PRINCIPLES OF DATA SCIENCE

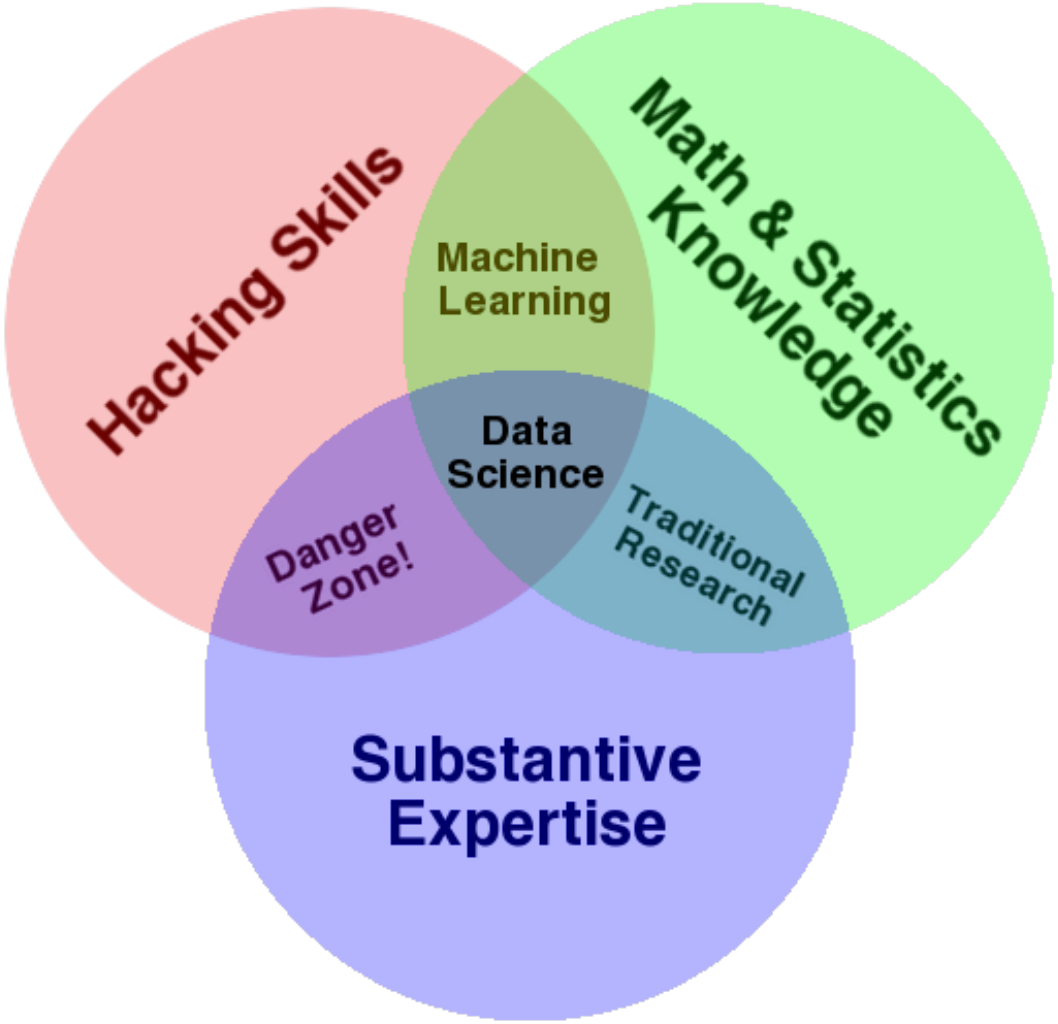
MOHAMMAD NAYEEM TELI

COMPUTER SCIENCE
UNIVERSITY OF MARYLAND

Thanks to John Dickerson for most of the slides

Data science is the application of computational and statistical techniques to address or gain [managerial or scientific] insight into some problem in the real world.

Zico Kolter
Machine Learning Prof, CMU



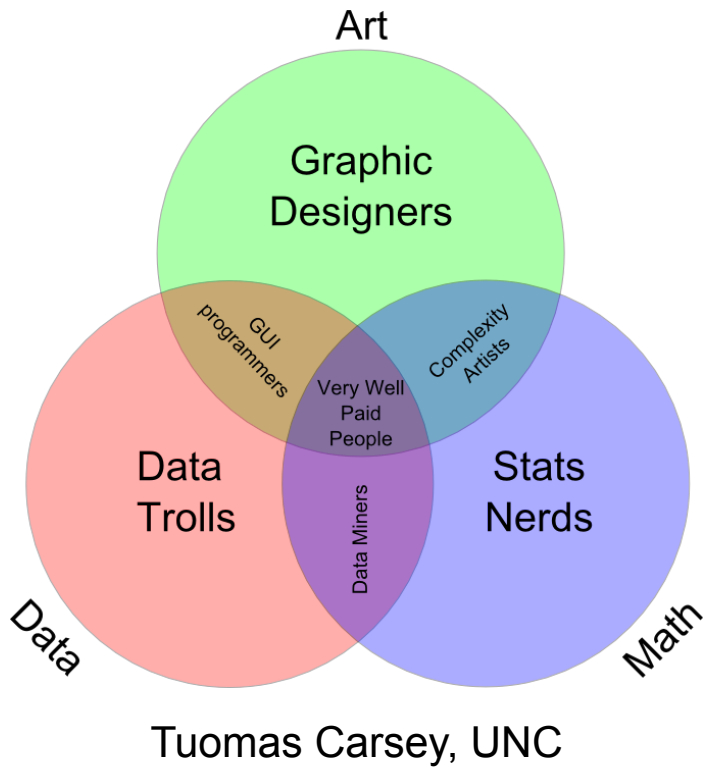
Drew Conway
CEO, Alluvium (analytics company)

MANY DEFINITIONS

Broad: necessarily **larger** than a single discipline

Interdisciplinary: statistics, computer science, operations research, statistical and machine learning, data warehousing, visualization, mathematics, information science, …

Insight-focused: grounded in the desire to find insights in data and leverage them to inform decision making



Tuomas Carsey, UNC

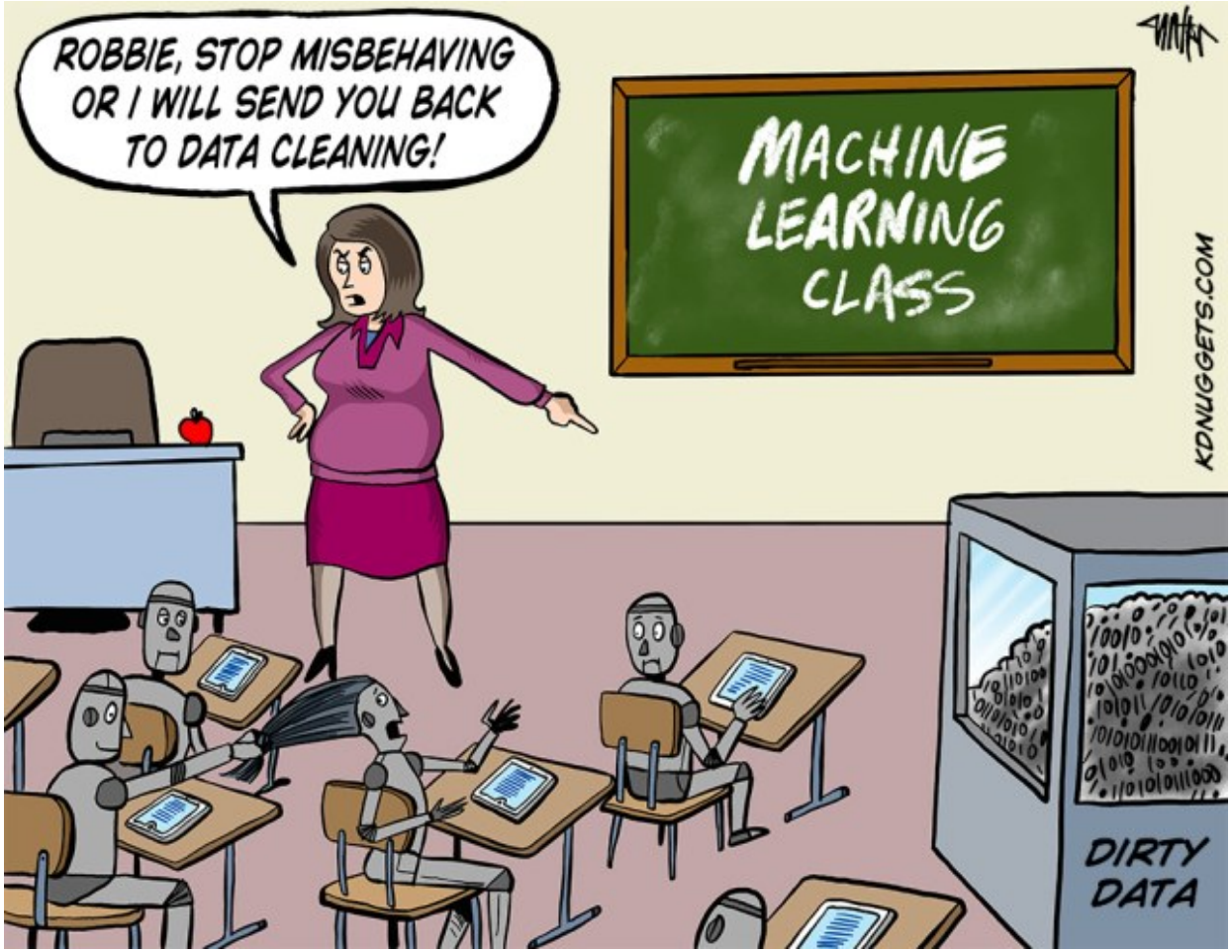
DATA SCIENCE LIFECYCLE

1. Collect Data

Remember Mr Pooter is not just a 'patient', he's an important source of valuable and readily marketable data!

