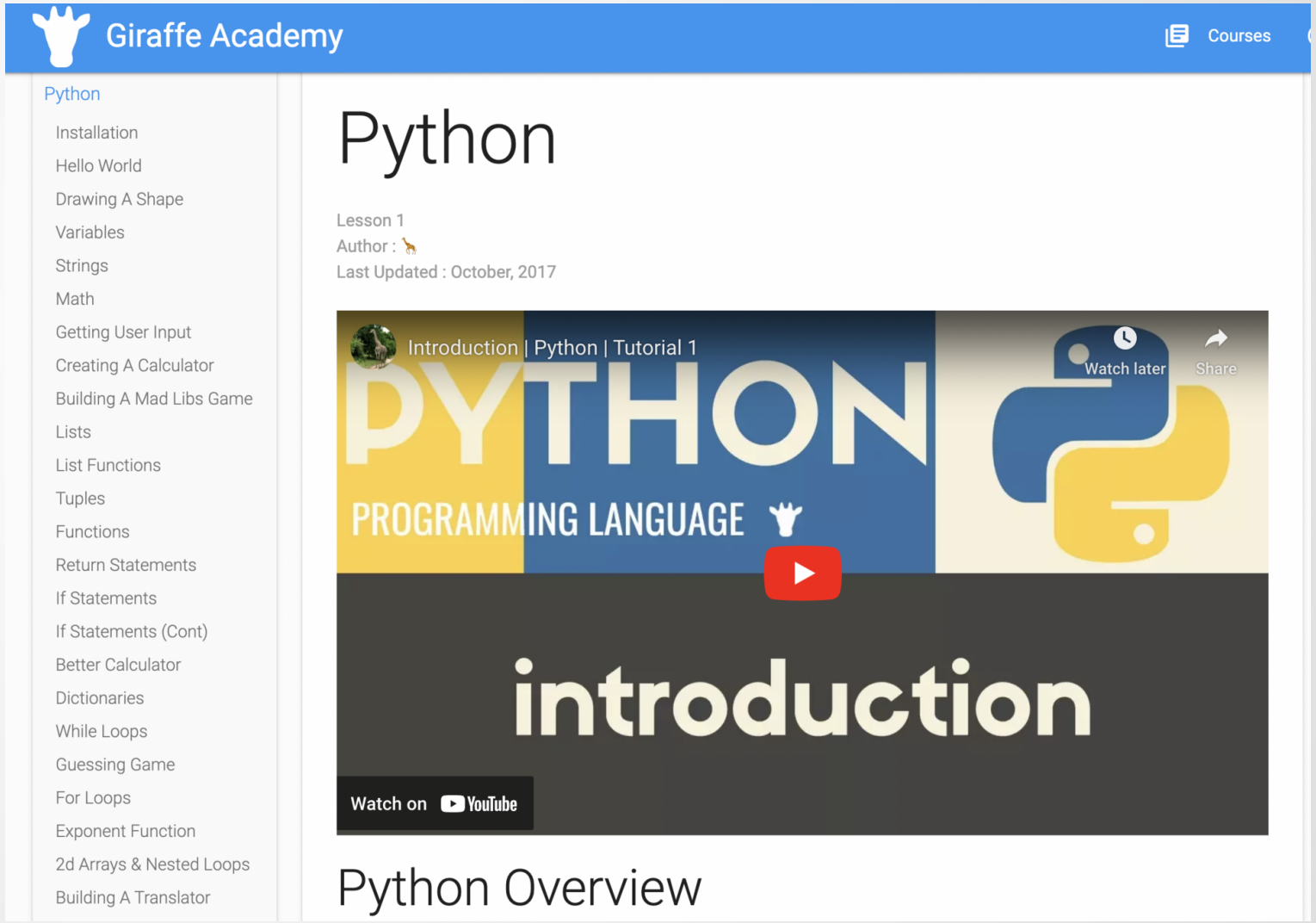
https://sharmamohit.com/work/courses/ucsl/

python

Resources: other

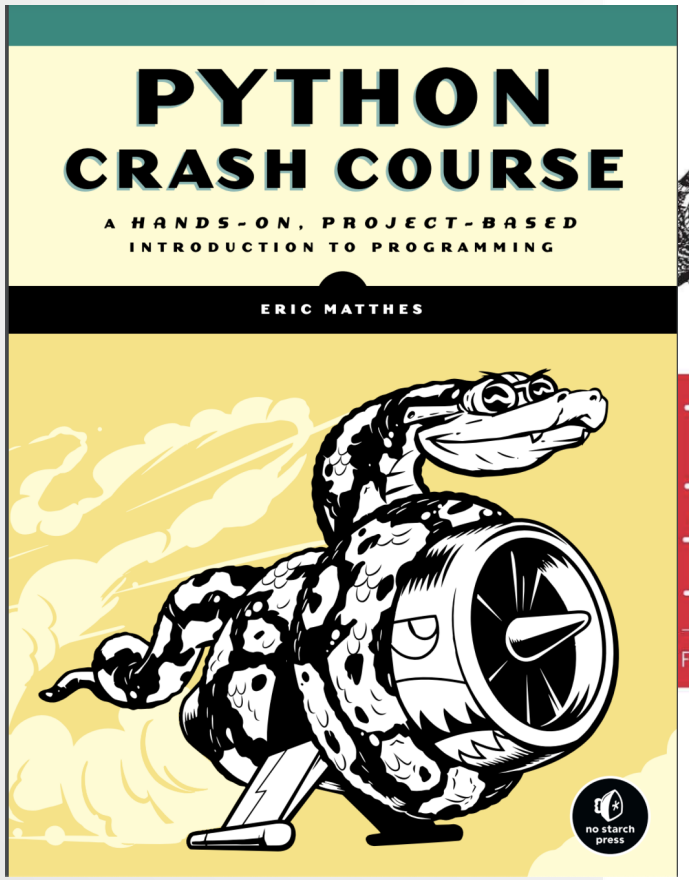
Free series of videos on the Giraffe Academy

https://www.giraffeacademy.com/programming-languages/python



Resources

many books, on *github* you can find links to the PDFs... but we will do things a bit differently



Resources

Jake Vanderplas is a physicst-data scientists

https://www.academia.edu/40917232/Python_Data_Science_Handbook

Just as before we stretched or broadcasted one value to match the shape of the other, here we've stretched *both* a and b to match a common shape, and the result is a two-dimensional array! The geometry of these examples is visualized in Figure 2-4.[1]

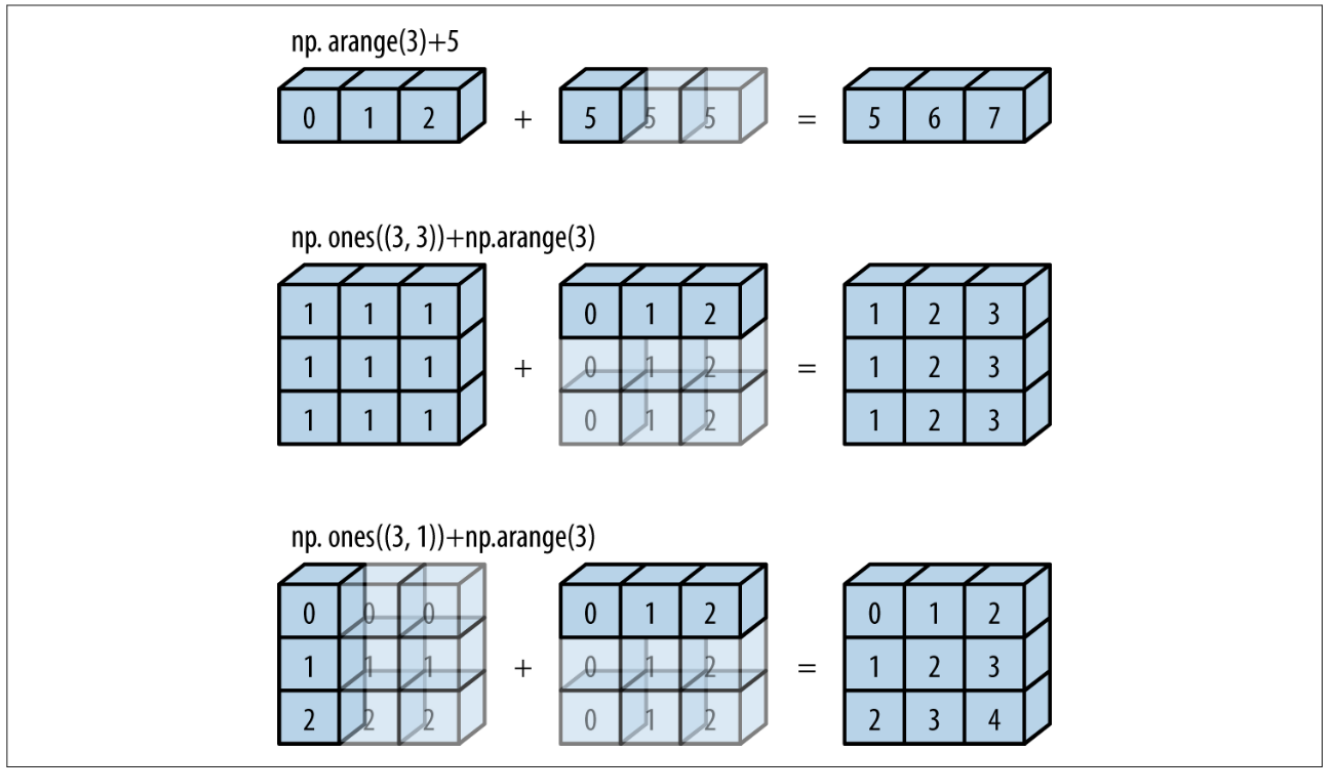


Figure 2-4. Visualization of NumPy broadcasting

python

PEP8: Python Enhancement Proposals 8

"This document gives coding conventions for the Python code comprising the standard library in the main Python distribution."

Indentation, *Tabs vs Spaces*, *Maximum Line Length*, *Blank Lines*, *Source File Encoding*, *Imports*, *Whitespace in Expressions and Statements* , *Imports*, *Comments Bookeeping*, *Naming*

github

reproducibility

https://github.com

Reproducible research means:

all numbers in a data analysis can be recalculated exactly (down to stochastic variables!) using the **code** and **raw data** provided by the analyst.

Claerbout, J. 1990,

Active Documents and Reproducible Results, Stanford Exploration Project Report, 67, 139

allows reproducibility through code distribution

github

version control

https://github.com

the Git software

is a distributed *version control system:*

a version of the files on your local computer is made also available at a central server.

The history of the files is saved remotely so that any version (that was checked in) is retrievable.

allows version control

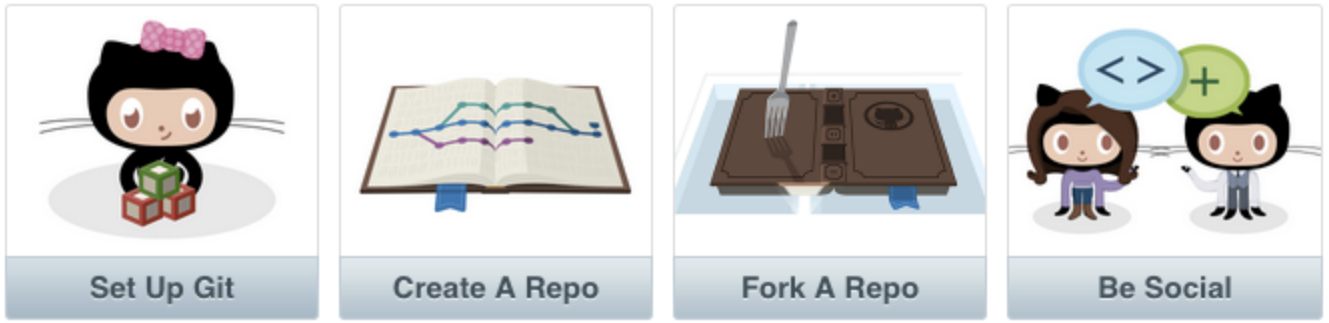
github

collaborative platform

https://github.com

collaboration tool

by fork, fork and pull request, or by working directly as a collaborator



allows effective collaboration

stackoverflow

for when you need help

https://stackoverflow.com/

you can ask coding questions, installation questions, colab questions...

How to type list comprehensions

Ask Question

0

I have the following list comprehensions in Python:

```
from typing import cast

# everything is fine
print([value for value in [1, 2, 3, 4]])

# on the first "value": Expression type contains "Any" (has type "List[Any]")
print("{}".format([value for value in [1, 2, 3, 4]]))

# on the "cast": Expression type contains "Any" (has type "List[Any]")
print("{}".format([cast(int, value) for value in [1, 2, 3, 4]]))
```

Why does using `format` cause Mypy to give me back errors? As you can see, I tried to use casting and it still failed.

