

INTRODUCTION TO DATA SCIENCE

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Lecture #3 – 09/07/2021

CMSC320

Tuesdays & Thursdays

5:00pm – 6:15pm

<https://cmsc320.github.io/>



COMPUTER SCIENCE

UNIVERSITY OF MARYLAND

ANNOUNCEMENTS

Register on Piazza: piazza.com/umd/fall2021/cmssc320

- 288 have registered already
- Some have not registered yet

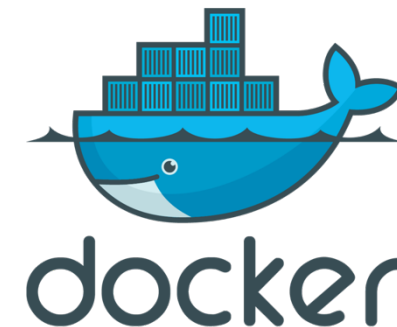


If you were on Piazza, you'd know ...

- **Project 0 is out!** And is also “due” today. **(Worth zero points!)**
- Link: <https://github.com/cmssc320/fall2021/tree/master/project0>

We've also linked some reading for the week!

- Second **quiz** is due Tuesday at noon; on ELMS now.



ANNOUNCEMENTS

Quiz #1, Question #7 caused some issues:

Question 7 1 pts

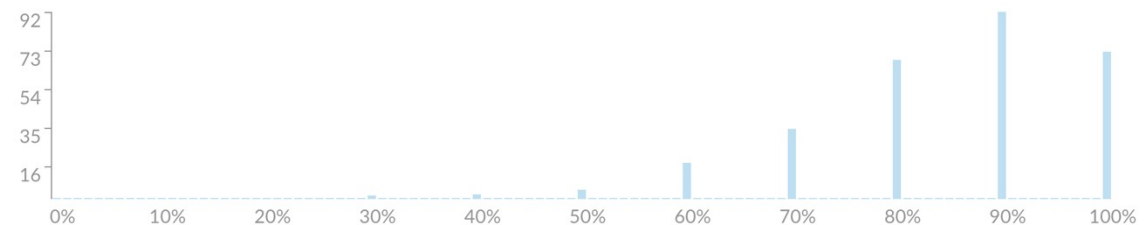
Use NumPy, imported as `np`, as well as `np.arange` to create the following array:

```
array([10, 16, 22, 28, 34])
```

(Do not include spaces in your answer.)

Multiple correct answers, my key missed some of them; let me know if this made difference between passing and failing

Average Score	High Score	Low Score	Standard Deviation	Average Time
85%	100%	30%	1.32	06:33:61



ANNOUNCEMENTS

Office hours will be posted tonight course webpage:

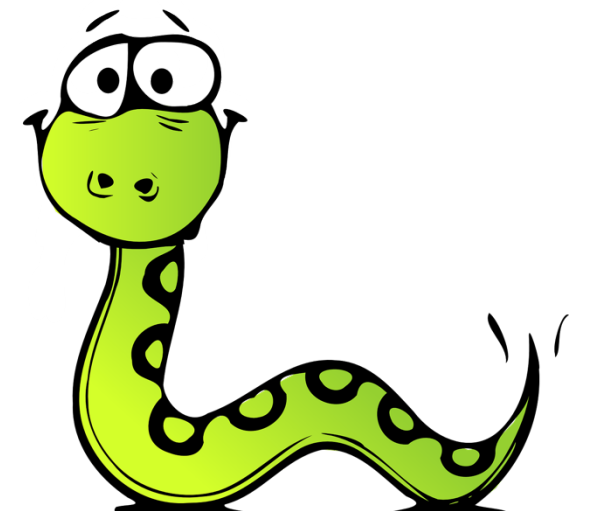
- <https://cmssc320.github.io/>
- Subject to change; I will update the course webpage if so!

Office hours are held in person or via Zoom – TAs to provide details in the future, on Piazza, will keep Piazza updated as well.

We have coverage for every weekday (MTWThF).

- TAs will also “cover” Piazza for the working hours of the day on which they are holding office hours.

VERY SHORT WRAP-UP ON “PYTHON STUFF” FROM LAST LECTURE ...