DATA SCIENCE LIFECYCLE

2. Scrub Data

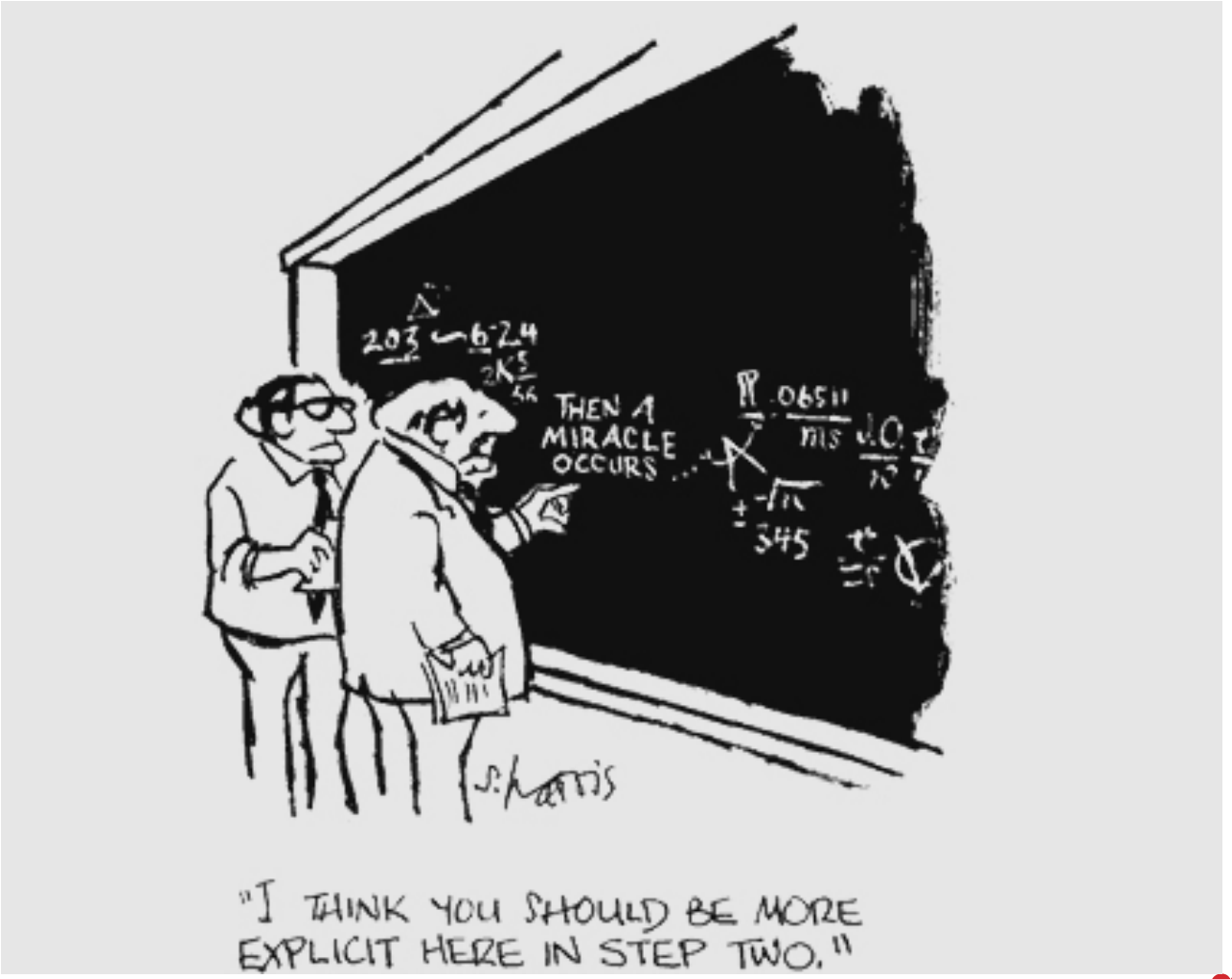


DATA SCIENCE LIFECYCLE

3. Explore Data

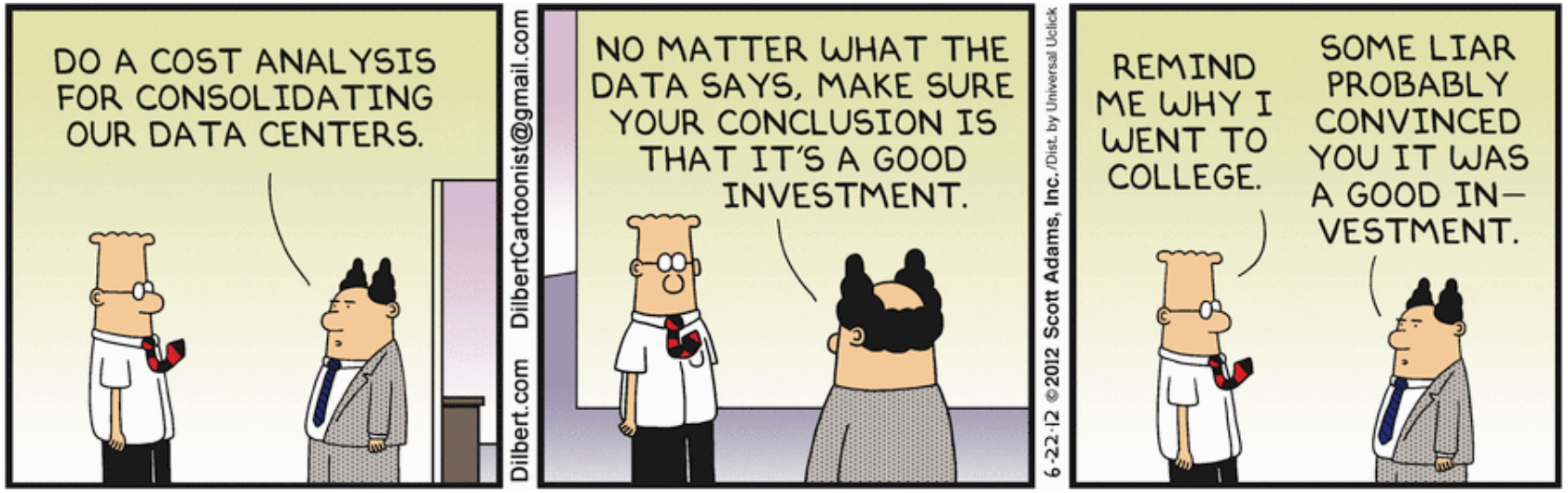
DATA SCIENCE LIFECYCLE

4. Build a model

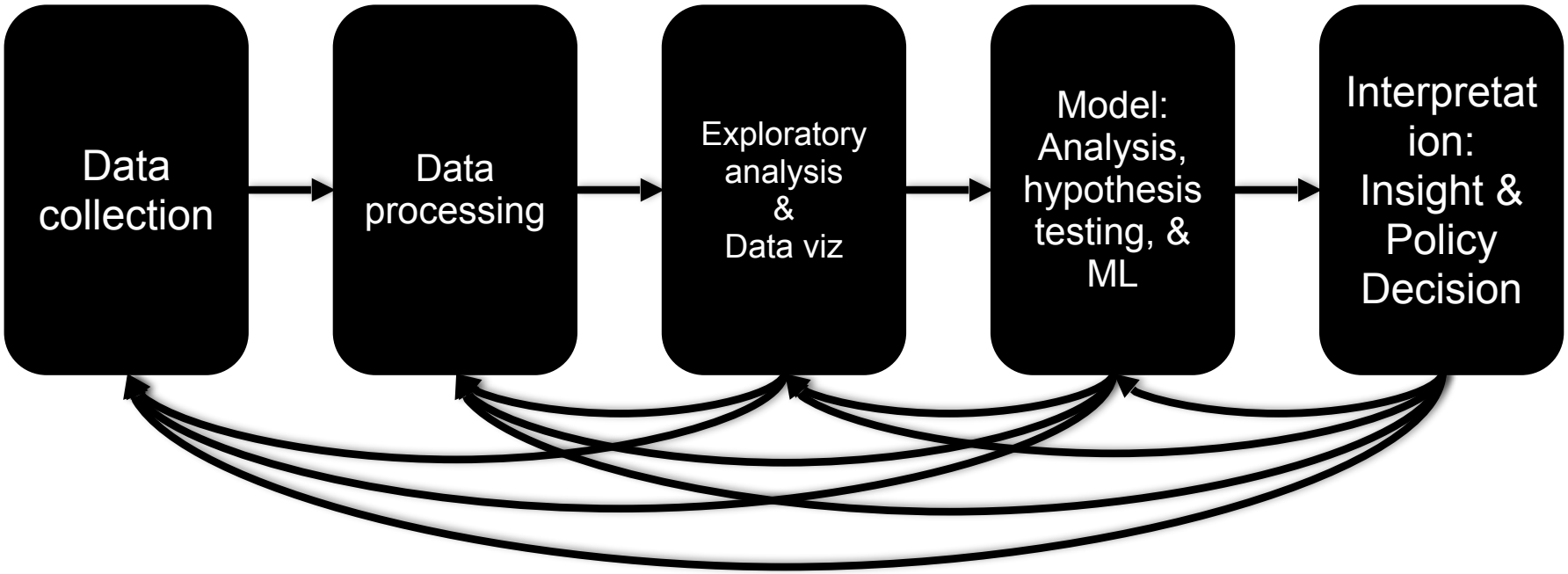


DATA SCIENCE LIFECYCLE

5. Interpretation



THE DATA SCIENCE LIFECYCLE



"The ability to take data—to be able to understand it, to process it, to extract value from it, to visualize it, to communicate it—that's going to be a hugely important skill in the next decades, not only at the professional level but even at the educational level for elementary school kids, for high school kids, for college kids."

Hal Varian
Chief Economist at Google

MOTIVATION

Explosion of data, in pretty much every domain

- Sensing devices and sensor networks that can monitor everything 24/7 from temperature to pollution to vital signs
- Increasingly sophisticated smart phones
- Internet, social networks makes it easy to publish data
- Scientific experiments and simulations → astronomical data volumes
- Internet of Things
- Dataification: taking all aspects of life and turning them into data (e.g., what you like/enjoy has been turned into a stream of your "likes")

How to handle that data? How to extract interesting actionable insights and scientific knowledge?

Data volumes expected to get much worse

FOUR V'S OF BIG DATA

Increasing data Volumes

- Scientific data: human genome can be sequenced in a day.
- Hundreds of millions of tweets per day
- Trillions of MB of data created every day

Variety:

- Structured data, spreadsheets, photos, videos, natural text, ...

Velocity

- Sensors everywhere -- can generate high-rate "data streams"
- Real-time analytics requires data to be consumed as fast as it is generated

Veracity

- How do you decide what to trust? How to remove noise? How to fill in missing values?

THIS COURSE

End-to-end data science lifecycle

Acquiring, wrangling, cleaning, and integrating data; Setting up pipelines for ETL (Extract, transform and load)

Data modeling

Information Visualization

Ethics, Privacy, and Reproducibility

Piazza: https://piazza.com/

Gradescope: https://www.gradescope.com/

ELMS: (everyone should be registered automatically)

PREREQUISITE KNOWLEDGE

Aimed at folks with some programming experience and mathematical maturity.