This question looks similar, but my particular case is weird because Mypy seems to be fine as long as I'm not using the `format` function (yet it's always okay with the `print` function).

Is there anything I can do to not have the lines with formatting give me errors? (Or should I just `# type: ignore` them?)

python | python-3.x | list-comprehension | typing | mypy

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Multiple output regression or classifier with one (or more) parameters with Python

Ask Question

5

I wrote a simple linear regression and decision tree classifier code with Python's Scikit-learn library for predicting the outcome. It works good.

My question is, Is there a way to do this backwards, to predict the best combination of parameter values based on imputed outcome (parameters where accuracy will be the best).

Or I can ask like this, is there a classification, regression or some other type of algorithm (decision tree, SVM, KNN, logistic regression, linear regression, polynomial regression...) that can predict multiple outcomes based on one (or more) parameter/s?

I have tried to do this with putting multivariate outcome, but it shows the error:

```
ValueError: Expected 2D array, got 1D array instead:
array=[101 905 182 268 646 624 465].
Reshape your data either using array.reshape(-1, 1) if your data has a single feature
```

This is the code that I wrote for regression:

```
import pandas as pd
from sklearn import linear_model
from sklearn import tree

dic = {'par_1': [10, 30, 13, 19, 25, 33, 23],
       'par_2': [1, 3, 1, 2, 3, 3, 2],
       'outcome': [101, 905, 182, 268, 646, 624, 465]}
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stackoverflow

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it can be a toxic environment...

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```

1 some administrative stuff (cont'd)

homework

- 5% pre-class questions
- 15% class participation
- 25% homework
- 15% midterm
- 30% final

Homework projects must be turned in as *jupyter notebooks* by checking them into your github account in a DSPS_<firstinitialLastname> repo and the project directories HW<hw number> (unless otherwise stated).

<finitialLastname> is e.g. fBianco

homework

homework are assigned as skeleton notebooks with missing code

You will have to insert the code to get the correct output

You should then discuss the results you got (e.g. comment on a plot

you will be graded on

(80% of the grade)

1) rendered plots (does it show what it should)

2) plot captions (can you interpret what it shows)

2) obtaining "correct" numbers where needed

3) interpreting each result you get

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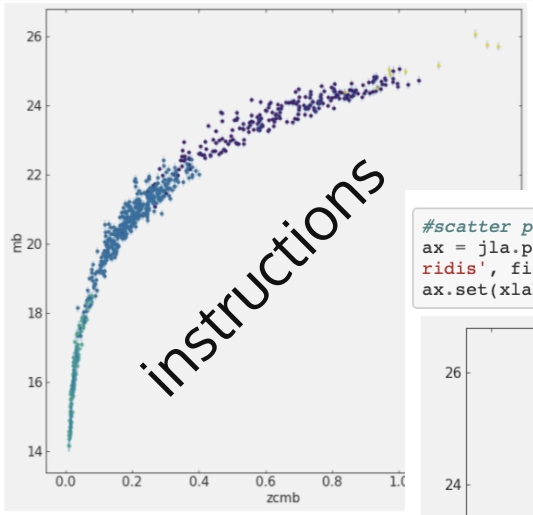
The target variables for our analysis are redshift and brightness: "zcmb" and "mb". This an exercise about fitting lines to data. Why does it lot look like there is a line relationship between them? How can does the relationship look? Plot the "zcmb" vs "mb". Include the y uncertainty which is reported in "dmb". Plot each data point with a different color based on the survey it comes from. The survey data is indicated by the variable "set". To do it you can use the dataframe plotting methods (`df.plot.scatter()`), or pylab: `pylab.scatter()`, or `pylab.plot()` --asking to plot the data as point ('.')-- but for each the way you relate the color to a column value is a bit different. Stackoverflow is your friend here!

In [0]:



It is a **power law**, which means it will be linear in logarithmic space - specif

Replot the data with natural y axis and logarithmic x axis, you can do th `df.plot.scatter()` you can use `logx=True`)

Note that when we talk about log we (generally) talk about log base 10!