PYTHON 2 VS 3

Python 3 is intentionally **backwards incompatible**

- (But not *that* incompatible)

Biggest changes that matter for us:

- `print "statement"` → `print("function")`
- `1/2 = 0` → `1/2 = 0.5` and `1//2 = 0`
- ASCII str default → default Unicode

Namespace ambiguity fixed:

```
i = 1
[i for i in range(5)]
print(i)    # ????????
```

Python 2: prints "4"; Python 3: prints "1" (narrow scope)

TO ANY CURMUDGEONS ...

If you're going to use Python 2 anyway, use the `_future_` module:

- Python 3 introduces features that will throw runtime errors in Python 2 (e.g., `with` statements)
- `_future_` module incrementally brings 3 functionality into 2
- https://docs.python.org/2/library/__future__.html

```
from _future_ import division
from _future_ import print_function
from _future_ import please_just_use_python_3
```

SO, HOW DOES IMPORT WORK?

Python code is stored in **module** – simply put, a file full of Python code

A **package** is a directory (tree) full of modules that also contains a file called `__init__.py`

- Packages let you structure Python's module namespace
- E.g., `x.y` is a submodule `y` in a package named `x`

For one module to gain access to code in another module, it must **import** it

```
sound/
  __init__.py
  formats/
    __init__.py
    wavread.py
    wavwrite.py
    aiffread.py
    aiffwrite.py
    auread.py
    auwrite.py
    ...
  effects/
    __init__.py
    echo.py
    surround.py
    reverse.py
    ...
  filters/
    __init__.py
    equalizer.py
    vocoder.py
    karaoke.py
    ...
```

Top-level **package**
Initialize the sound **package**
Sub**package** for file format conversions

Sub**package** for sound effects

Sub**package** for filters

```
# Load (sub)module sound.effects.echo
import sound.effects.echo
# Must use full name to reference echo functions
sound.effects.echo.echofilter(input, output, delay=0.7)
```


EXAMPLE

```
# Load (sub)module sound.effects.echo
import sound.effects.echo
# Must use full name to reference echo functions
sound.effects.echo.echofilter(input, output, delay=0.7)
```

```
# Load (sub)module sound.effects.echo
from sound.effects import echo
# No longer need the package prefix for functions in echo
echo.echofilter(input, output, delay=0.7)
```

```
# Load a specific function directly
from sound.effects.echo import echofilter
# Can now use that function with no prefix
echofilter(input, output, delay=0.7)
```

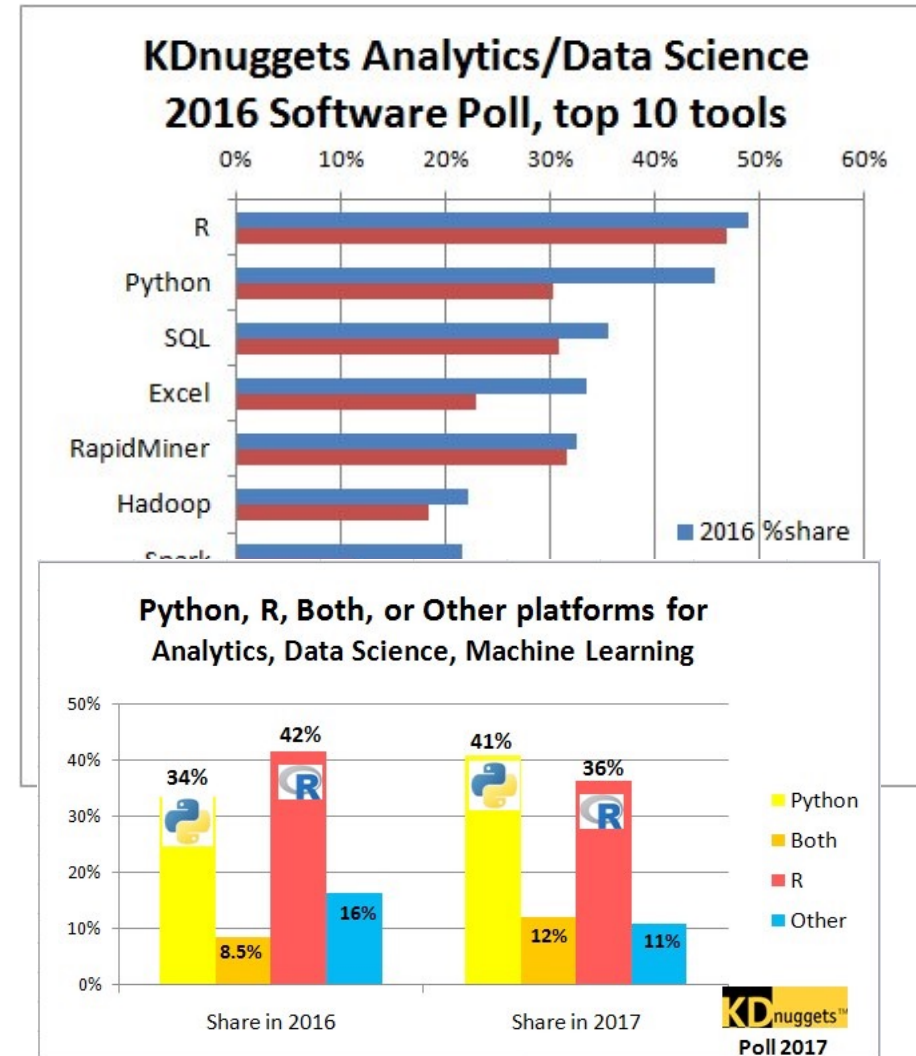
PYTHON VS R (FOR DATA SCIENTISTS)