We do not assume:

- Experience with Pandas, scikit-learn, matplotlib, etc …
- Deep statistics or any ML knowledge
- Database or distributed systems knowledge

We do assume:

- Experience in probability and hypothesis testing
- Python programming experience

(TENTATIVE) COURSE STRUCTURE

First few lectures: intro & primers in the Python data science stack

Next : data collection & management

- Best practices, data wrangling, exploratory analysis, ethics, debugging, visualization, etc …

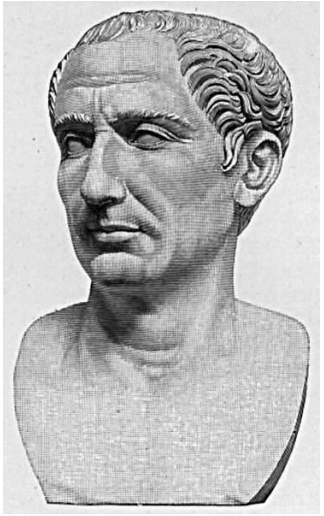
Next lectures: statistical modeling & ML

- Statistical learning, regression, classification, cross-validation, model evaluation, hypothesis testing, etc …

Midterms, Final exam and Final tutorial

Final lectures: advanced topics

- Dimensionality reduction, distributed learning, big data, distributed computation
- *M*ore lectures



Ambitious …

GRADE #1: MINI-PROJECTS

Students will complete Project 0 + three / four mini-project assignments:

- **Case studies** meant to mimic what you, a future data scientist, will see in industry. They should be fun ☺.

The rules:

- Allowed: small group **discussions**
- Required: individual **programming & writing**
- Never allowed: public posting of solutions

Deliverable:

- Turn in an **.ipynb** of a Jupyter notebook on Gradescope.

GRADE #2: READING HOMEWORKS / QUIZZES

We will post (bi)weekly reading assignments. Mix of:

- Blog posts
- Academic articles
- News articles

Weekly quizzes on ELMS.

GRADE #3: MIDTERM

You know what this is.

Will cover roughly the material up to the week before of class:

- Qualitative, and
- Quantitative

GRADE #4: FINAL

You know what this is.

Will cover roughly the material up to the week before of class:

- Qualitative, and
- Quantitative

GRADE #5: TUTORIAL

You'll create a tutorial that:

- Identifies a raw data source
- Processes and stores that data
- Performs exploratory data analysis & visualization
- Derives insight(s) using statistics and ML
- Communicates those insights as actionable text

Individual or group project

Will be hosted publicly online (GitHub Pages) and will strengthen your portfolio.

READY-MADE DATASET REPOSITORIES

https://www.data.gov/

- US-centric agriculture, climate, education, energy, finance, health, manufacturing data, …

https://cloud.google.com/bigquery/public-data/

- BigQuery (Google Cloud) public datasets (bikeshare, GitHub, Hacker News, Form 990 non-profits, NOAA, …)

https://www.kaggle.com/datasets *****

- Microsoft-owned, various (Billboard Top 100 lyrics, credit card fraud, crime in Chicago, global terrorism, world happiness, …)

https://aws.amazon.com/public-datasets/

- AWS-hosted, various (NASA, a bunch of genome stuff, Google Books n-grams, Multimedia Commons, …)

READY-MADE DATASET REPOSITORIES

- StrataScratch: https://platform.stratascratch.com/data-projects
- https://datasetsearch.research.google.com/
- https://data.fivethirtyeight.com/
- https://data.worldbank.org/
- https://www.openml.org/
- https://www.reddit.com/r/datasets/
- https://ec.europa.eu/eurostat
- https://data.humdata.org/
- https://data.cdc.gov/
- https://www.bls.gov/data/
- https://data.nasa.gov/

NEW DATASET IDEAS

Fraternal Order of Police vs Black Lives Matter

Linking finance data to ${anything_else}

Something having to do with Pokémon statistics?

Look through http://www.alexa.com/topsites and scrape something interesting!

University of Maryland-related, or College Park-related, stuff

- Check out http://umd.io/ – open source project; maybe your data collection and cleaning scripts can be added to this!

Honestly, pretty much anything! Just document everything.

Reproducibility!

FINAL TUTORIAL

Deliverable: URL of your own GitHub Pages site hosting an .ipynb/.html export of your final tutorial

- https://pages.github.com/ – make a GitHub account, too!
- https://github.com/blog/1995-github-jupyter-notebooks-3

The project itself:

- ~1500+ words of Markdown prose (excluding comments)
- ~150+ lines of Python
- Should be viewable as a **static webpage** – that is, if I (or anyone else) opens the link up, everything should render and I shouldn't have to run any cells to generate output

FINAL TUTORIAL RUBRIC

It will be graded on a scale of 1-10:

Motivation: Does the tutorial make the reader believe the topic is important (a) in general and (b) with respect to data science?

Understanding: After reading the tutorial, does the reader understand the topic?

Further resources: Does the tutorial "call out" to other resources that would help the reader understand basic concepts, deep dive, related work, etc?

Prose: Does the prose in the Markdown portion of the .ipynb add to the reader's understanding of the tutorial?

Code: Does the code help solidify understanding, is it well documented, and does it include helpful examples?

Subjective Evaluation: If somebody linked to this tutorial from Hacker News, would people actually read the whole thing?

Thanks to: John Dickerson

GRADE BREAKDOWN

Project 0 - development environment set up

20% mini-projects:

- **There are 3-4 of them**

20% Quizzes

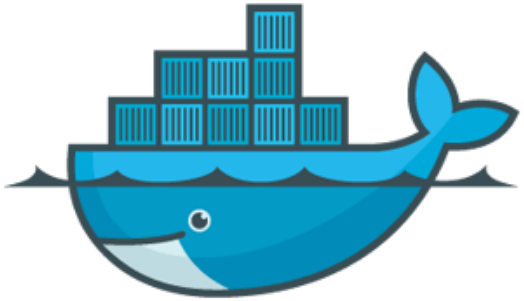
20% Midterm

20% Midterm

20% final tutorial

SOME TECHNOLOGIES WE WILL USE

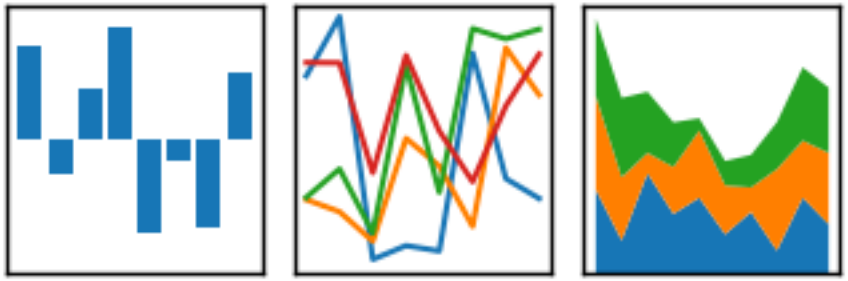
python™

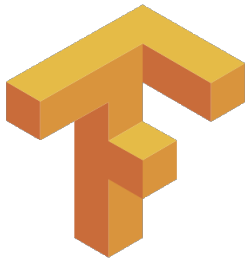


docker

pandas

$$y_{it} = \beta' x_{it} + \mu_i + \epsilon_{it}$$





IMPORTANT WALLS OF TEXT

ANTI-HARASSMENT

(Adapted from ACM SIGCOMM's policies)

Common Sense!

The open exchange of ideas and the freedom of thought and expression are central to our aims and goals. These require an environment that recognizes the inherent worth of every person and group, that fosters dignity, understanding, and mutual respect, and that embraces diversity. For these reasons, we are dedicated to providing a harassment-free experience for participants in (and out) of this class.

Harassment is unwelcome or hostile behavior, including speech that intimidates, creates discomfort, or interferes with a person's participation or opportunity for participation, in a conference, event or program.

ACADEMIC INTEGRITY

Common Sense!

(Text unironically stolen from Hal Daumé III)

Any assignment or exam that is handed in must be your own work (unless otherwise stated). However, talking with one another to understand the material better is strongly encouraged. Recognizing the distinction between cheating and cooperation is very important. If you copy someone else's solution, you are cheating. If you let someone else copy your solution, you are cheating (this includes *posting solutions online in a public place)*. If someone dictates a solution to you, you are cheating.

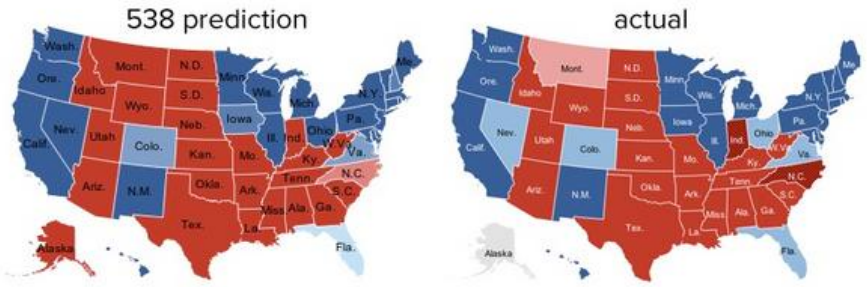
Everything you hand in must be in your own words, and based on your own understanding of the solution. If someone helps you understand the problem during a high-level discussion, you are not cheating. We strongly encourage students to help one another understand the material presented in class, in the book, and general issues relevant to the assignments. When taking an exam, you must work independently. Any collaboration during an exam will be considered cheating. Any student who is caught cheating will be given an F in the course and referred to the University Office of Student Conduct. Please don't take that chance – if you're having trouble understanding the material, please let me know and I will be more than happy to help.