```
#scatter plot of the z-shift zcmb and brightness mb of supernovaes
ax = jla.plot.scatter("zcmb","mb",yerr="dmb",s=40,c= "set",colormap='viridis', figsize=(15,15))
ax.set(xlabel='zcmb', ylabel='mb');
```

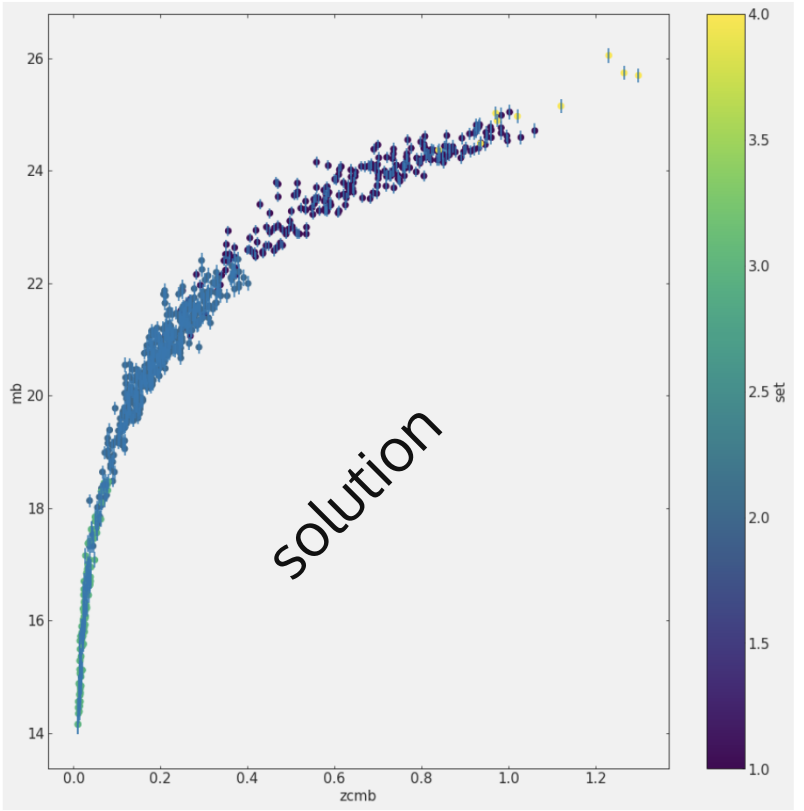


Figure 2: Supernovae brightness plotted against redshift z. Errorbars are shown for each data points. Different color of points indicate different sets of data. The plot shows power law between brightness and redshift of supernovae.

homework

A statement **must be included in the README** explaining each team member's contribution (similar to an acknowledge of contribution you would find in a *Nature* letter see, for example these contributions).

- 5% pre-class questions
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- 15% midterm
- 30% final

nature

Contributions

All authors contributed to the drafting of the paper. A.R., N.S. and R.C.S. imaged the area around η Car. A.R. and M.E.H. reduced the imaging data. H.E.B. provided images of the echoes that guided our spectroscopic pointings. J.L.P., R.C., R.J.F. and W.F. obtained the spectra and reduced them. A.R. and J.L.P. performed spectral analysis and interpretation. A.R., N.R.W. and F.B.B. performed spectral classification. F.B.B. and K.M. correlated the spectra. A.R., D.L.W. and B.S. modelled the light echo. I.T. and D.M. provided imaging of η Car. F.B.B. and D.A.H. provided the FTS images, and F.B.B. and A.R. reduced them.

homework

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Homework 4:

Data importing and formatting by Victor Ramirez and Liam Kelley.

Astronomy knowledge by Victor Ramirez. Administrative direction by Victor Ramirez

Debugging by Liam Kelley

Mathematical derivation by Shea Fitzgerald

General structure of the code by Shea Fitzgerald

README.md

Partners were Theodore Fessaras, Melvin Tejada, Samuel Matylewicz, and Desi Pilla. We all met up on Saturday to do the lab. I wrote the derivation and data ingestion part on my own the day prior, and compared with the rest of the group when we met up. Desi helped the group a lot with writing the functions. Each of us proofread and error tested his functions and gave feedback.

homework

- 5% pre-class questions
- 15% class participation
- 25% homework
- 15% midterm
- 30% final

Each student must write a README file for their repository

(20% of the points)

in the readme you must state in your own words

1. what was this homework about? relate it to what we discussed in class
2. what was the hardest part of the homework for you?
3. what was the easiest part of the homework for you?
4. one new thing that you have learned

homework

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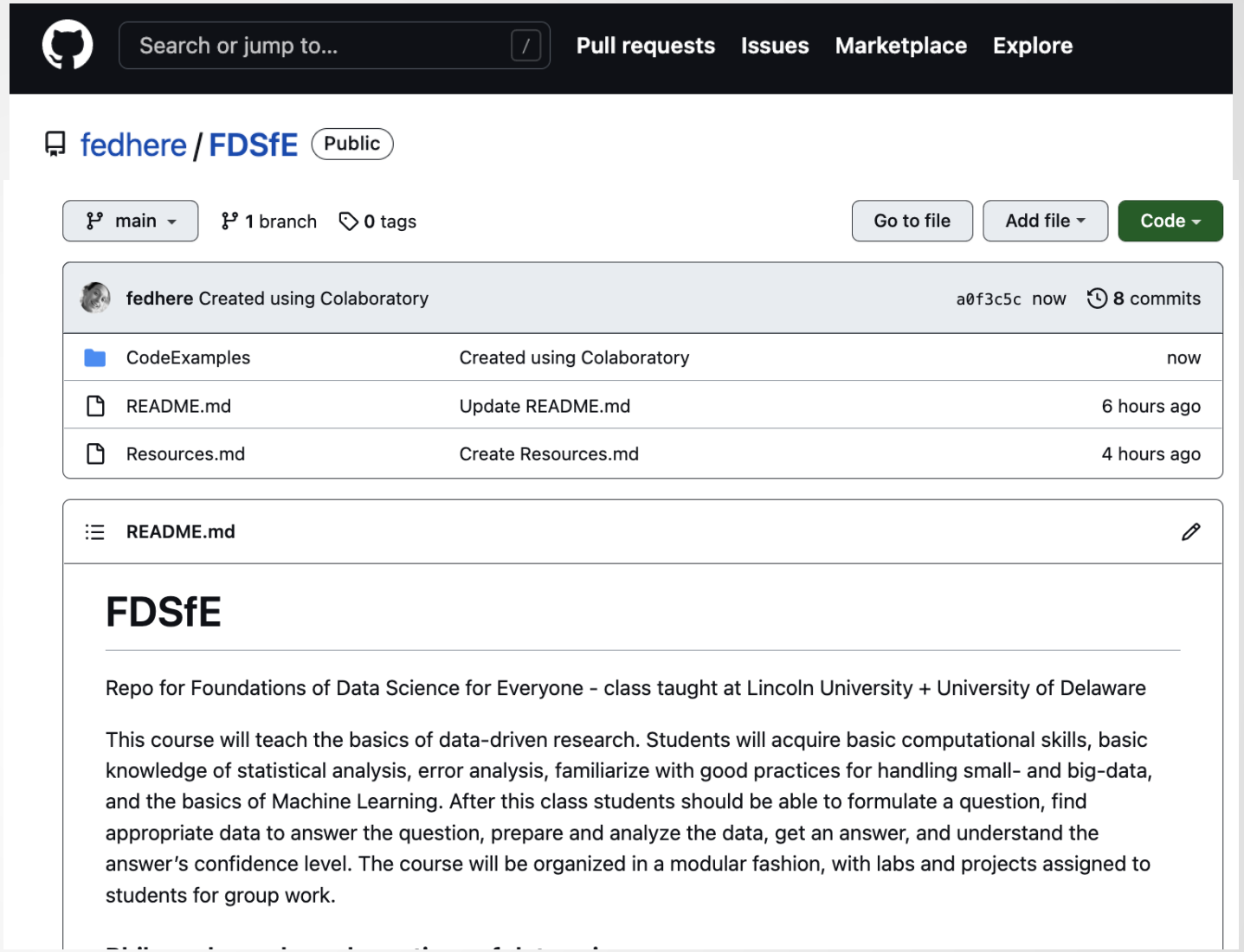

instructions will be here

https://github.com/fedhere/FDSfe_FBianco

homework