There is no right answer here!

- Python is a “full” programming language – easier to integrate with systems in the field
- R has a more mature set of pure stats libraries ...
- ... but Python is catching up quickly ...
- ... and is already ahead **specifically for ML.**

You will see Python more in the tech industry.

- <https://insights.stackoverflow.com/survey/2021>



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:

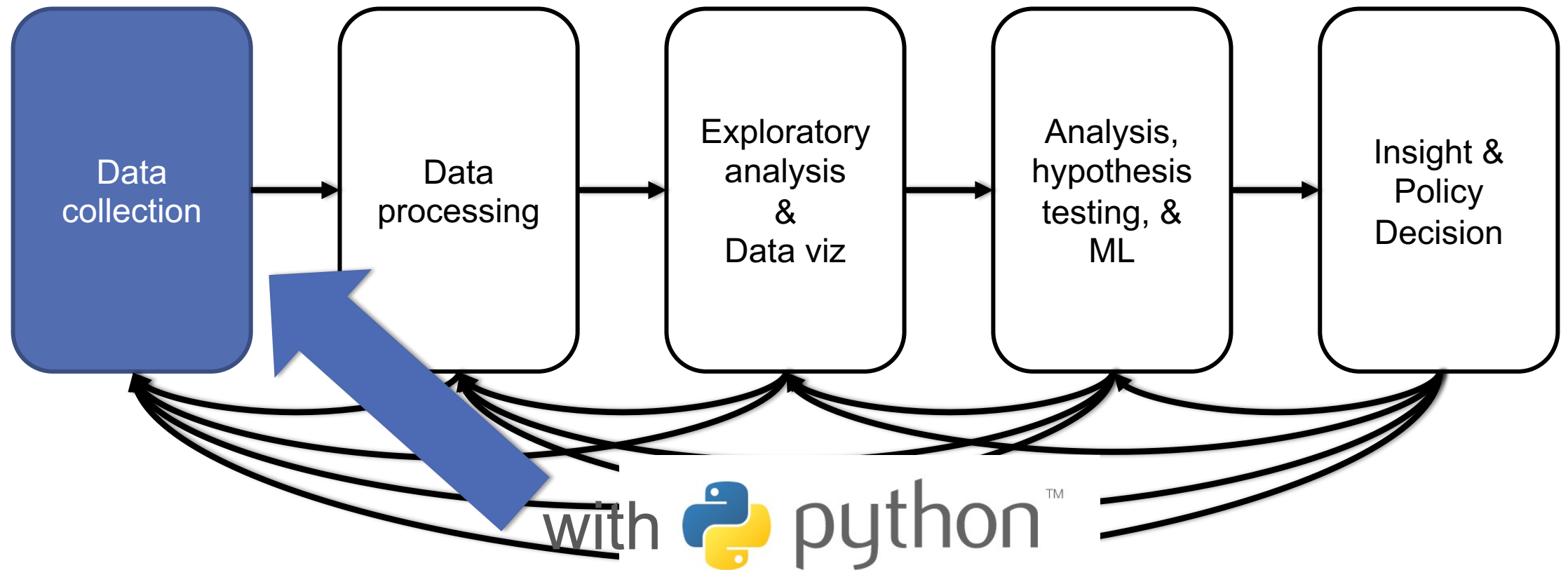
- (We'll also post some more readings soon.)