(A FEW) DATA SCIENCE SUCCESS STORIES & CAUTIONARY TALES

POLLING: 2008, 2012 & 2020, 2022

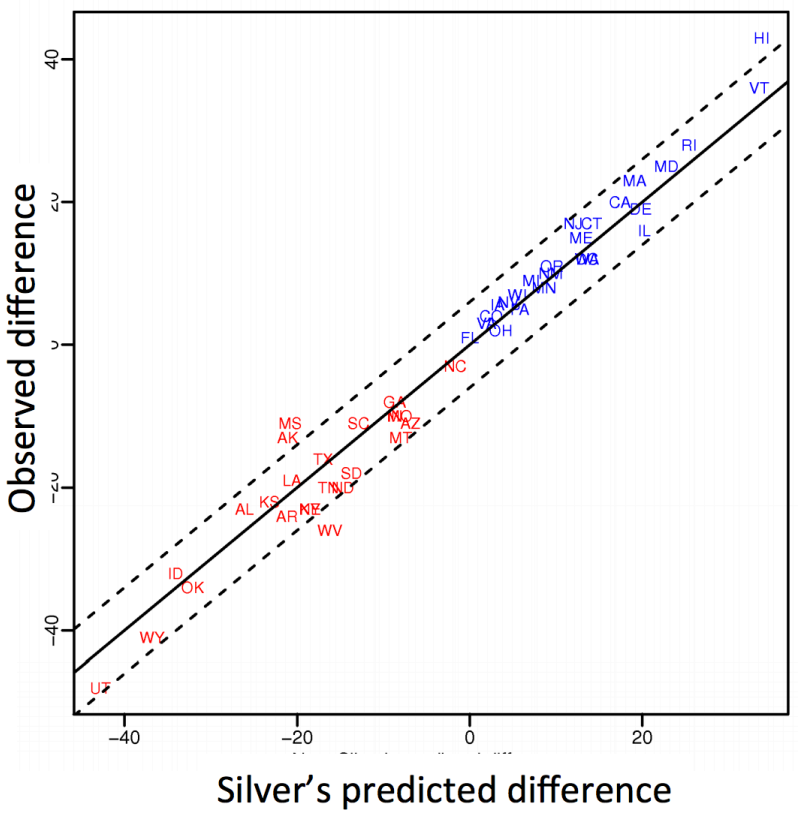
Nate Silver uses a simple idea – taking a principled approach to aggregating polling instead of relying on punditry – and:

- **Predicts 49/50 states in 2008**
- **Predicts 50/50 states in 2012**



- **(He is also a great case study in creating a brand.)**

https://hbr.org/2012/11/how-nate-silver-won-the-2012-p



Democrat (+) or Republican (-) in 2012

POLLING: 2016

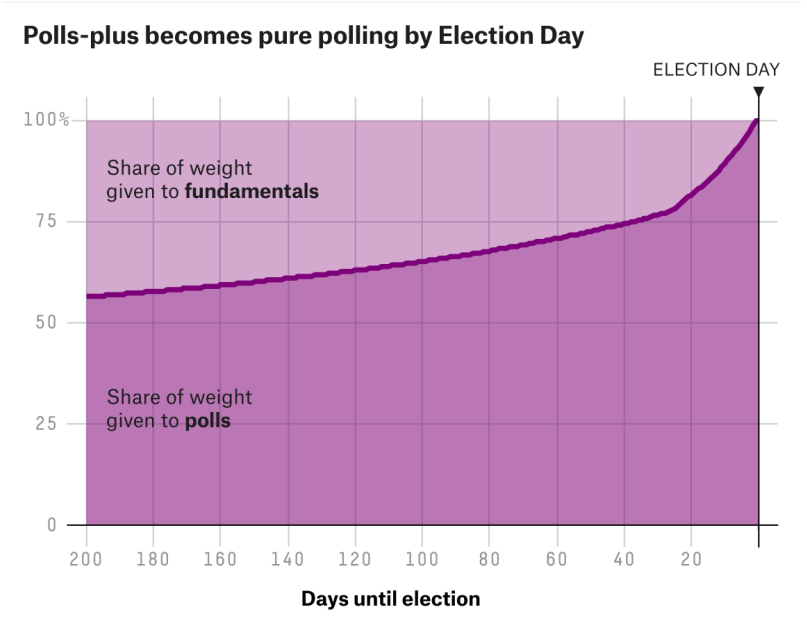
POLITICS

Nate Silver Is Unskewing Polls — All Of Them — In Trump's Direction

The vaunted 538 election forecaster is putting his thumb on the scales.

HuffPo: "He may end up being right, but he's just guessing. A "trend line adjustment" is merely political punditry dressed up as sophisticated mathematical modeling."

538: Offers quantitative reasoning for re-/under-weighting older polls, & changing as election approaches



http://www.huffingtonpost.com/entry/nate-silver-election-forecast_us_581e1c33e4b0d9ce6fbc6f7f
https://fivethirtyeight.com/features/a-users-guide-to-fivethirtyeights-2016-general-election-forecast/

AD TARGETING

Pregnancy is an expensive & habit-forming time

- **Thus, valuable to consumer-facing firms**

2012:

- **Target identifies 25 products and subsets thereof that are commonly bought in early pregnancy**
- **Uses purchase history of patrons to predict pregnancy, targets advertising for post-natal products (cribs, etc)**
- **Good: increased revenue**
- **Bad: this can expose pregnancies – as famously happened in Minneapolis to a high schooler**

https://www.forbes.com/sites/kashmirhill/2012/02/16/how-target-figured-out-a-teen-girl-was-pregnant-before-her-father-did/

AUTOMATED DECISIONS OF CONSEQUENCE

[Sweeney 2013, Miller 2015, Byrnes 2016, Rudin 2013, Barry-Jester et al. 2015, Dressel and Farid 2018]

textio

DOXA

gild

GJ GapJumpers

zest finance

LendingClub

Kabbage

PREDPOL

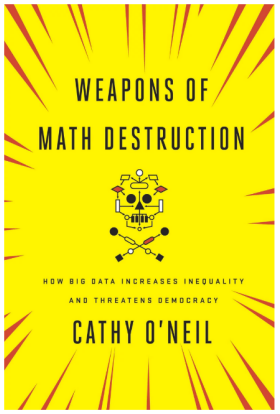
NORTHPOINTE
Advancing Justice. Embracing Community.

Hiring

Lending

Policing/ sentencing

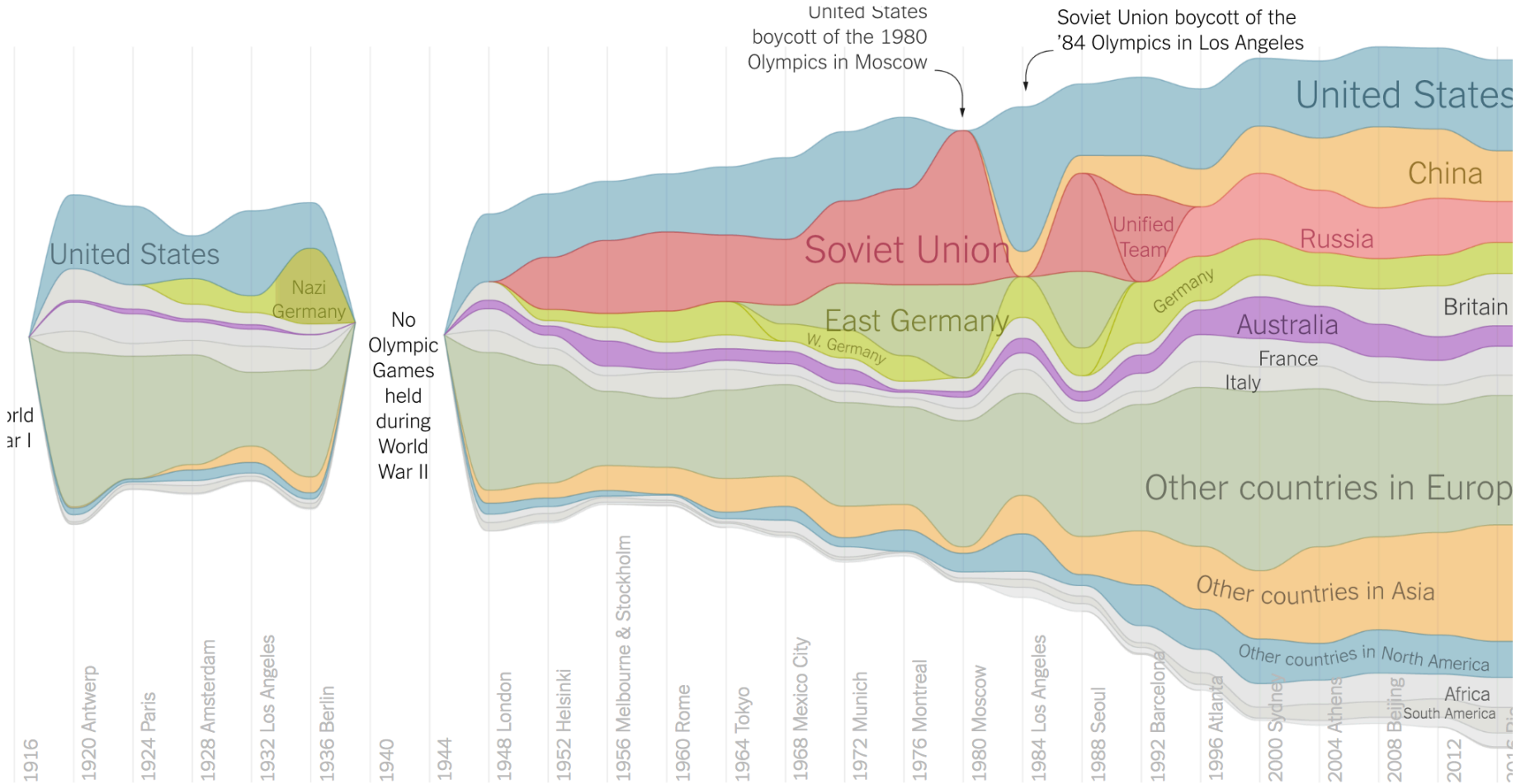
Name Discrimination Study Finds Lakisha And Jamal Still Less Likely To Get Hired Than Emily And Greg



"… a lot remains unknown about how big data-driven decisions may or may not use factors that are proxies for race, sex, or other traits that U.S. laws generally prohibit from being used in a wide range of commercial decisions … What can be done to make sure these products and services–and the companies that use them treat consumers fairly and ethically?"