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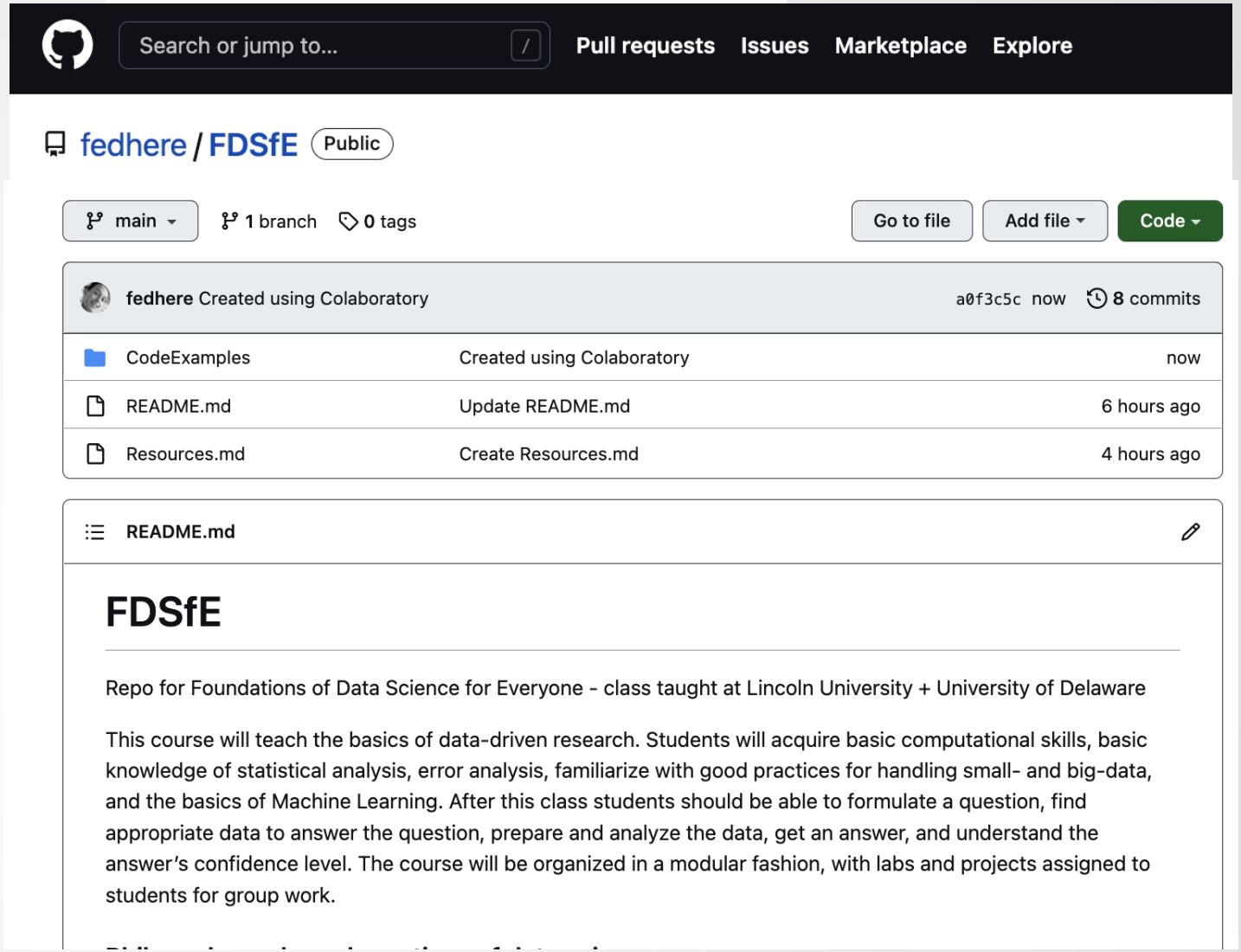
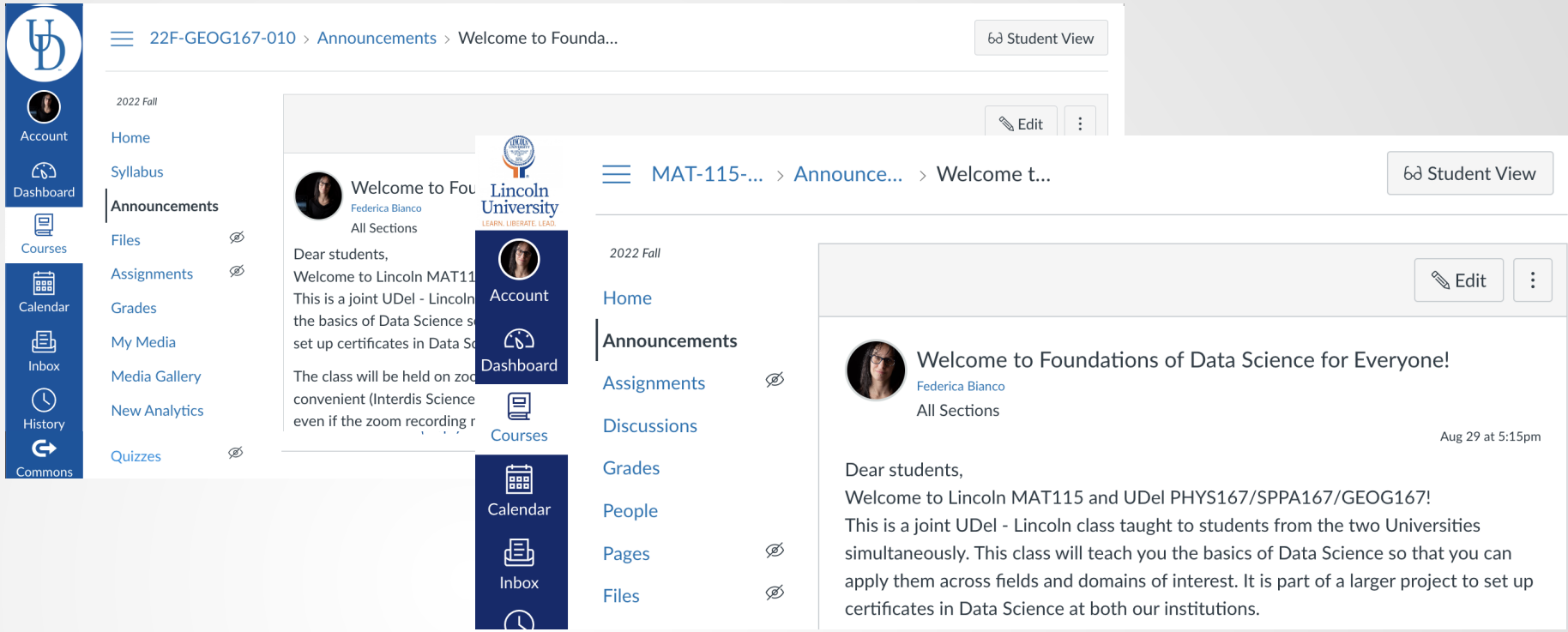


help: always available on slack!
please sign up asap by filling in the form!!

https://forms.gle/j4vejz7R2qwwQrdr9

slack

homework



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of course there is also Canvas, which will be used to give you grades and occasionally post messages

midterm

For the *Midterm* and the *Final* you are responsible for material in the labs, the reading, and the homework. **In preparing for the exams, use the homework as a guide to which material is essential. In the Midterm and Final YOU WILL BE EXPECTED TO WORK INDIVIDUALLY.**

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- 25% homework
- 15% midterm
- 30% final

Midterm... probably in class

advantages: interviews for jobs are often timed

issues: working under derass is not necessarily a required skill but that is why the midterm counts only 15%!

final

For the *Midterm* and the *Final* you are responsible for material in the labs, the reading, and the homework. **In preparing for the exams, use the homework as a guide to which material is essential. In the Midterm and Final YOU WILL BE EXPECTED TO WORK INDIVIDUALLY.**

- 5% pre-class questions
- 15% class participation
- 25% homework
- 15% midterm
- 30% final

Final: take home, multiple days.

Resources

- SLIDES --> https://slides.com/federicabianco/decks/fdsfe
- HOMEWORK INSTRUCTIONS --> github
- RESOURCES --> slack, github

If notebooks do not display

use

https://nbviewer.jupyter.org

https://github.com/fedhere/FDSfE_FBianco

Resources

Foundations of Data Science for Everyone - Resources

Instructors: Dr. Federica Bianco
contact: fbianco@udel.edu
Synchronous online class
Mon-Wed 3:35-4:50pm

Attendence is required.

Code of Conduct Syllabus

Academic Calendar - LU and UD have different calendars. Stay tuned for modifications of the schedule

Resources

Class material

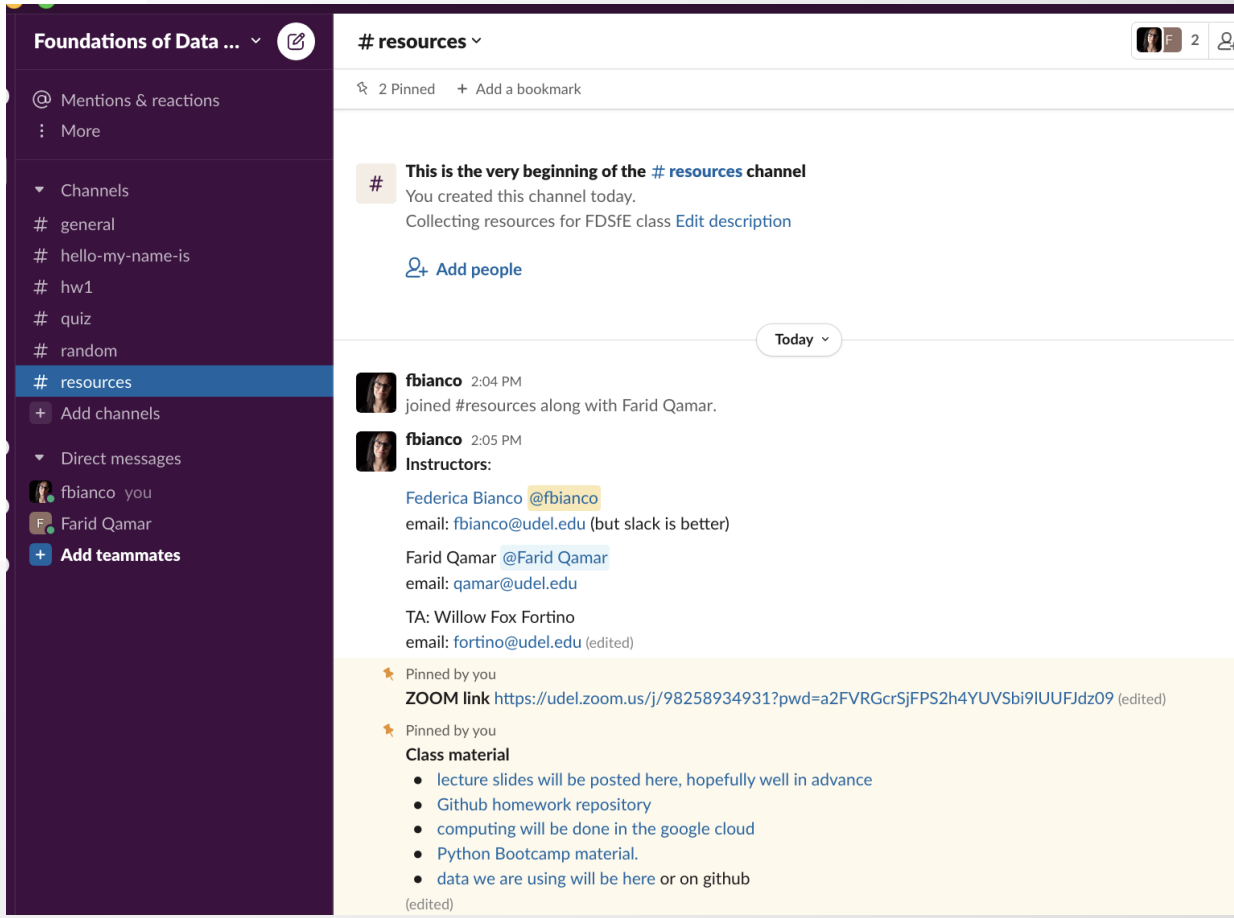
- lecture slides will be posted here, hopefully well in advance
- Github homework repository
- computing will be done in the google cloud
- Python Bootcamp material.
- data we are using will be here or on github

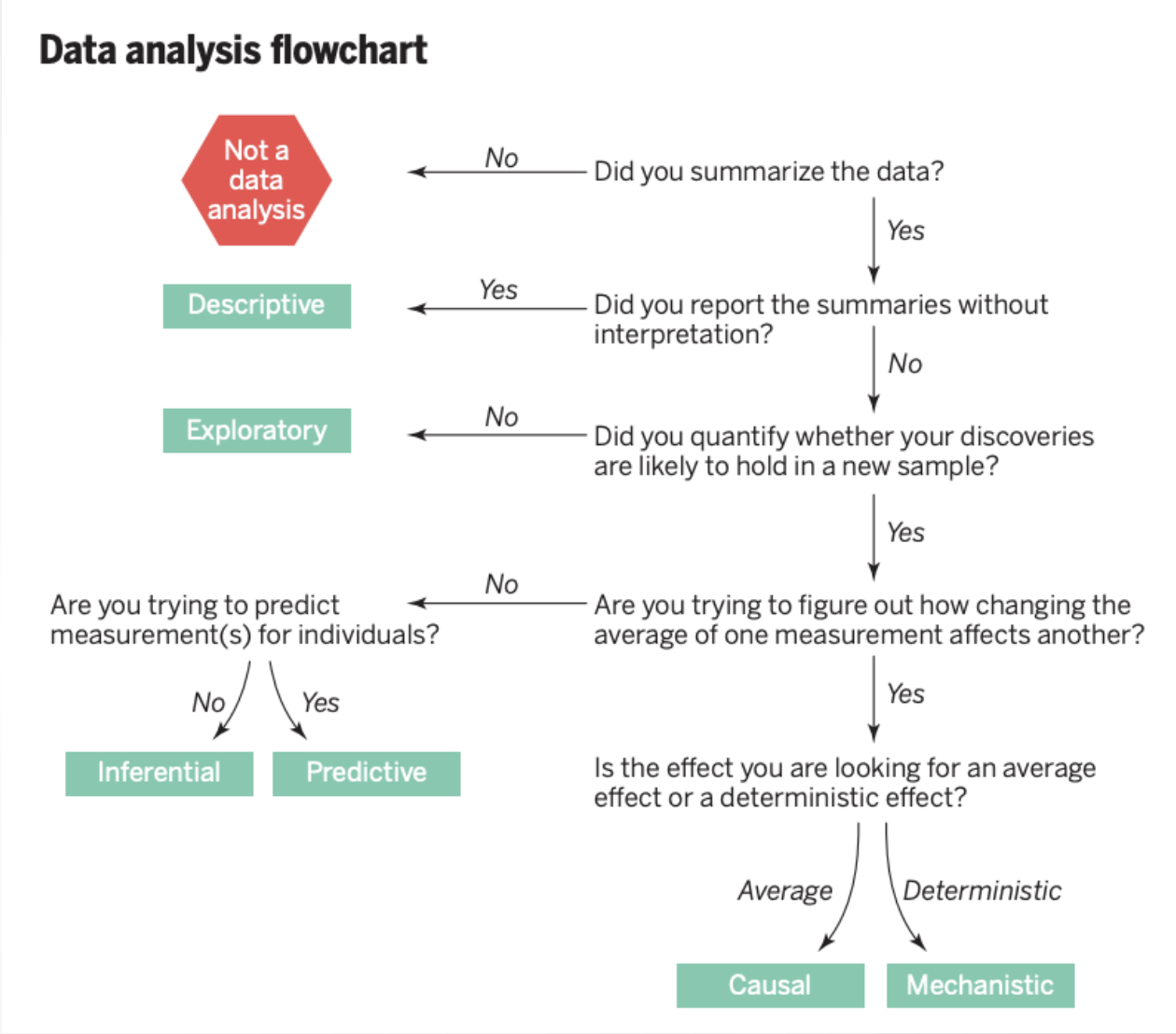
Python resources

- Mohit's excellent python guide for the CUSP bootcamp
- the zen of python
- PEP8 python guide style
- @Mark_Graph python cheat-sheet
- @Mark_Graph Pandas cheat-sheet
- Matplotlib cheat-sheet 1
- Matplotlib cheat-sheet 1

https://github.com/fedhere/FDSfE_FBianco/blob/main/Resources.md

slack





4

the steps of data-analysis and inference:

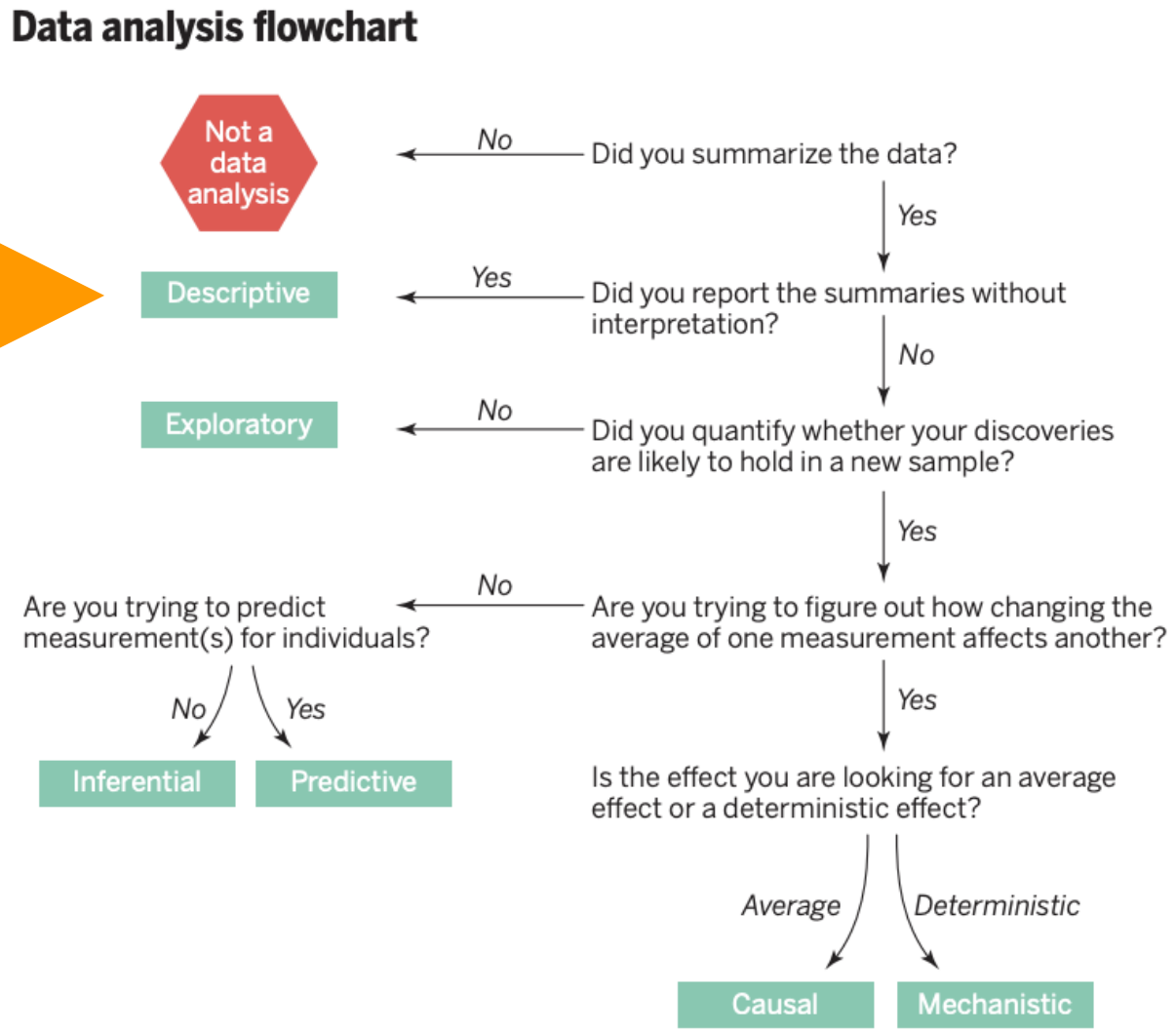
descriptive and exploratory analysis

- how is data organized
- is data complete?
- what are the statistical properties of the data