Come (virtually?) hang out at office hours:

- All office hours will be on the website/Piazza by tonight.
- Will have coverage MTWThF.



TODAY'S LECTURE





Data - Wikipedia en.wikipedia.org



Data - Wikipedia en.wikipedia.org



Data vs Information | Comparison and ... svitla.com



to Extract Value from Customer Data ... digitalmarketinginstitute.com



Big Data is not about the Data, but the ... clevertap.com



Data management made simple nature.com



What is Data: Types of Data, and How To ... simplilearn.com



What is Big Data? Let's answer this ... towardsdatascience.com



Big Data and Privacy: What You Need to ... informatica.com



Data, Stupid ... datanami.com

WHAT IS THIS "DATA"?

TABULAR DATA

Quick teaser. We'll go into greater depth when discussing tidy data.

Data is an abstraction of some real world entity.

- Also called: instance, example, record, object, case, individual.

Each of these entities is described by a set of features.

- Sometimes called variables, features, attributes, ...

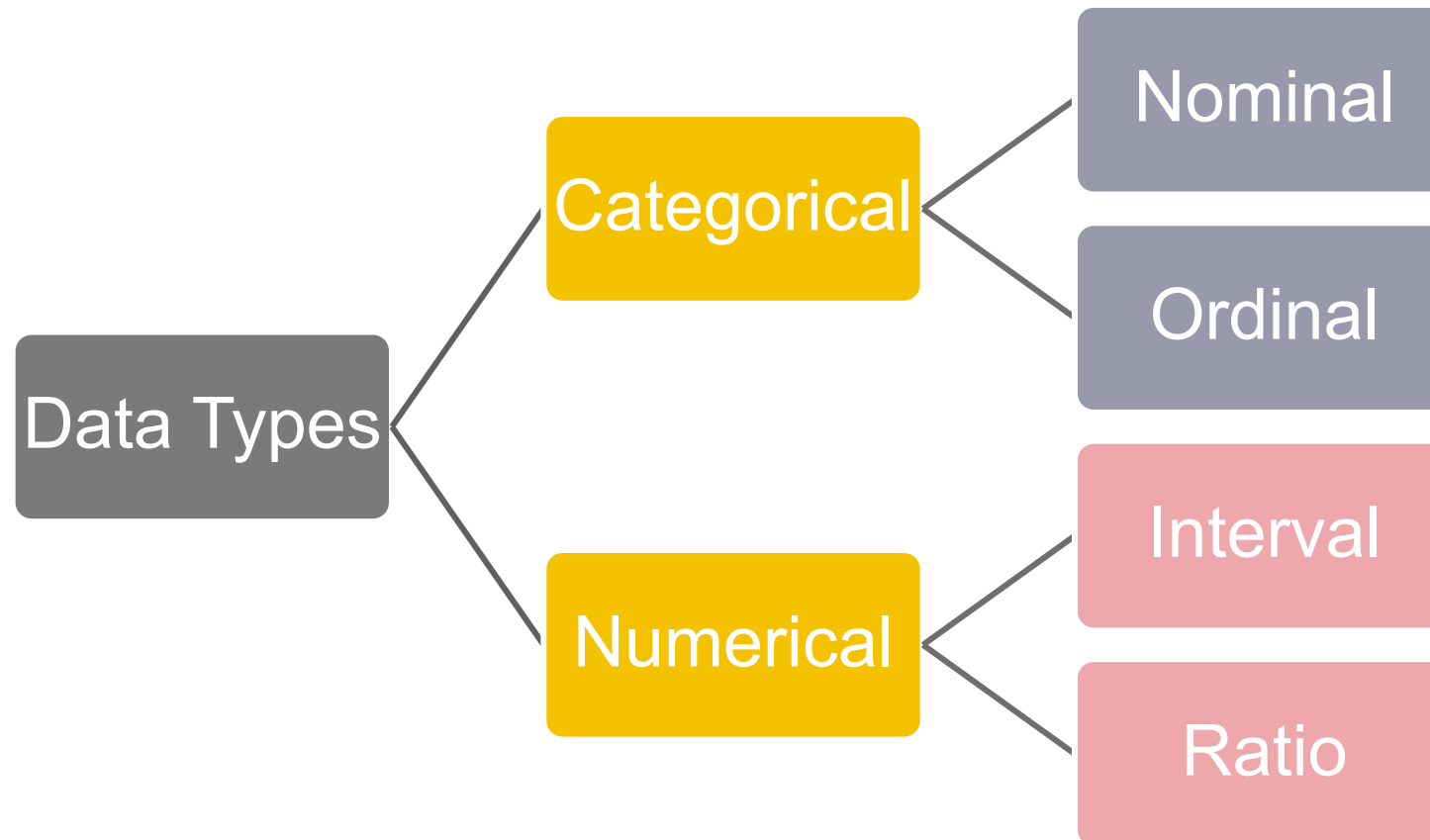
Can be processed into an n (number of entities) by m (number of attributes) matrix.