- FTC Commissioner Julie Brill [2015]

OLYMPIC MEDALS



https://www.nytimes.com/interactive/2016/08/08/sports/olympics/history-olympic-dominance-charts.html

NETFLIX PRIZE I

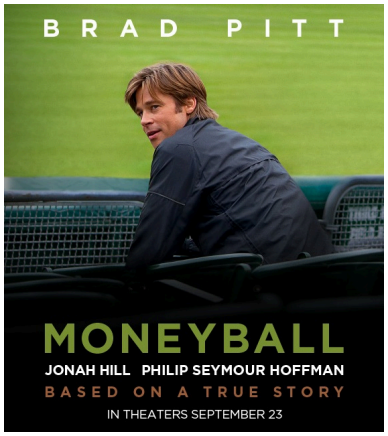
Recommender systems: predict a user's rating of an item

	Twilight	Wall-E	Twilight II	Furious 7
User 1	+1	-1	+1	?
User 2	+1	-1	?	?
User 3	-1	+1	-1	+1

Netflix Prize: $1MM to the first team that beats our in-house engine by 10%

- **Happened after about three years**
- **Model was never used by Netflix for a variety of reasons**
  - Out of date (DVDs vs streaming)
  - Too complicated / not interpretable

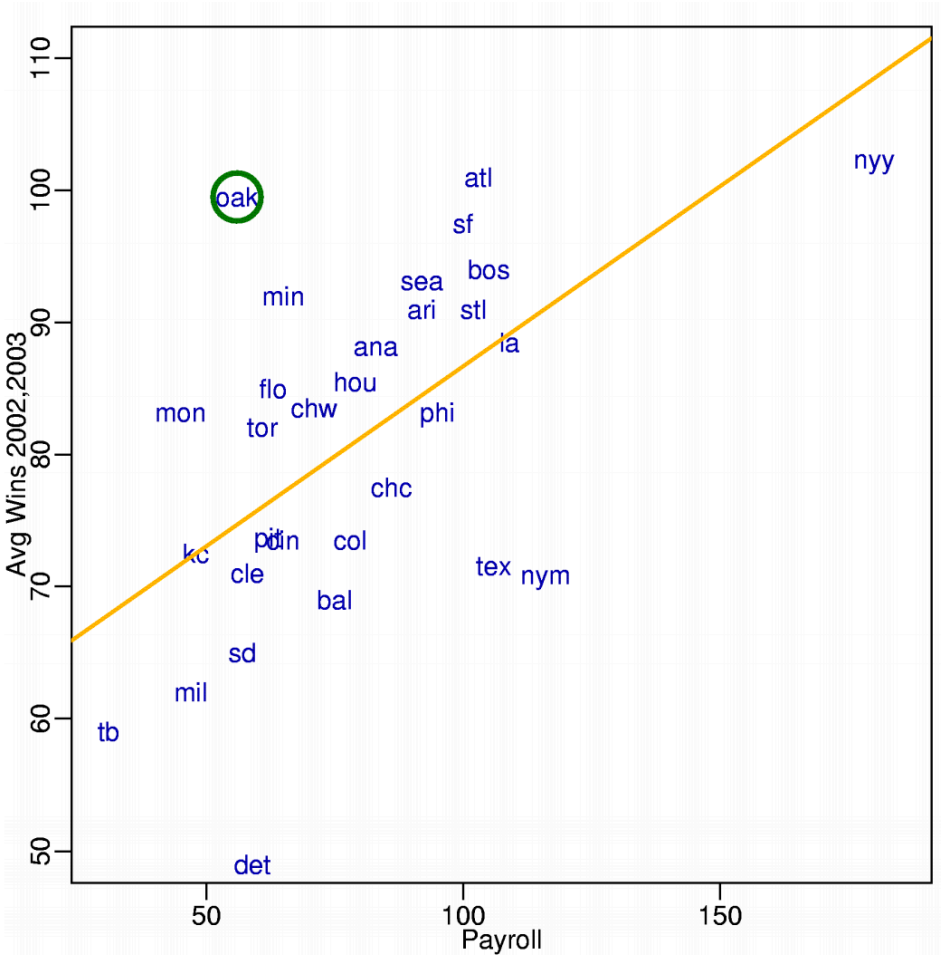
MONEYBALL



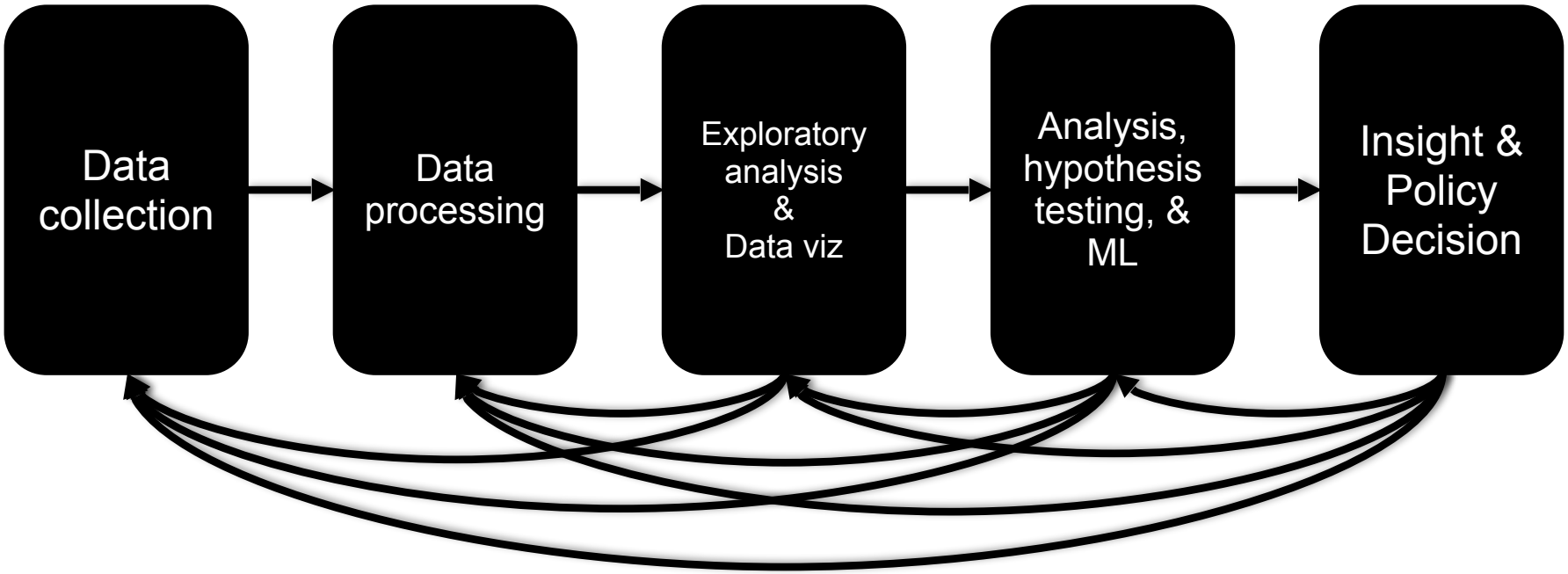
Baseball teams drafted rookie players primarily based on human scouts' opinions of their talents

Billy Bean, data scientist *du jour*, convinces the {bad, poor} Oakland Athletics to use a quantitative aka sabermetric approach to hiring

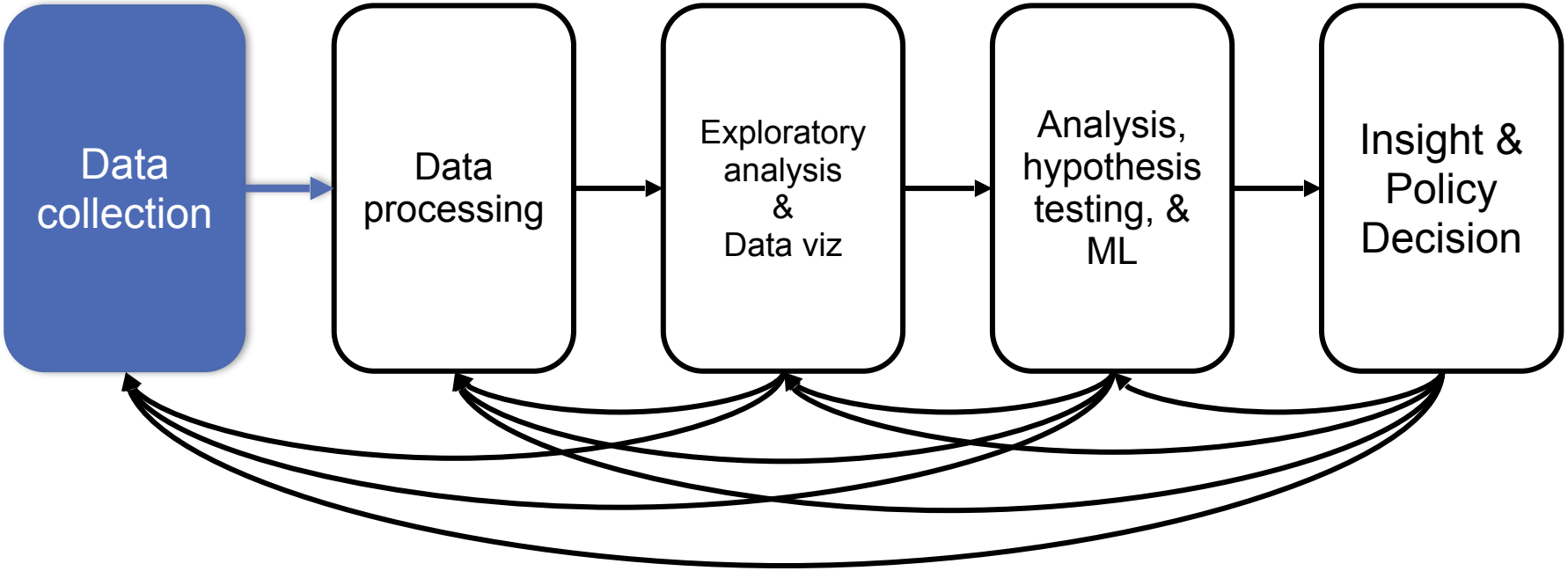
(Spoiler: Red Sox offer Bean a job, he says no, they take a sabermetric approach and win the World Series.)



THE DATA LIFECYCLE



TODAY'S LECTURE



BUT FIRST, SNAKES!

Python is an interpreted, dynamically-typed, high-level, garbage-collected, object-oriented-functional-imperative, and widely used scripting language.

- **Interpreted:** instructions executed without being compiled into (virtual) machine instructions*
- **Dynamically-typed:** verifies type safety at runtime
- **High-level:** abstracted away from the raw metal and kernel
- **Garbage-collected:** memory management is automated
- **OOF:** you can do bits of OO, F programming

Not the point of this class!

- Python is fast (developer time), intuitive, and used in industry!

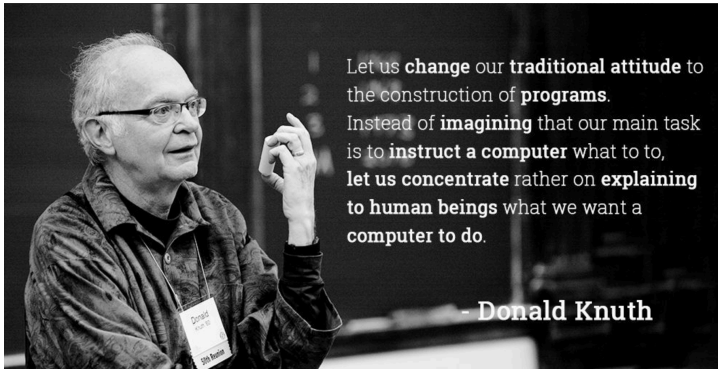
*you can compile Python source, but it's not required

THE ZEN OF PYTHON

- Beautiful is better than ugly.
- Explicit is better than implicit.
- Simple is better than complex.
- Complex is better than complicated.
- Flat is better than nested.
- Sparse is better than dense.
- Readability counts.
- Special cases aren't special enough to break the rules …
- … although practicality beats purity.
- Errors should never pass silently …
- … unless explicitly silenced.