```
1 import pandas as pd
2 df = pd.read_csv(file_name)
3 df.describe()
```

```
videos.describe()
```

	category_id	views	likes	dislikes	comment_count
count	40949.000000	4.094900e+04	4.094900e+04	4.094900e+04	4.094900e+04
mean	19.972429	2.360785e+06	7.426670e+04	3.711401e+03	8.446804e+03
std	7.568327	7.394114e+06	2.288853e+05	2.902971e+04	3.743049e+04
min	1.000000	5.490000e+02	0.000000e+00	0.000000e+00	0.000000e+00
25%	17.000000	2.423290e+05	5.424000e+03	2.020000e+02	6.140000e+02
50%	24.000000	6.818610e+05	1.809100e+04	6.310000e+02	1.856000e+03
75%	25.000000	1.823157e+06	5.541700e+04	1.938000e+03	5.755000e+03
max	43.000000	2.252119e+08	5.613827e+06	1.674420e+06	1.361580e+06



we will look at the statistical properties next week: mean, standard deviation, median, quantiles...

- how is data organized
- is data complete?
- what are the statistical properties of the data

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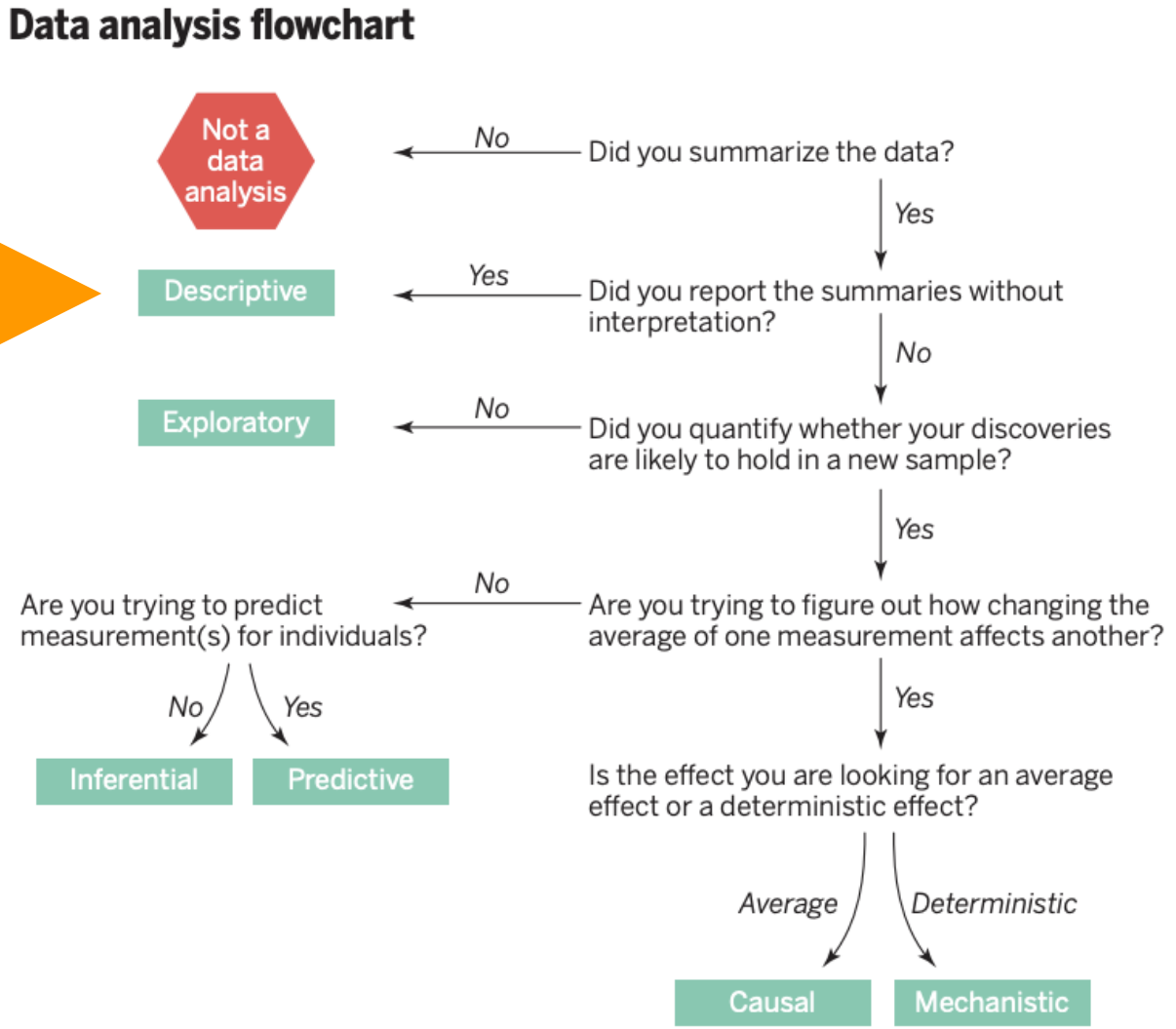
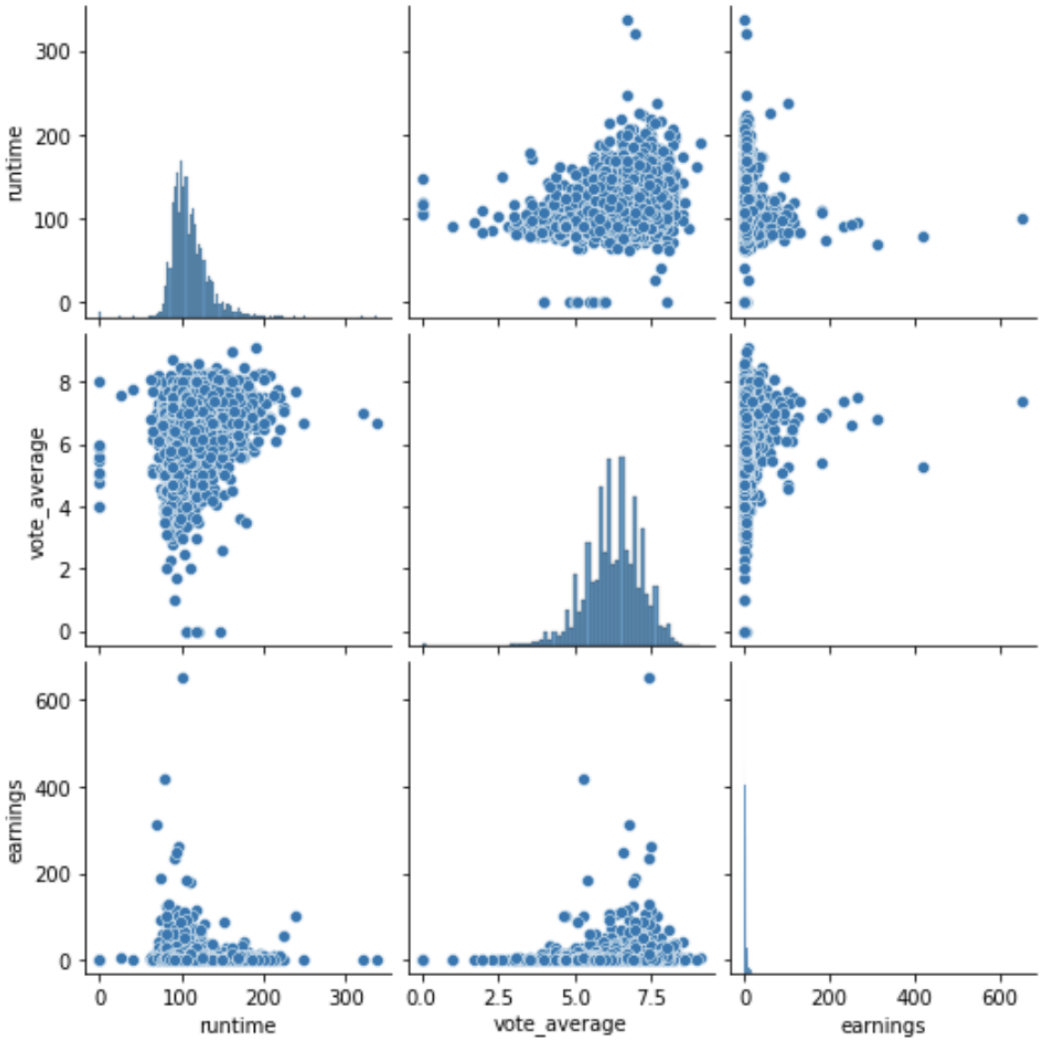
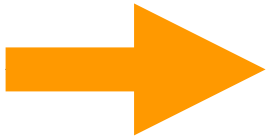
std	7.568327	7.394114e+06	2.288853e+05	2.902971e+04	3.743049e+04
min	1.000000	5.490000e+02	0.000000e+00	0.000000e+00	0.000000e+00
25%	17.000000	2.423290e+05	5.424000e+03	2.020000e+02	6.140000e+02
50%	24.000000	6.818610e+05	1.809100e+04	6.310000e+02	1.856000e+03
75%	25.000000	1.823157e+06	5.541700e+04	1.938000e+03	5.755000e+03
max	43.000000	2.252119e+08	5.613827e+06	1.674420e+06	1.361580e+06

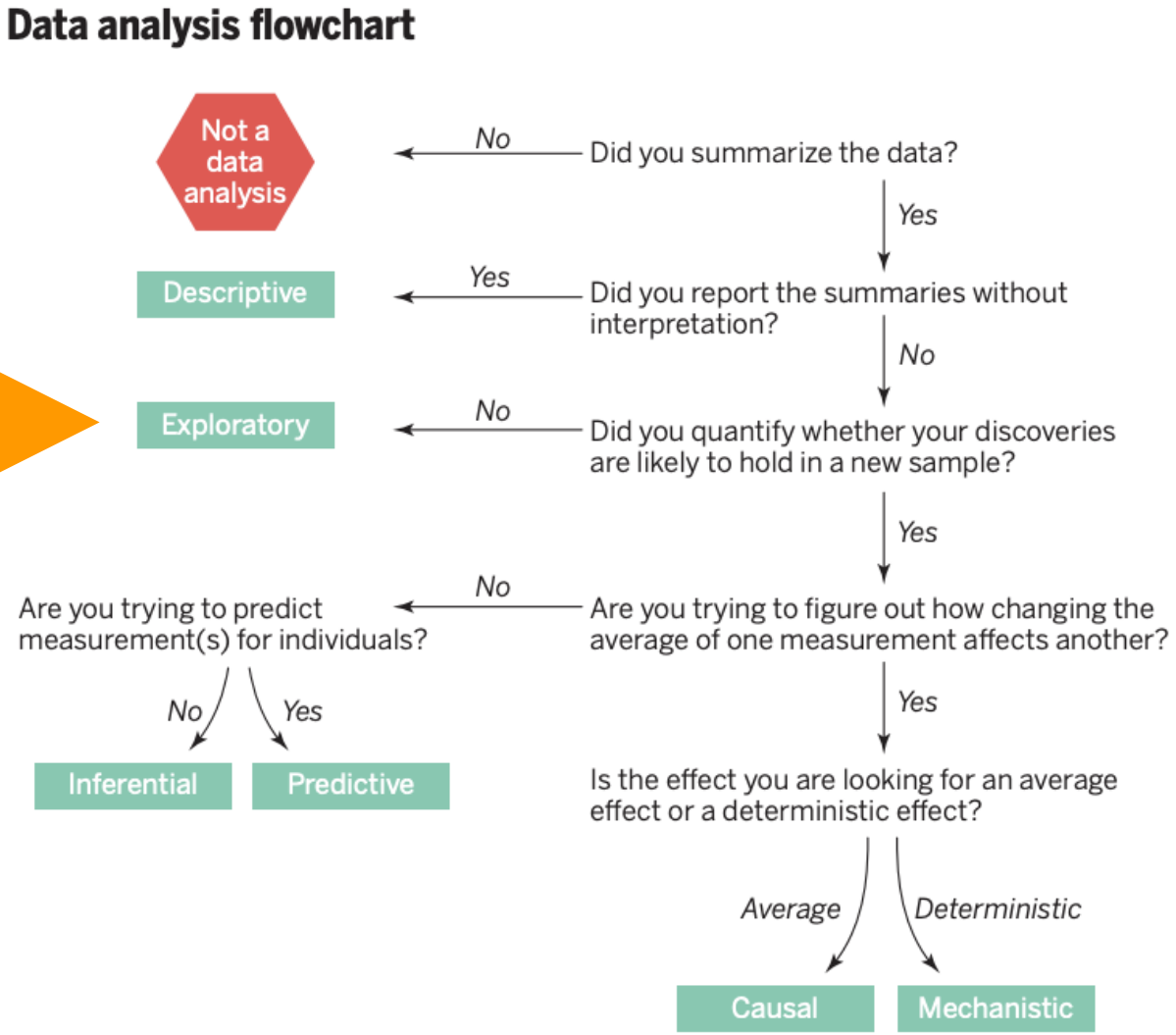


we will look at the statistical properties next week: mean, standard deviation, median, quantiles...

- searching for anomalies, trends, correlations, or relationships between the measurements

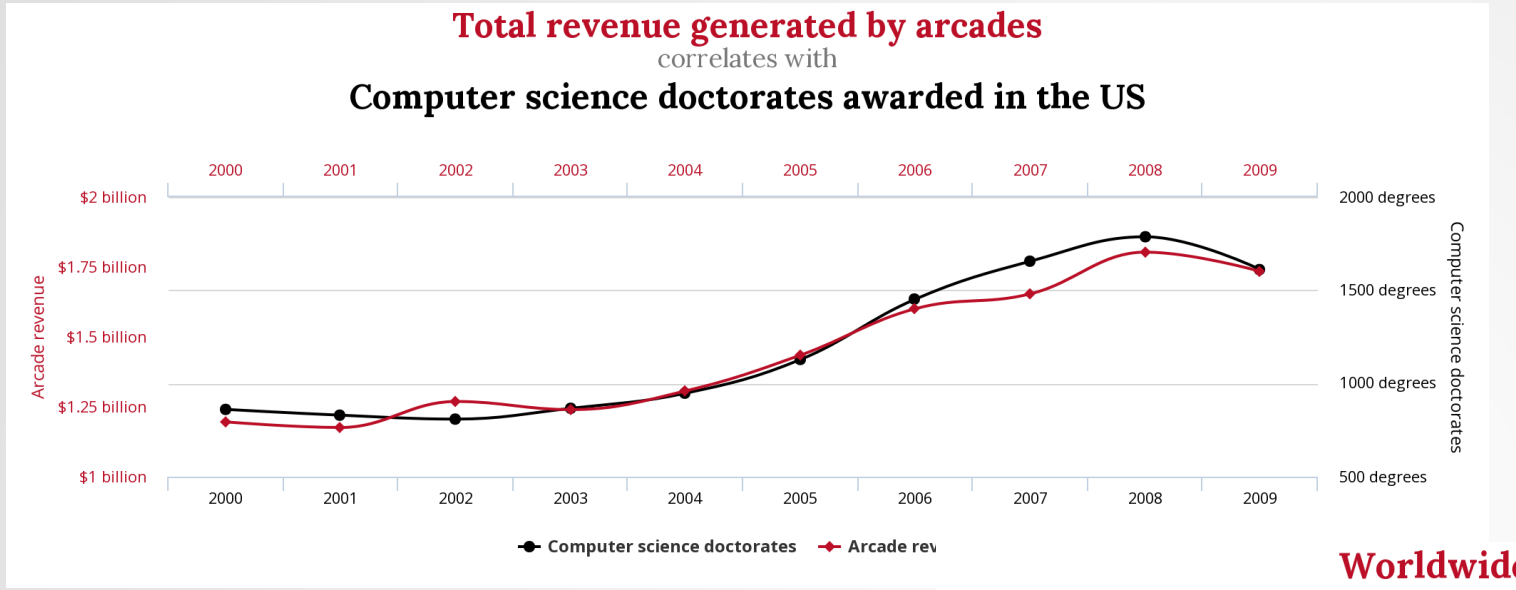