- Result of merging & processing different records!
- Picking the data that goes into this table has both technical and ethical concerns (recall: Target, Netflix, AOL examples)

ID	Title	Author	Year	Cover	Edition	Price
1	Emma	Austen	1815	Paper	20th	\$5.75
2	Dracula	Stoker	1897	Hard	15th	\$12.00
3	Ivanhoe	Scott	1820	Hard	8th	\$25.00
4	Kidnapped	Stevenson	1886	Paper	11th	\$5.00

CLASSICAL STATISTICAL VIEW OF DATA

There are four classical types of data



CATEGORICAL DATA: TAKES A VALUE FROM A FINITE SET

Nominal (aka Categorical) Data:

- Values have names: describe the categories, classes, or states of things
- Marital status, drink type, or some binary attribute
- Cannot compare easily, thus cannot naturally order them

Ordinal Data:

- Values have names: describe the categories, classes, or states of things
- However, there is an *ordering* over the values:
 - Strongly like, like, neutral, strongly dislike
- Lacks a mathematical notion of *distance* between the values

This distinction can be blurry...

- Is there an ordering over: sunny, overcast, rainy?



NUMERICAL DATA: MEASURED USING INTEGERS OR REALS

Interval Scale:

- Scale with fixed but arbitrary interval (e.g., dates)
- The difference between two values is *meaningful*:
 - Difference between 9/1/2019 and 10/1/2019 is the same as the difference between 9/1/2018 and 10/1/2018
- Can't compute ratios or scales: e.g., what unit is $9/1/2019 * 8/2/2020$?

Ratio Scale:

- All the same properties as interval scale data, but the scale of measurement also possesses a **true-zero origin**
- Can look at the *ratio* of two quantities (unlike interval)
- E.g., zero money is an absolute, one money is half as much as two money, and so on

NUMERICAL DATA: EXAMPLES

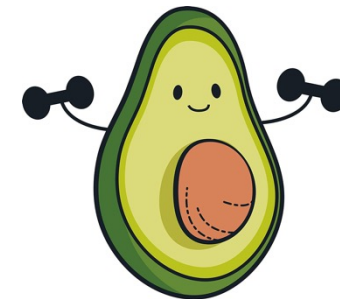
Temperatures:

- Celsius / Fahrenheit: interval or ratio scale ??????????????
- **Interval:** 0C is not 0 heat, but is an arbitrary fixed point
- Hence, we can't say that 30F is twice as warm as 15F.
- Kelvin (K): interval or ratio scale ??????????????
- **Ratio:** 0K is assumed to mean zero heat, a true fixed point



Weight:

- Grams: interval or ratio scale ??????????????
- **Ratio:** 0g served as fixed point, 4g is twice 2g, ...



GENERAL RULES

OK to compute....	Nominal	Ordinal	Interval	Ratio
frequency distribution	?	?	?	?

GENERAL RULES

OK to compute....	Nominal	Ordinal	Interval	Ratio
frequency distribution	Yes	Yes	Yes	Yes
median and percentiles	?	?	?	?

GENERAL RULES

OK to compute....	Nominal	Ordinal	Interval	Ratio
frequency distribution	Yes	Yes	Yes	Yes
median and percentiles	No	Yes	Yes	Yes
addition or subtraction	?	?	?	?