Thanks: SDSMT ACM/LUG

LITERATE PROGRAMMING



Literate code contains in one document:

- the source code;
- text explanation of the code; and
- the end result of running the code.

Basic idea: present code in the order that logic and flow of human thoughts demand, not the machine-needed ordering

- Necessary for data science!
- Many choices made need textual explanation, ditto results.

Stuff you'll be using in Project 0 (and beyond)!

IP[y]: IPython Interactive Computing

jupyter

10-MINUTE PYTHON PRIMER

Define a function:

```
def my_func(x, y):
    if x > y:
        return x
    else:
        return y
```

Define a function that returns a tuple:

```
def my_func(x, y):
    return (x-1, y+2)

(a, b) = my_func(1, 2)
```

```
a = 0; b = 4
```

USEFUL BUILT-IN FUNCTIONS: COUNTING AND ITERATING

`len`: returns the number of items of an enumerable object

```
len( ['c', 'm', 's', 'c', 3, 2, 0] )
```

```
7
```

`range`: returns an iterable object

```
list( range(10) )
```

```
[0, 1, 2, 3, 4, 5, 6, 7, 8, 9]
```

`enumerate`: returns iterable tuple (index, element) of a list

```
enumerate( ["311", "320", "330"] )
```

```
[(0, "311"), (1, "320"), (2, "330")]
```

https://docs.python.org/3/library/functions.html

USEFUL BUILT-IN FUNCTIONS: MAP AND FILTER

`map`: apply a function to a sequence or iterable

```
arr = [1, 2, 3, 4, 5]
map(lambda x: x**2, arr)
```

```
[1, 4, 9, 16, 25]
```

`filter`: returns a list of elements for which a predicate is true

```
arr = [1, 2, 3, 4, 5, 6, 7]
filter(lambda x: x % 2 == 0, arr)
```

```
[2, 4, 6]
```

We'll go over in much greater depth with pandas/numpy.

PYTHONIC PROGRAMMING

Basic iteration over an array in Java:

```
int[] arr = new int[10];
for(int idx=0; idx<arr.length; ++idx) {
    System.out.println( arr[idx] );
}
```

Direct translation into Python:

```
idx = 0
while idx < len(arr):
    print( arr[idx] ); idx += 1
```

A more “Pythonic” way of iterating:

```
for element in arr:
    print( element )
```

LIST COMPREHENSIONS

Construct sets like a mathematician!

- ***P*** **= { 1, 2, 4, 8, 16, …,** 2^{16} **}**
- ***E*** **= {** ***x*** **|** ***x*** **in** $\mathbb{N}$ **and** ***x*** **is odd and** ***x*** **< 1000 }**

Construct lists like a mathematician who codes!

```
P = [ 2**x for x in range(17) ]
```

```
E = [ x for x in range(1000) if x % 2 != 0 ]
```

- **You'll see these way more than `map` in the wild**
- **Many people consider `map`/`filter` not "pythonic"**
- **They can perform differently (`map` is "lazier")**

EXTRA RESOURCES

Plenty of tutorials on the web:

- https://www.learnpython.org/

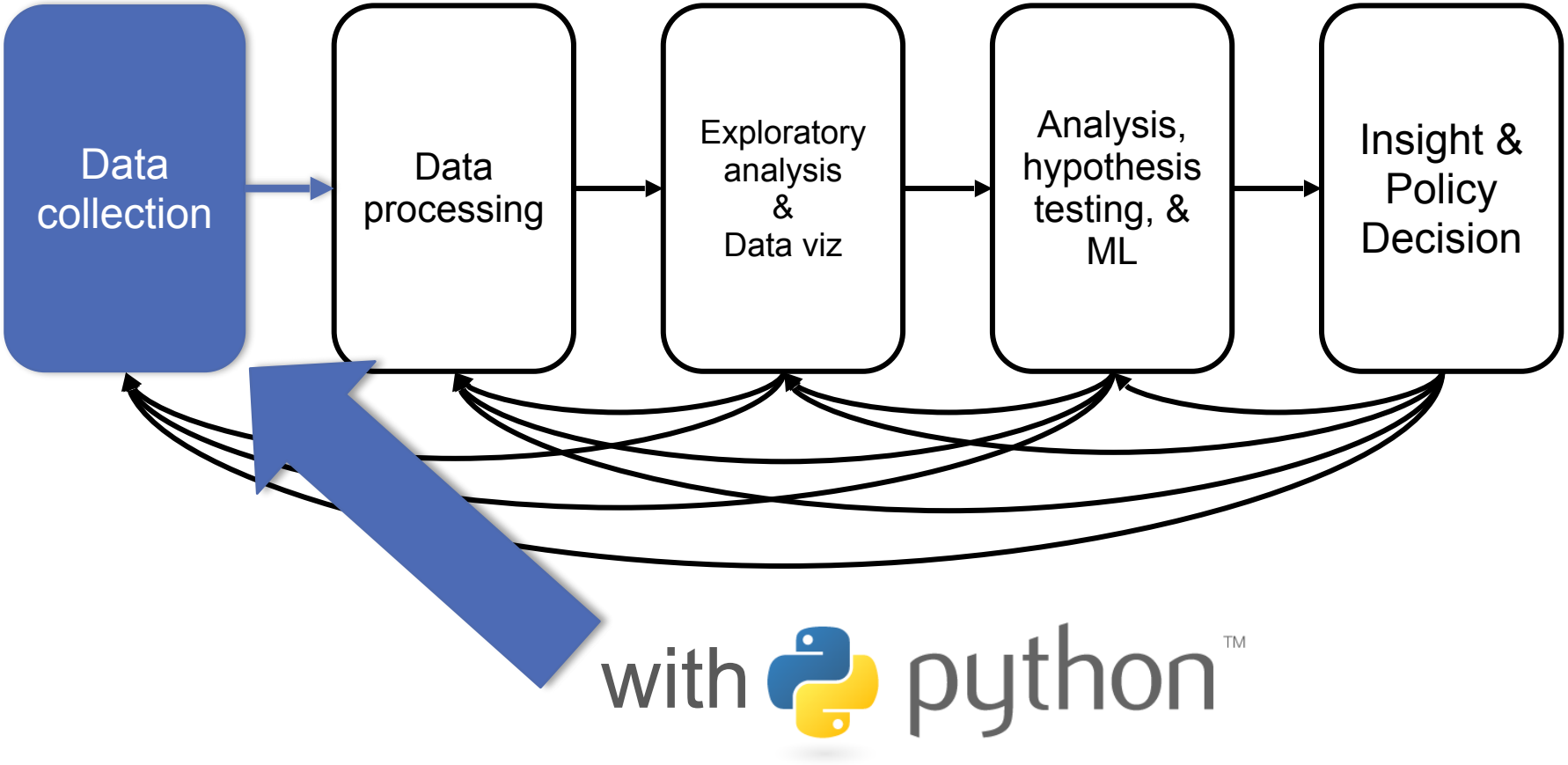
Work through Project 0, which will take you through some baby steps with Python and the Pandas library:

- (We'll also post some readings soon.)

Come hang out at office hours

- Office hours are on the website.
- Also, email me – if it doesn't fit your schedules.

TODAY'S LECTURE



Thanks: Zico Kolter's 15-388

GOTTA CATCH 'EM ALL

Five ways to get data:

- **Direct download and load from local storage**
- **Generate locally via downloaded code (e.g., simulation)**
- **Query data from a database (covered in a few lectures)**
- **Query an API from the intra/internet**
- **Scrape data from a webpage**

} Covered today.

WHEREFORE ART THOU, API?

A web-based Application Programming Interface (API) like we'll be using in this class is a contract between a server and a user stating:

> **"If you send me a specific request, I will return some information in a structured and documented format."**

(More generally, APIs can also perform actions, may not be web-based, be a set of protocols for communicating between processes, between an application and an OS, etc.)

“SEND ME A SPECIFIC REQUEST”

Most web API queries we’ll be doing will use HTTP requests:

- `conda install –c anaconda requests=2.21.0`

```
r = requests.get(   ‘cmsc webpages website url’ )
```

```
r.status_code
```

```
200
```

```
r.headers[‘content-type’]
```

```
'text/html'
```

```
r.content
```

```
b'<!DOCTYPE html>\n<html lang="en">\n\n  <head>\n\n    <meta charset="utf-8">\n
<meta name="viewport" ……
```

http://docs.python-requests.org/en/master/

HTTP REQUESTS

https://www.google.com/**?q=msml602&tbs=qdr:m**

??????????

HTTP GET Request:

GET /?q=cmsc320&tbs=qdr:m HTTP/1.1
Host: www.google.com
User-Agent: **Mozilla/5.0 (X11; Linux x86_64; rv:10.0.1) Gecko/20100101 Firefox/10.0.1**

```
params = { “q”: “msml602”, “tbs”: “qdr:m” }
r = requests.get(    “https://www.google.com”,
                     params = params )
```

*be careful with https:// calls; `requests` will not verify SSL by default

RESTFUL APIS

This class will just query web APIs, but full web APIs typically allow more.

Representational State Transfer (RESTful) APIs:

- GET: perform query, return data
- POST: create a new entry or object
- PUT: update an existing entry or object
- PATCH: partially update an existing entry or object
- DELETE: delete an existing entry or object

Can be more intricate, but verbs ("put") align with actions

QUERYING A RESTFUL API

Stateless: with every request, you send along a token/ authentication of who you are

```
token = "super_secret_token"
r = requests.get("https://github.com/user",
                 params={"access_token": token})
print( r.content )
```

```
{"login":"Mohammad Nayeem
Teli","id":10536112,"avatar_url":"ht…
```

- PUT/POST/DELETE can edit your repositories, etc.
- Try it out: https://github.com/settings/tokens/new

RESTFUL APIS - STATUS CODE

Representational State Transfer (RESTful) APIs status code:

- 200: request action was successful
- 201: A new resource was created.
- 202: request received but no modification made.
- 204: request was successful, but response has no content
- 400: request was malformed
- 401: the client is not authorized
- 404: requested resource was not found
- 415: requested data format is not supported
- 422: requested data format had missing data
- 500: server threw an error while processing

AUTHENTICATION AND OAUTH

Old and busted:

```
r = requests.get("https://api.github.com/user",
                 auth=("nayeemmz", "database name"))
```

New Approach:

- What if I wanted to grant an app access to, e.g., my Facebook account without giving that app my password?
- OAuth: grants access tokens that give (possibly incomplete) access to a user or app without exposing a password

"... I WILL RETURN INFORMATION IN A STRUCTURED FORMAT."