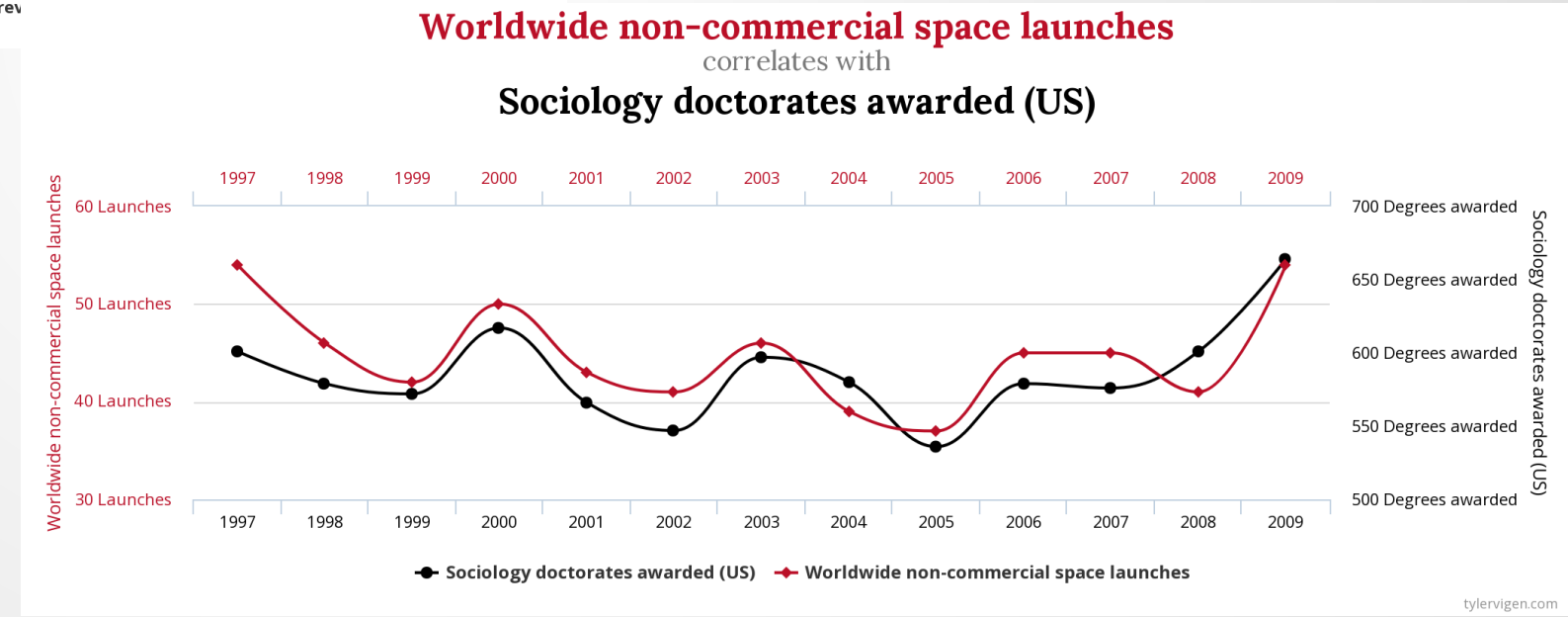




An exploratory data analysis builds on a descriptive analysis by searching for discoveries, trends, correlations, or relationships between the measurements to generate ideas or hypotheses.

correlation





http://www.tylervigen.com/spurious-correlations

Pearson's correlation

$$r_{xy} = \frac{1}{n-1} \sum_{i=1}^{N} \left(\frac{x_i - \bar{x}}{s_x} \right) \left(\frac{y_i - \bar{y}}{s_y} \right)$$

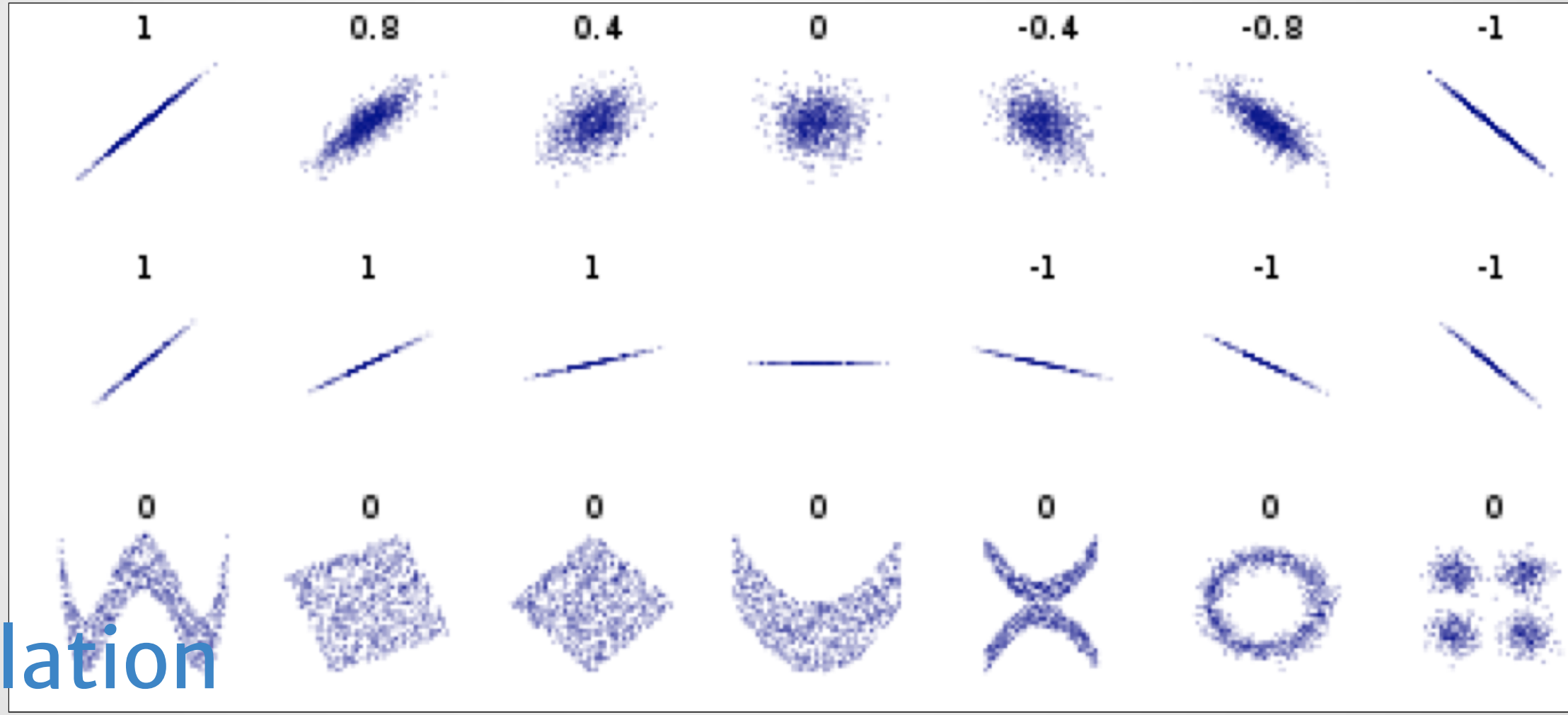
$\bar{x}$: mean value of x

$\bar{y}$: mean value of y

n : number of datapoints

$$s_x = \sqrt{\frac{1}{n-1} \sum_{i=1}^{N} (x_i - \bar{x})^2}$$

Pearson's correlation measures *linear* correlation



correlation

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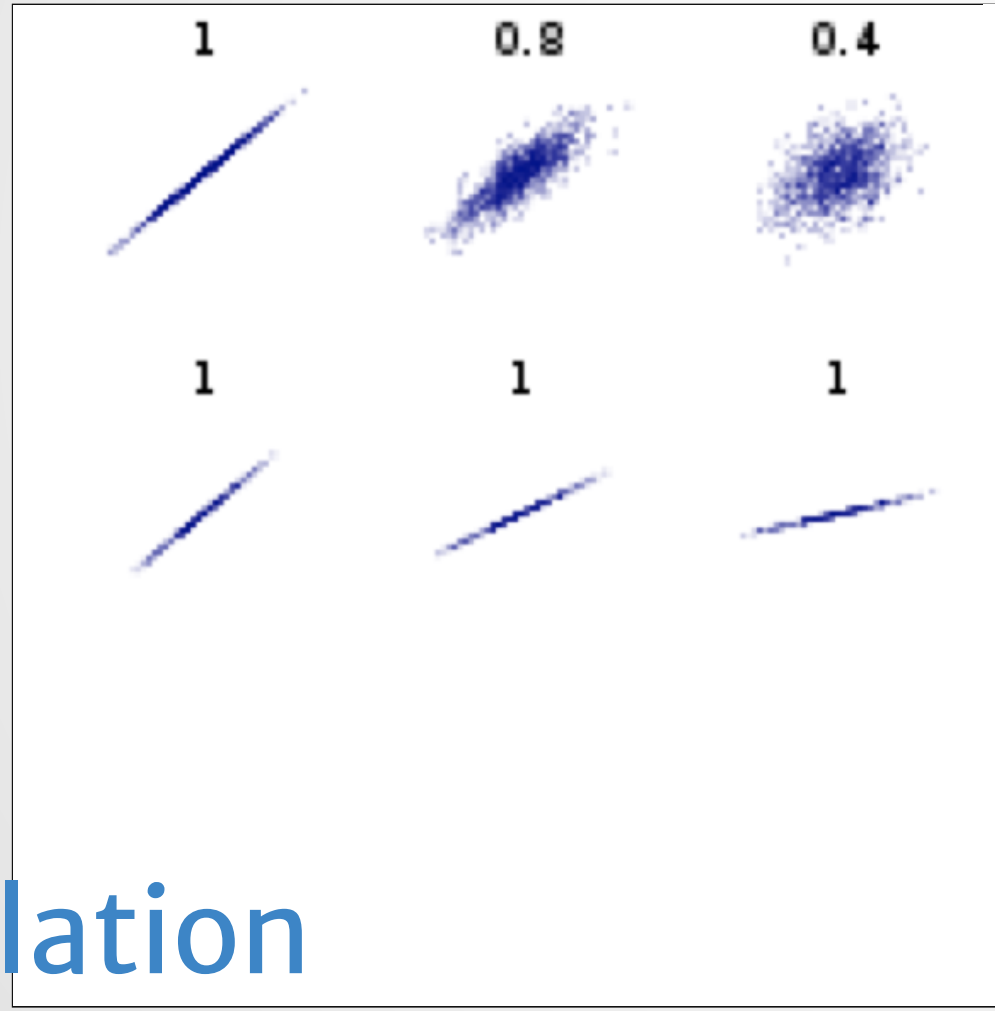

correlated

"positively" correlated

correlation

Pearson's correlation

$$r_{xy} = \frac{1}{n-1} \sum_{i=1}^{N} \left(\frac{x_i - \bar{x}}{s_x} \right) \left(\frac{y_i - \bar{y}}{s_y} \right)$$

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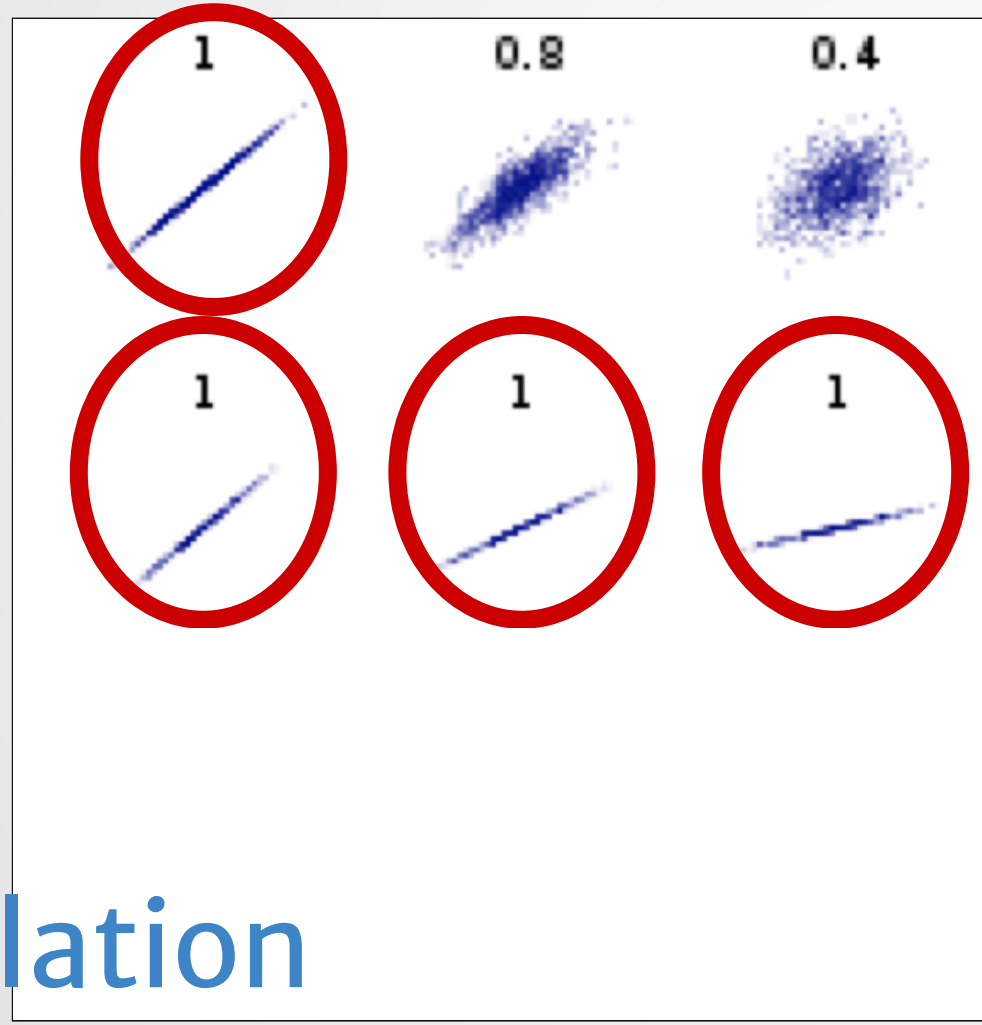

correlated

"positively" correlated

$r_{xy} = 1$ iff $y = ax$

maximally correlated

correlation

Pearson's correlation

$$r_{xy} = \frac{1}{n-1} \sum_{i=1}^{N} \left(\frac{x_i - \bar{x}}{s_x} \right) \left(\frac{y_i - \bar{y}}{s_y} \right)$$

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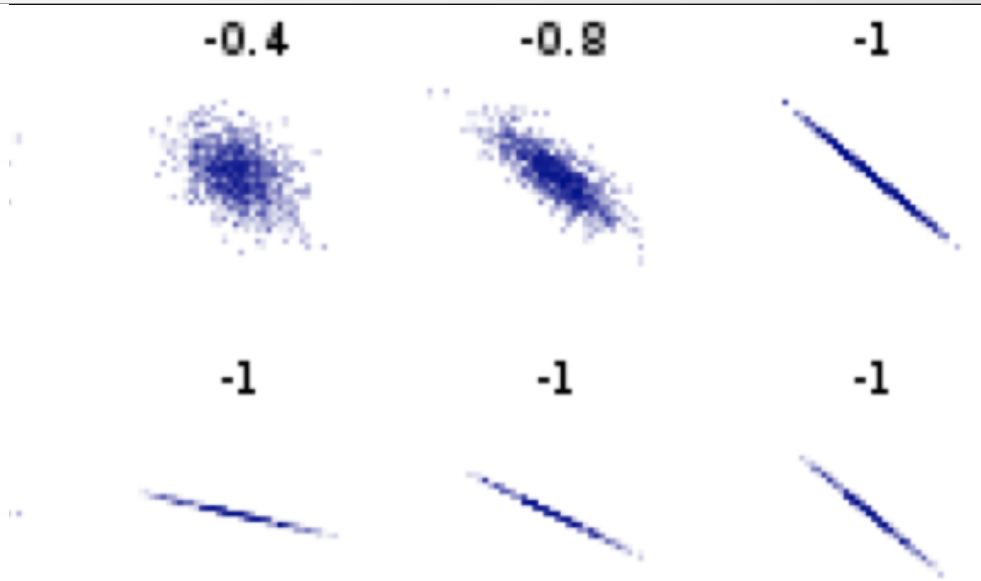
Pearson's correlation measures *linear* correlation

anticorrelated

"negatively" correlated



correl

Pearson's correlation

$$r_{xy} = \frac{1}{n-1} \sum_{i=1}^{N} \left(\frac{x_i - \bar{x}}{s_x} \right) \left(\frac{y_i - \bar{y}}{s_y} \right)$$

Pearson's correlation measures *linear* correlation