GENERAL RULES

OK to compute....	Nominal	Ordinal	Interval	Ratio
frequency distribution	Yes	Yes	Yes	Yes
median and percentiles	No	Yes	Yes	Yes
addition or subtraction	No	No	Yes	Yes
mean or standard deviation	?	?	?	?

GENERAL RULES

OK to compute....	Nominal	Ordinal	Interval	Ratio
frequency distribution	Yes	Yes	Yes	Yes
median and percentiles	No	Yes	Yes	Yes
addition or subtraction	No	No	Yes	Yes
mean or standard deviation	No	No	Yes	Yes
ratio, or coefficient of variation	?	?	?	?

GENERAL RULES

OK to compute....	Nominal	Ordinal	Interval	Ratio
frequency distribution	Yes	Yes	Yes	Yes
median and percentiles	No	Yes	Yes	Yes
addition or subtraction	No	No	Yes	Yes
mean or standard deviation	No	No	Yes	Yes
ratio, or coefficient of variation	No	No	No	Yes

DATA MANIPULATION AND COMPUTATION

Data Science == manipulating and computing on data

Large to very large, but somewhat “structured” data

We will see several tools for doing that this semester

Thousands more out there that we won't cover

Need to learn to shift thinking from:

Imperative code to manipulate data structures

to:

Sequences/pipelines of operations on data

Should still know how to implement the operations themselves, especially for debugging performance (covered in classes like 420, 424), but we won't cover that much

DATA MANIPULATION AND COMPUTATION

1. Data Representation, i.e., what is the natural way to think about given data

One-dimensional Arrays, Vectors

0.1	2	3.2	6.5	3.4	4.1
-----	---	-----	-----	-----	-----

"data"	"representation"	"i.e."
--------	------------------	--------

Indexing

Slicing/subsetting

Filter

'map' → apply a function to every element

'reduce/aggregate' → combine values to get a single scalar (e.g., sum, median)

Given two vectors: **Dot and cross products**

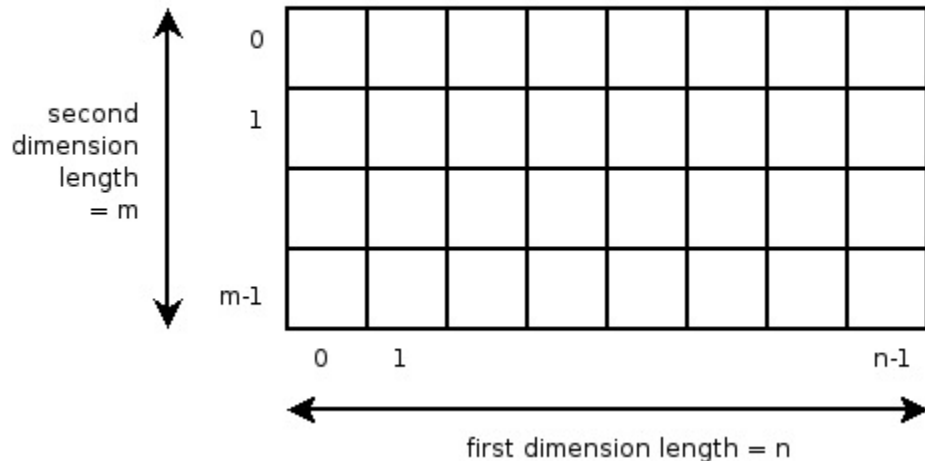
2. Data Processing Operations, which take one or more datasets as input and produce one or more datasets as output

DATA MANIPULATION AND COMPUTATION

1. **Data Representation**, i.e., what is the natural way to think about given data

n-dimensional arrays

Two-dimensional array



Indexing

Slicing/subsetting

Filter

'map' → apply a function to every element

'reduce/aggregate' → combine values across a row or a column (e.g., sum, average, median etc..)