So we've queried a server using a well-formed GET request via the `requests` Python module. What comes back?

General structured data:

- Comma-Separated Value (CSV) files & strings
- Javascript Object Notation (JSON) files & strings
- HTML, XHTML, XML files & strings

Domain-specific structured data:

- Shapefiles: geospatial vector data (OpenStreetMap)
- RVT files: architectural planning (Autodesk Revit)
- You can make up your own! Always document it.

CSV FILES IN PYTHON

Any CSV reader worth anything can parse files with any delimiter, not just a comma (e.g., “TSV” for tab-separated)

1,28-May,Introduction,—,"pdf, pptx",Teli,
2,29-May,Scraping Data with Python,Anaconda's Test Drive.,,Teli,
3,30-May,"Vectors, Matrices, and Dataframes",Introduction to pandas.,,Teli,
4,31-May,Jupyter notebook lab,,,”Hanyu, Jue”,

Don’t write your own CSV or JSON parser

```
import csv
with open(“schedule.csv”, ”rb”) as f:
    reader = csv.reader(f, delimiter=“,”, quotechar=’”’)
    for row in reader:
        print(row)
```

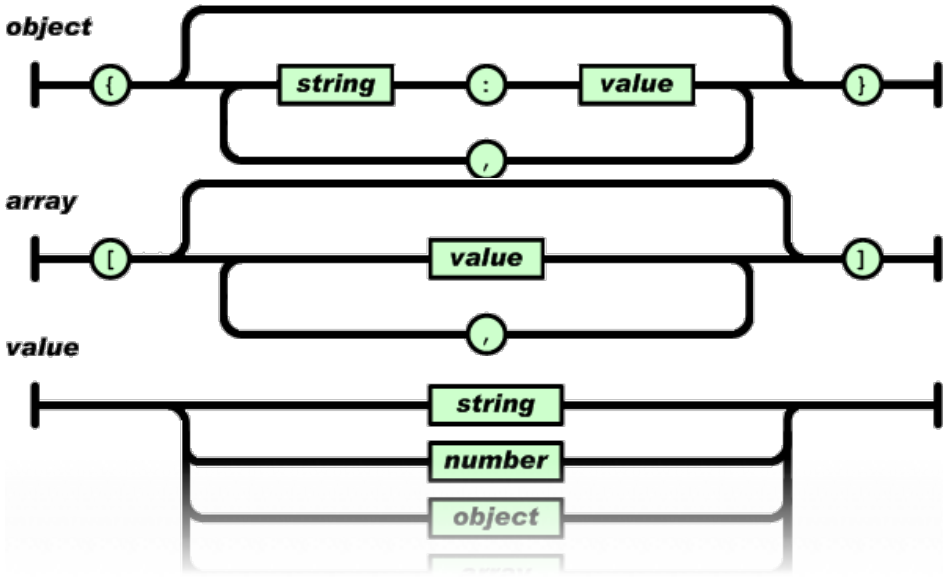
JSON FILES & STRINGS

JSON is a method for serializing objects:

- Convert an object into a string
- Deserialization converts a string back to an object

Easy for humans to read (and sanity check, edit)

Defined by three universal data structures



Python dictionary, Java Map, hash table, etc …

Python list, Java array, vector, etc …

Python string, float, int, boolean, JSON object, JSON array, …

Images from: http://www.json.org/

JSON IN PYTHON

Some built-in types: `"Strings", 1.0, True, False, None`

Lists: `["Goodbye", "Cruel", "World"]`

Dictionaries: `{"hello": "bonjour", "goodbye", "au revoir"}`

Dictionaries within lists within dictionaries within lists:

```
[1, 2, {"Help":[
                "I'm", {"trapped": "in"},
                "CMSC641"
                ]}]
```

JSON FROM TWITTER

```
GET https://api.twitter.com/1.1/friends/list.json?
cursor=-1&screen_name=twitterapi&skip_status=true&include_user_
entities=false
```


```
{
      "previous_cursor": 0,
      "previous_cursor_str": "0",
      "next_cursor": 1333504313713126852,
      "users": [{
            "profile_sidebar_fill_color": "252429",
            "profile_sidebar_border_color": "181A1E",
            "profile_background_tile": false,
            "name": "Sylvain Carle",
            "profile_image_url": "http://a0.twimg.com/profile_images/
 2838630046/4b82e286a659fae310012520f4f756bb_normal.png",
            "created_at": "Thu Jan 18 00:10:45 +0000 2007", …
```

PARSING JSON IN PYTHON

Repeat: don't write your own CSV or JSON parser

- https://news.ycombinator.com/item?id=7796268
- rsdy.github.io/posts/dont_write_your_json_parser_plz.html

Python comes with a fine JSON parser

```
import json

r = requests.get(
    'https://api.github.com/search/repositories',
    params={'q': 'users'},
)
data = json.loads(r.content)
```

```
json.load(some_file)  # loads JSON from a file
json.dump(json_obj, some_file)  # writes JSON to file
json.dumps(json_obj)  # returns JSON string
```

XML, XHTML, HTML FILES AND STRINGS

Still hugely popular online, but JSON has essentially replaced XML for:

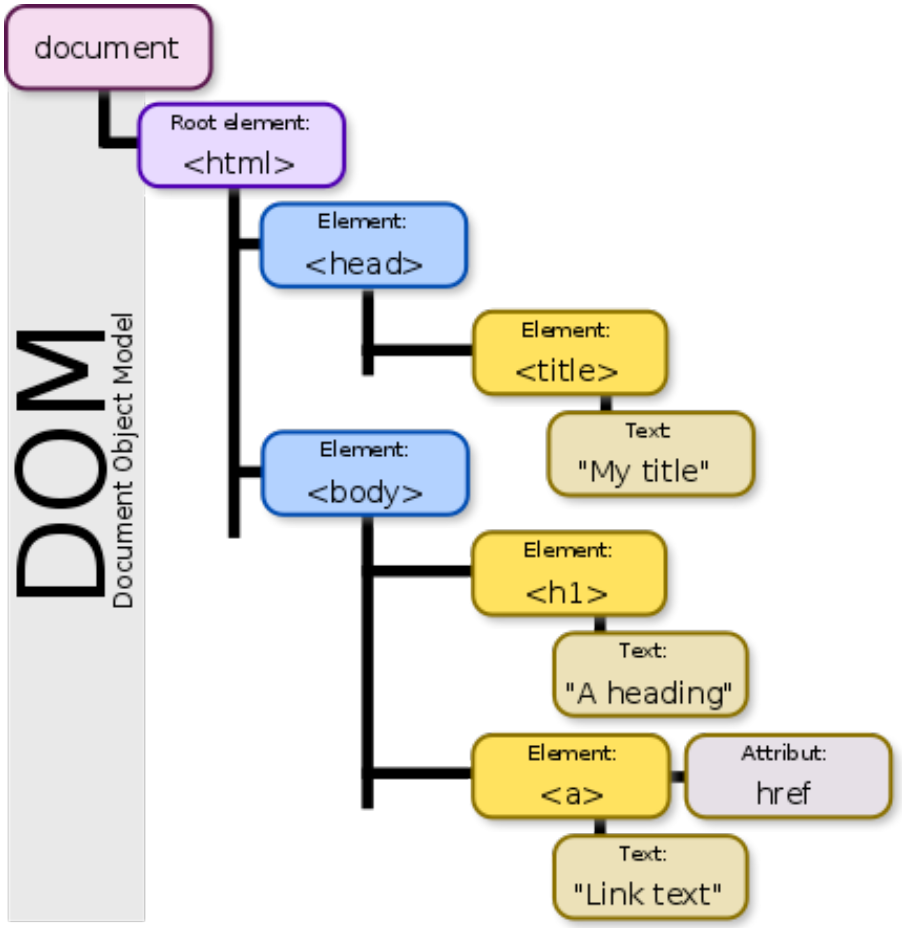
- Asynchronous browser ←→ server calls
- Many (most?) newer web APIs

XML is a hierarchical markup language:

```
<tag attribute="value1">
        <subtag>
                Some cool words or values go here!
        </subtag>
        <openclosetag attribute="value2" />
</tag>
```

You probably won't see much XML, but you will see plenty of HTML, its substantially less well-behaved cousin …

DOCUMENT OBJECT MODEL (DOM)



SCRAPING HTML IN PYTHON

HTML – the specification – is fairly pure

HTML – what you find on the web – is horrifying

We'll use BeautifulSoup:

- `conda install -c asmeurer beautiful-soup=4.3.2`

```
import requests
from bs4 import BeautifulSoup

r = requests.get( "https://www.cs.umd.edu/class/
fall2025/cmsc422-0101/" )

root = BeautifulSoup( r.content )
root.findAll("a")  # links for CMSC422
```

BUILDING A WEB SCRAPER IN PYTHON

Totally not hypothetical situation:

- You really want to learn about data science, so you choose to download all of last semester's CMSC422 lecture slides to wallpaper your room …
- … but you now have carpal tunnel syndrome from clicking refresh on Piazza last night, and can no longer click on the PDF and PPTX links.

Hopeless? No! Earlier, you built a scraper to do this!

```
lnks = root.findAll("a")  # links for CMSC422
```

Sort of. You only want PDF and PPTX files, not links to other websites or files.

REGULAR EXPRESSIONS

Given a list of URLs (strings), how do I find only those strings that end in *.pdf or *.pptx?