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n : number of datapoints

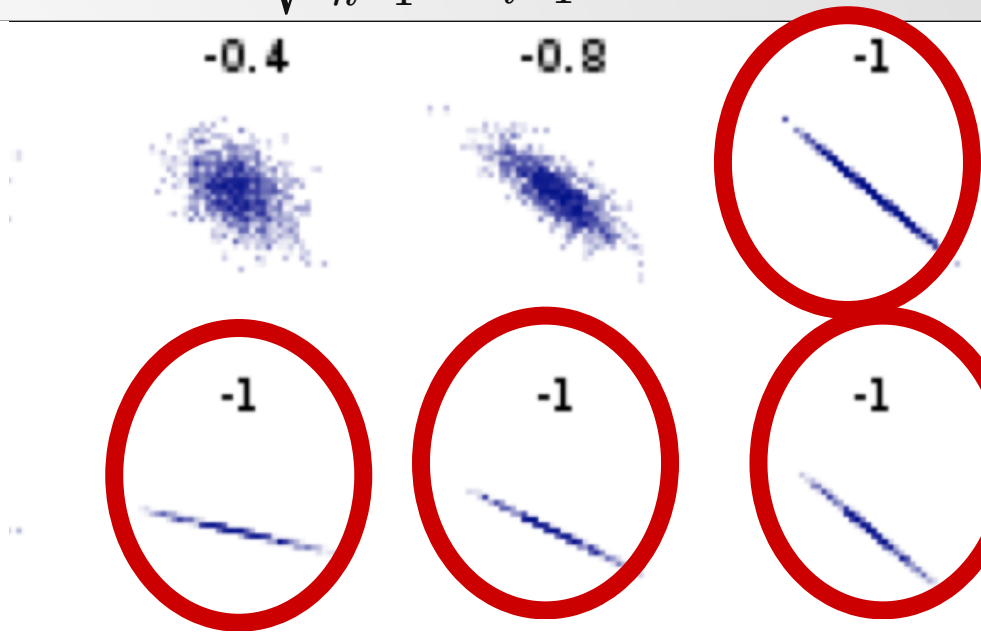
$$s_x = \sqrt{\frac{1}{n-1} \sum_{i=1}^{N} (x_i - \bar{x})^2}$$

anticorrelated

"negatively" correlated

$$r_{xy} = 1 \text{ iff } y = -ax$$

maximally anticorrelated



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not *linearly* correlated

Pearson's coefficient = 0

does not mean that *x* and *y* are independent!

correlation

Pearson's correlation

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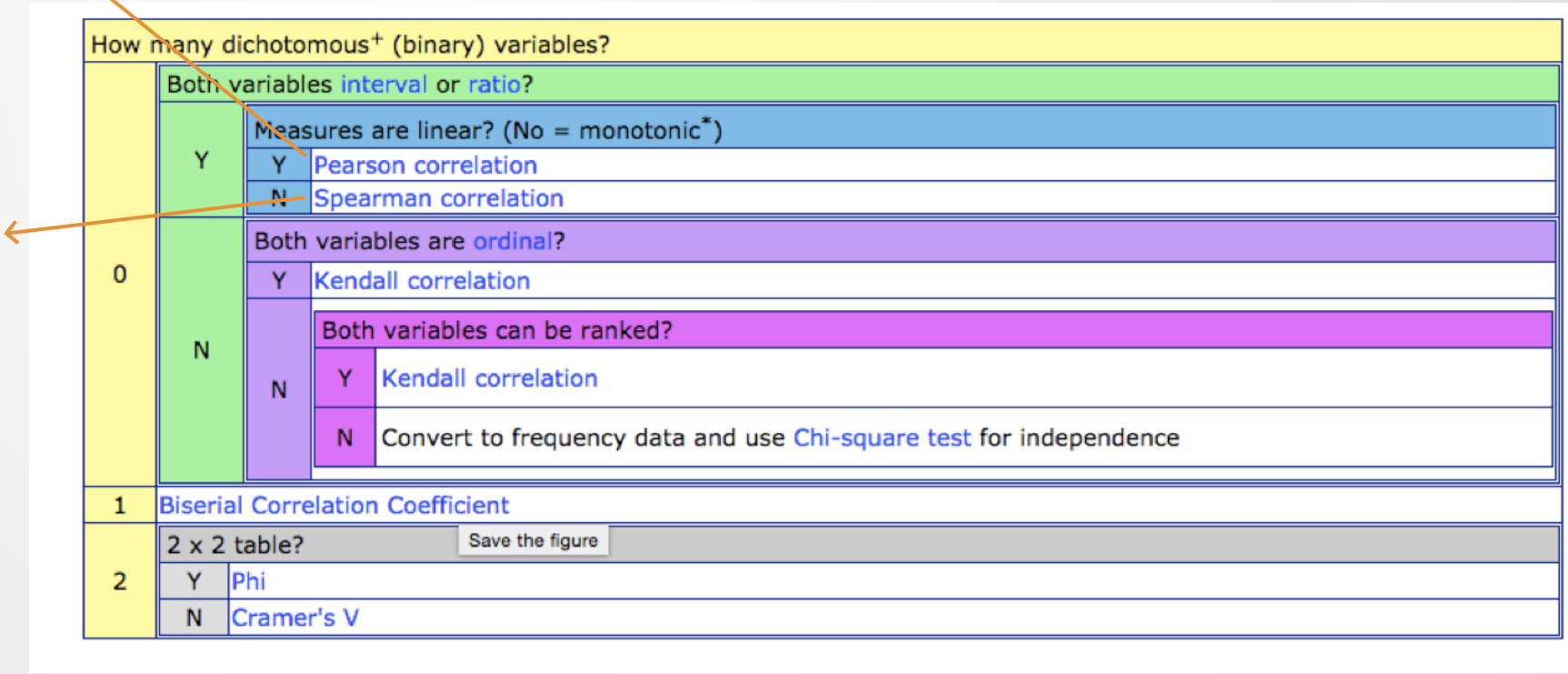
Spearman's test

(Pearson's for ranked values)

$$\rho_{xy} = 1 - \frac{6 \sum_{i=1}^{N} (x_i - y_i)^2}{n(n^2-1)}$$



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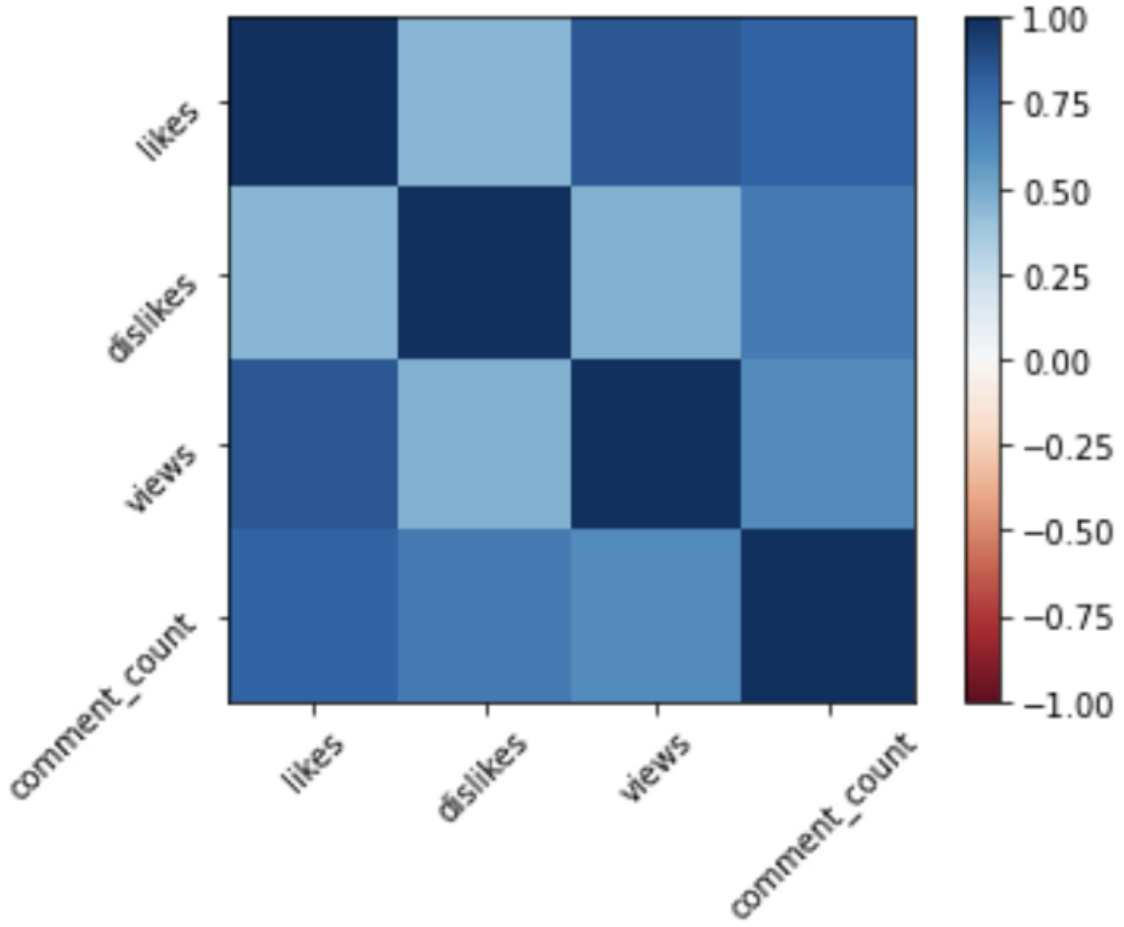
```
1 import pandas as pd
2 df = pd.read_csv(file_name)
3 df.corr()
```

	likes	dislikes	views	comment_count
likes	1.000000	0.447186	0.849177	0.803057
dislikes	0.447186	1.000000	0.472213	0.700184
views	0.849177	0.472213	1.000000	0.617621
comment_count	0.803057	0.700184	0.617621	1.000000

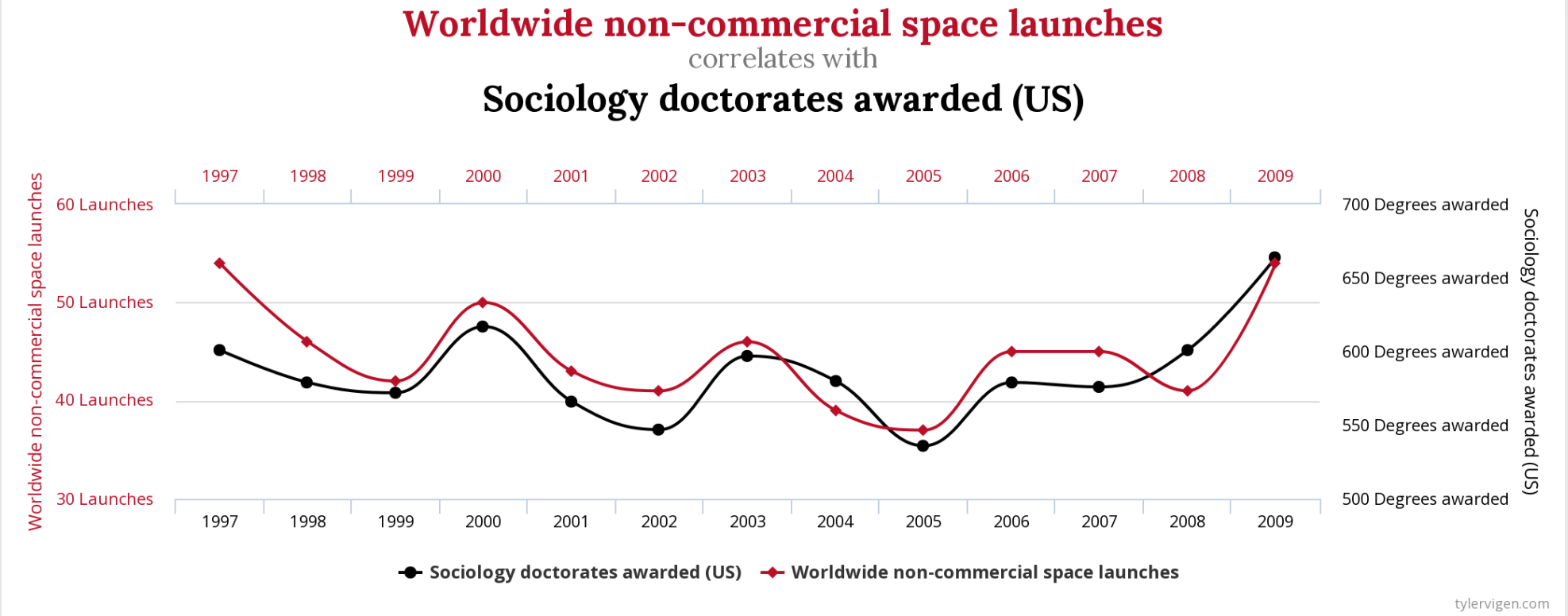
```
1 pl.imshow(vdf.corr(), clim=(-1,1),  cmap='RdBu')
2 pl.xticks(list(range(len(df.corr()))),
3                df.columns, rotation=45)
4 pl.yticks(list(range(len(df.corr()))),
5                df.columns, rotation=45)
6 pl.colorbar();
```



correlation

correlation

Correlation does not imply causality!!



2 things may be related because they share a cause but not cause each other:

icecream sales with temperature |death by drowning with temperature

In the era of big data you may encounter truly spurious correlations

divorce rate in Maine | consumption of Margarine

http://www.tylervigen.com/spurious-correlations