2. **Data Processing Operations**, which take one or more datasets as input and produce one or more datasets as output

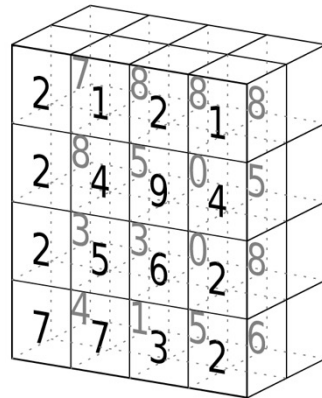
DATA MANIPULATION AND COMPUTATION

1. **Data Representation**, i.e., what is the natural way to think about given data

Matrices, Tensors

3	1	4	1
5	9	2	6
5	3	5	8
9	7	9	3
2	3	8	4
6	2	6	4

tensor of dimensions [6,4]
(matrix 6 by 4)



tensor of dimensions [4,4,2]

n-dimensional array operations

+

Linear Algebra

Matrix/tensor multiplication

Transpose

Matrix-vector multiplication

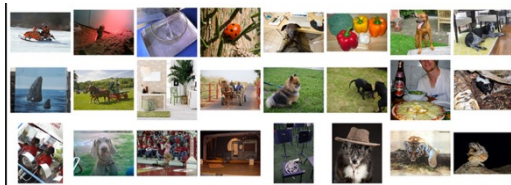
Matrix factorization

2. **Data Processing Operations**, which take one or more datasets as input and produce one or more datasets as output

DATA MANIPULATION AND COMPUTATION

1. Data Representation, i.e., what is the natural way to think about given data

Sets: of Objects



Filter
Map
Union

Reduce/Aggregate

Sets: of (Key, Value Pairs)

(amol@cs.umd.edu, (email1, email2, ...))

(john@cs.umd.edu, (email3, email4, ...))

Given two sets, **Combine/Join** using
“keys”

Group and then aggregate

2. Data Processing Operations, which take one or more datasets as input and produce one or more datasets as output

DATA MANIPULATION AND COMPUTATION

1. **Data Representation**, i.e., what is the natural way to think about given data

Filter rows or columns

Tables/Relations == Sets of Tuples

company	division	sector	tryint
00nil_Combined_Company	00nil_Combined_Division	00nil_Combined_Sector	14625
apple	00nil_Combined_Division	00nil_Combined_Sector	10125
apple	hardware	00nil_Combined_Sector	4500
apple	hardware	business	1350
apple	hardware	consumer	3150
apple	software	00nil_Combined_Sector	5625
apple	software	business	4950
apple	software	consumer	675
microsoft	00nil_Combined_Division	00nil_Combined_Sector	4500
microsoft	hardware	00nil_Combined_Sector	1890
microsoft	hardware	business	855
microsoft	hardware	consumer	1035
microsoft	software	00nil_Combined_Sector	2610
microsoft	software	business	1215
microsoft	software	consumer	1395

”Join” two or more relations

”Group” and “aggregate” them

Relational Algebra formalizes some of them

Structured Query Language (SQL)

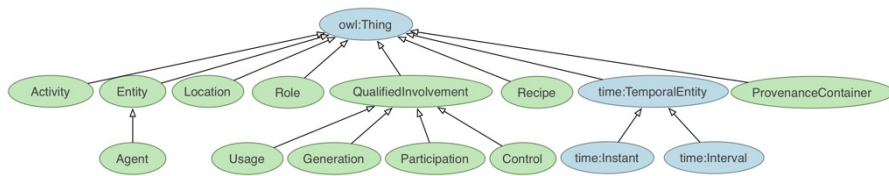
Many other languages and constructs, that look very similar

2. **Data Processing Operations**, which take one or more datasets as input and produce one or more datasets as output

DATA MANIPULATION AND COMPUTATION

1. **Data Representation**, i.e., what is the natural way to think about given data