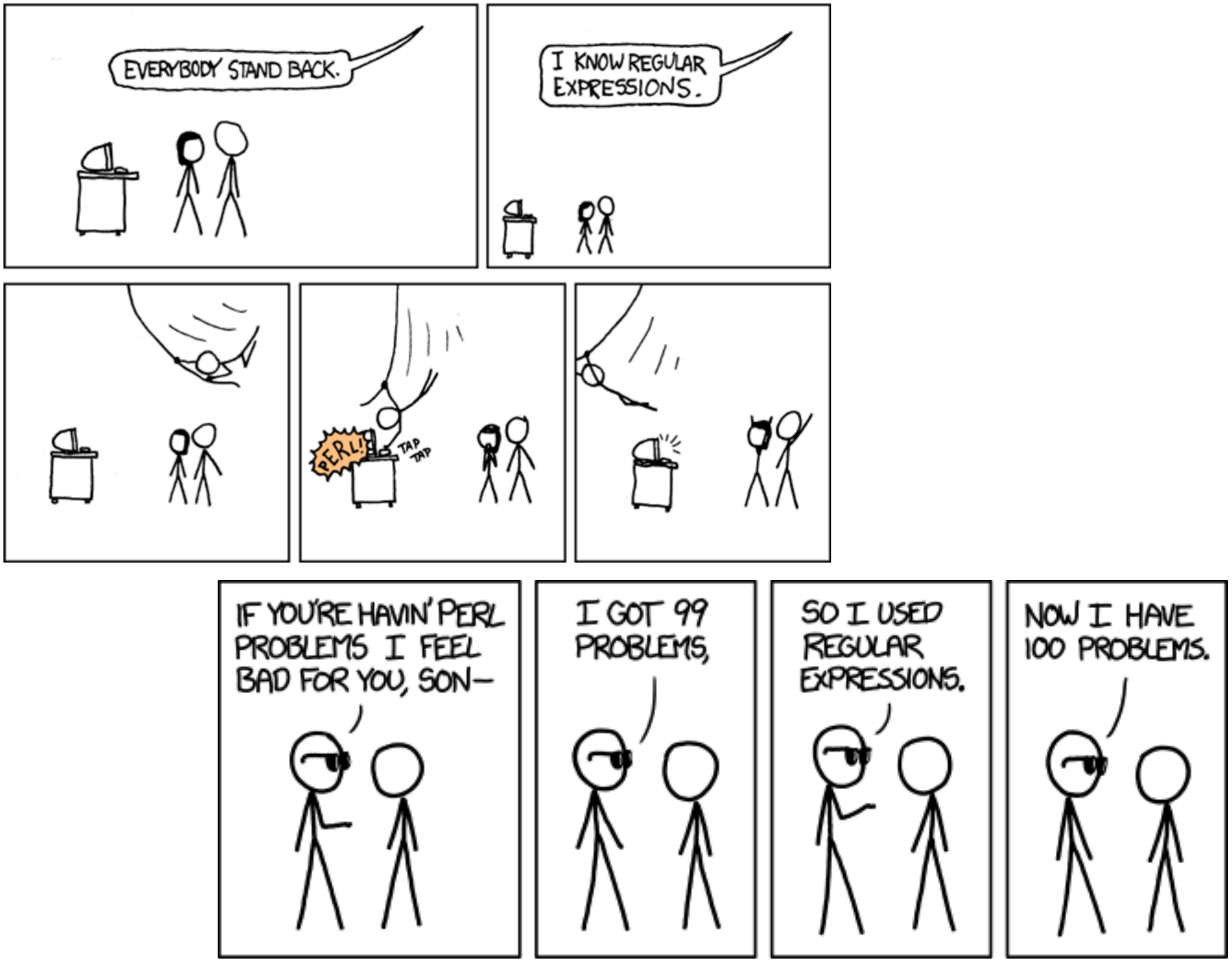
- Regular expressions!
- (Actually Python strings come with a built-in `endswith` function.)

```
"this_is_a_filename.pdf".endswith((".pdf", ".pptx"))
```

What about .pDf or .pPTx, still legal extensions for PDF/PPTX?

- Regular expressions!
- (Or cheat the system again: built-in string `lower` function.)

```
"tHiS_IS_a_FileNAme.pDF".lower().endswith(
                                    (".pdf", ".pptx"))
```


EVERYBODY STAND BACK.
I KNOW REGULAR EXPRESSIONS.
PERL!
TAP TAP
IF YOU'RE HAVIN' PERL PROBLEMS I FEEL BAD FOR YOU, SON—
I GOT 99 PROBLEMS,
SO I USED REGULAR EXPRESSIONS.
NOW I HAVE 100 PROBLEMS.

REGULAR EXPRESSIONS

Used to search for specific elements, or groups of elements, that match a pattern

```
import re

# Find the index of the 1st occurrence of "cmsc641"
match = re.search(r"cmsc122", text)
print( match.start() )
```

```
# Does start of text match "cmsc122"?
match = re.match(r"cmsc122", text)
```

```
# Iterate over all matches for "cmsc122" in text
for match in re.finditer(r"cmsc122", text):
    print( match.start() )
```

```
# Return all matches of "cmsc122" in the text
match = re.findall(r"cmsc122", text)
```

MATCHING MULTIPLE CHARACTERS

Can match sets of characters, or multiple and more elaborate sets and sequences of characters:

- Match the character ‘a’: `a`
- Match the character ‘a’, ‘b’, or ‘c’: `[abc]`
- Match any character except ‘a’, ‘b’, or ‘c’: `[^abc]`
- Match any digit: `\d` (= `[0123456789]` or `[0-9]`)
- Match any alphanumeric: `\w` (= `[a-zA-Z0-9_]`)
- Match any whitespace: `\s` (= `[ \t\n\r\f\v]`)
- Match any character: `.`

Special characters must be escaped: `.^$*+?{}\[]|()`

MATCHING SEQUENCES AND REPEATED CHARACTERS

A few common modifiers (available in Python and most other high-level languages; +, {n}, {n,} *may* not):

- Match character ‘a’ exactly once: `a`
- Match character ‘a’ zero or once: `a?`
- Match character ‘a’ zero or more times: `a*`
- Match character ‘a’ one or more times: `a+`
- Match character ‘a’ exactly *n* times: `a{n}`
- Match character ‘a’ at least n times: `a{n,}`

Example: match all instances of “University of <somewhere>” where <somewhere> is an alphanumeric string with at least 3 characters:

- `\s*University\sof\s\w{3,}`

COMPILED REGEXES

If you're going to reuse the same regex many times, or if you aren't but things are going slowly for some reason, try compiling the regular expression.

- https://blog.codinghorror.com/to-compile-or-not-to-compile/

```
# Compile the regular expression "cmsc320"
regex = re.compile(r"cmsc122")

# Use it repeatedly to search for matches in text
regex.match( text )    # does start of text match?
regex.search( text )   # find the first match or None
regex.findall( text )  # find all matches
```

DOWNLOADING A BUNCH OF FILES

Import the modules

```
import re
import requests
from bs4 import BeautifulSoup
try:
    from urllib.parse import urlparse
except ImportError:
    from urlparse import urlparse
```

Get some HTML via HTTP

```
# HTTP GET request sent to the URL url
r = requests.get( url )

# Use BeautifulSoup to parse the GET response
root = BeautifulSoup( r.content )
lnks = root.find("div", id="schedule")\
           .find("table")\
           .find("tbody").findAll("a")
```

DOWNLOADING A BUNCH OF FILES

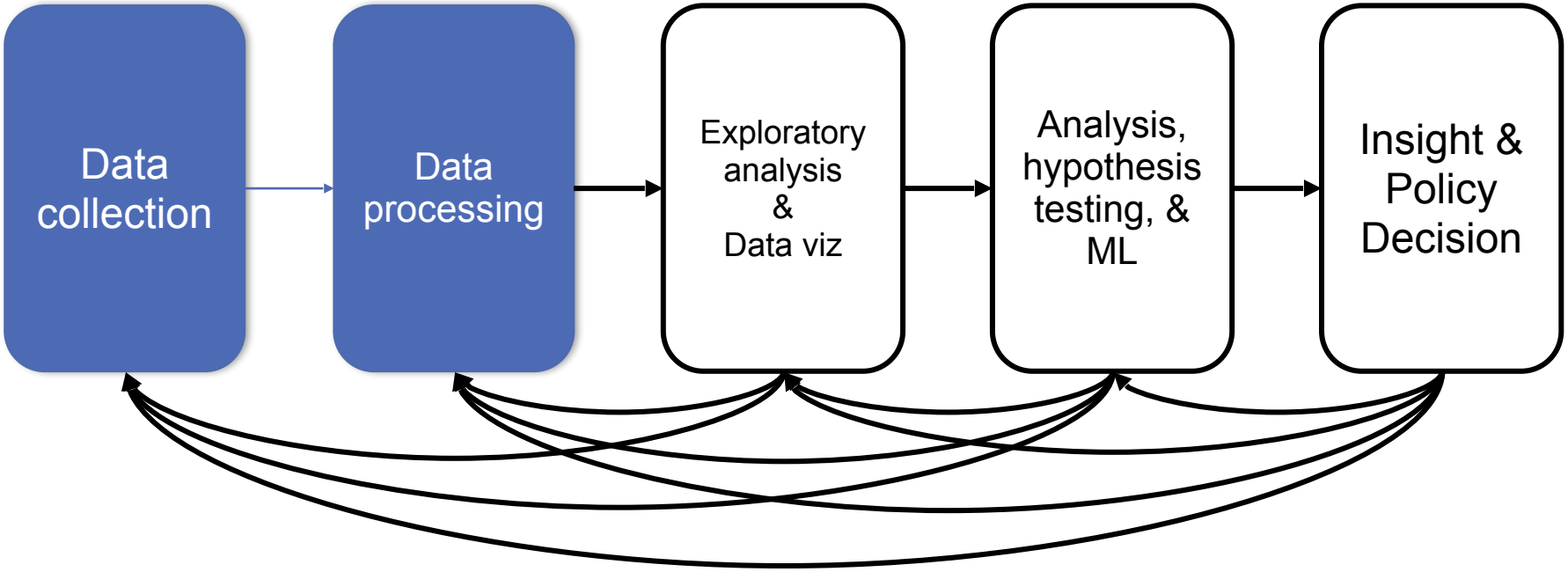
Parse exactly what you want

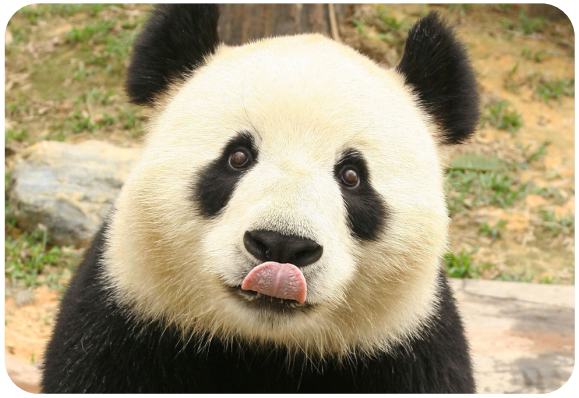
```
# Cycle through the href for each anchor, checking
# to see if it's a PDF/PPTX link or not
for lnk in lnks:
    href = lnk['href']

    # If it's a PDF/PPTX link, queue a download
    if href.lower().endswith(('.pdf', '.pptx')):
```

Get some more data?!

```
        urld = urlparse.urljoin(url, href)
        rd = requests.get(urld, stream=True)

        # Write the downloaded PDF to a file
        outfile = path.join(outbase, href)
        with open(outfile, 'wb') as f:
            f.write(rd.content)
```

NEXT LECTURE





NEXT CLASS:

NUMPY, SCIPY, AND DATAFRAMES

pandas

$$y_{it} = \beta' x_{it} + \mu_i + \epsilon_{it}$$