What is Data Science

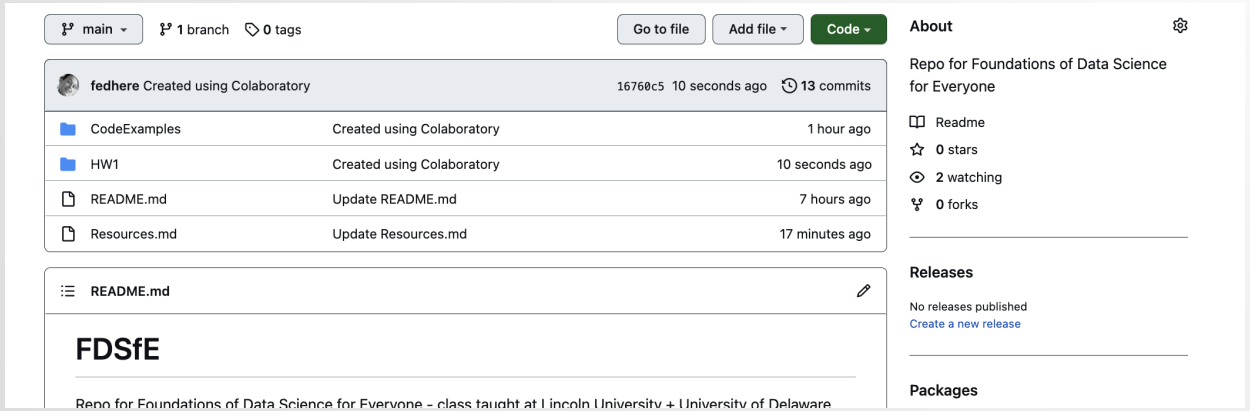
key concepts

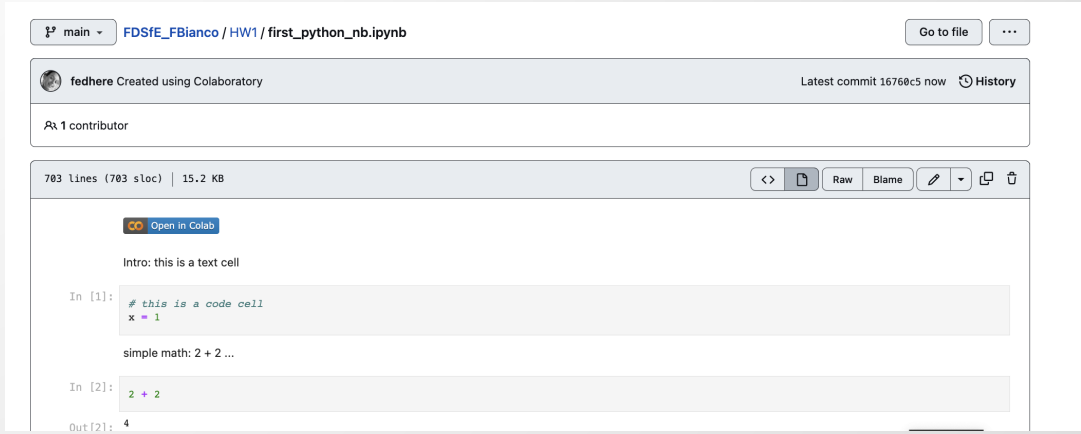
1 homework

- make an account on GitHub if you do not have one yet
- Create a repository called FDSfE_<firstinitialLastname>
- Add a README file to your repository that indicates that this is the repo for Foundations of Data Science

2 homework

- upload to your github repo the colab notebook we have worked on in class. the colab notebooks should appear in a folder HW1 and have a google colab link (more instructions will appear on github)





Jeff Leek & Rodger Peng.
2015,
What is the Question?

https://www.aaas.org/sites/default/files/Stats_What_Question_2015.pdf?g_zGQR5m3rDJqwXqJ3DxLI5pXZ3hNdHk

reading

the original link:
https://science.sciencemag.org/content/347/6228/1314.summary
(is link nees access to science magazine, but ou can use the link above which is the same file)

STATISTICS

What is the question?

Mistaking the type of question being considered is the most common error in data analysis

By **Jeffery T. Leek** *and* **Roger D. Peng**

Claerbout, J. 1990,

Active Documents and Reproducible Results, Stanford Exploration Project Report, 67, 139

http://sepwww.stanford.edu/data/media/public/docs/sep67/jon2/paper_html/

Reproducibility and Replicability in Science

Consensus Study Report (2019)

https://www.nap.edu/catalog/25303/reproducibility-and-replicability-in-science

additional reading

Text

STATISTICS

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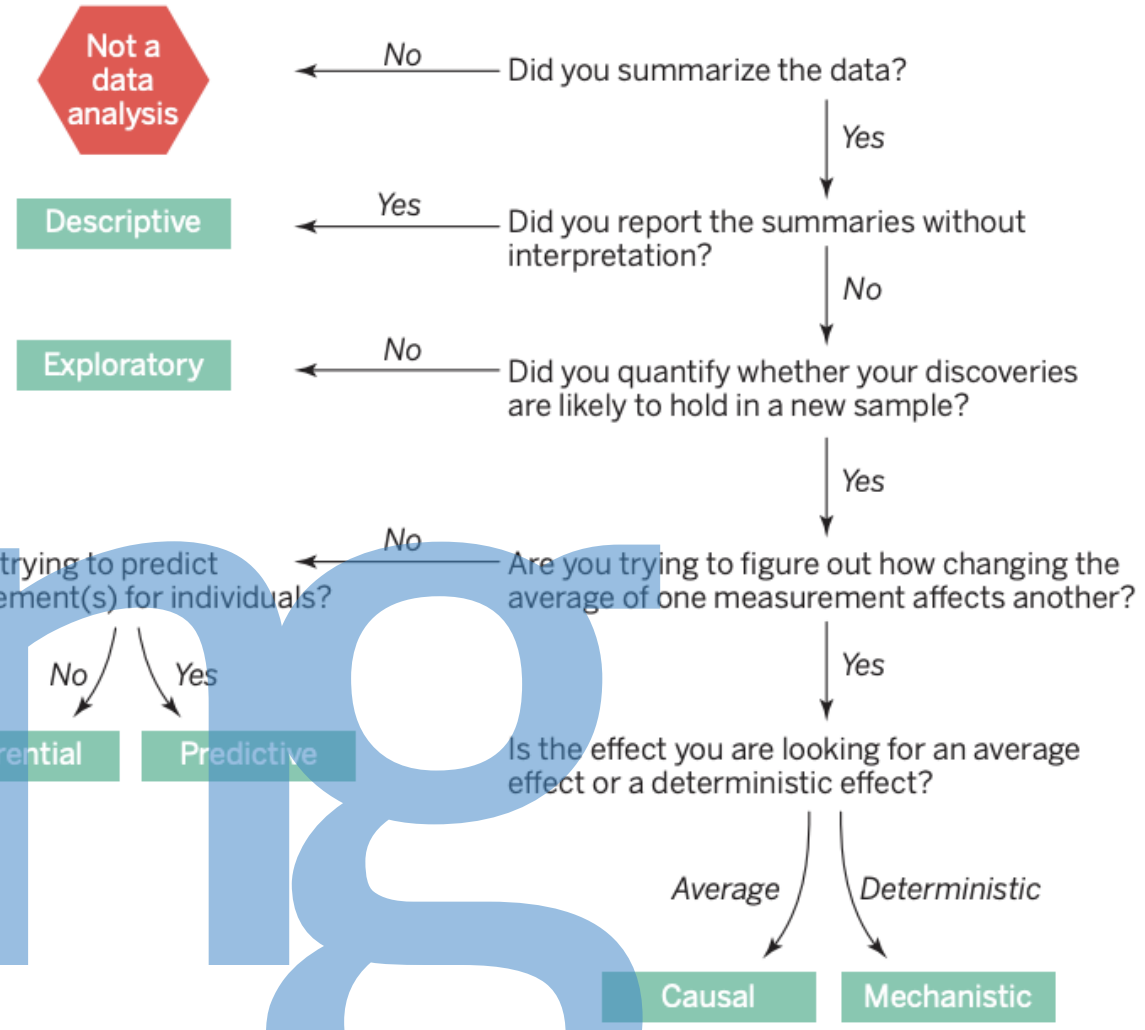
Mistaking the type of question being considered is the most common error in data analysis

By **Jeffery T. Leek** *and* **Roger D. Peng**

Data analysis flowchart



reading