Hierarchies/Trees/Graphs



“Path” queries

Graph Algorithms and Transformations

Network Science

Somewhat more ad hoc and special-purpose

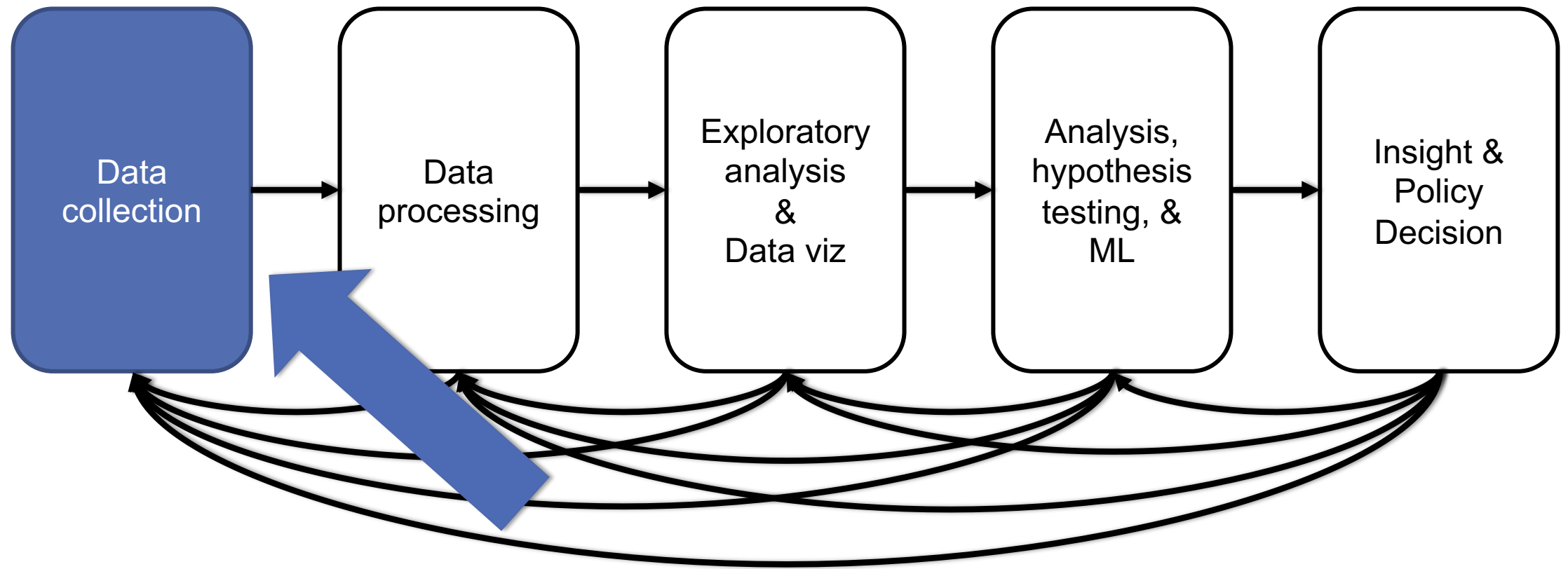
Changing in recent years

2. **Data Processing Operations**, which take one or more datasets as input and produce one or more datasets as output

DATA MANIPULATION AND COMPUTATION

1. **Data Representation**, i.e., what is the natural way to think about given data
2. **Data Processing Operations**, which take one or more datasets as input and produce
 - **Why?**
 - Allows one to think at a higher level of abstraction, leading to simpler and easier-to-understand scripts
 - Provides "independence" between the abstract operations and concrete implementation
 - Can switch from one implementation to another easily
 - **For performance debugging, useful to know how they are implemented and rough characteristics**

THE REST OF TODAY'S LECTURE



... on to the “collection” part of things ...

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 **A**pplication **P**rogramming **I**nterface (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=2.12.4`

```
r = requests.get( 'https://api.github.com/user',  
                 auth=('user', 'pass') )
```

```
r.status_code
```

```
200
```

```
r.headers[ 'content-type' ]
```

```
'application/json; charset=utf8'
```

```
r.json()
```

```
{u'private_gists': 419, u'total_private_repos': 77, ...}
```

HTTP REQUESTS

<https://www.google.com/?q=cmssc320&tbs=qdr:m>



???????????

HTTP GET Request:

GET /?q=cmssc320&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": "cmssc320", "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
- **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": "JohnDickerson", "id": 472985, "avatar_url": "ht..."}
```

GitHub is more than a GETHub:

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

AUTHENTICATION AND OAUTH

Old and busted:

```
r = requests.get("https://api.github.com/user",  
                 auth=("JohnDickerson", "ILoveKittens"))
```

New hotness:

- 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.*

GRAPHQL?

An alternative to REST and ad-hoc webservice architectures


- Developed internally by Facebook and released publicly

Unlike REST, the requester specifies the format of the response



```
GET /books/1

{
  "title": "Black Hole Blues",
  "author": {
    "firstName": "Janna",
    "lastName": "Levin"
  }
  // ... more fields here
}
```



```
GET /graphql?query={ book(id: "1") { title, author { firstName } } }

{
  "title": "Black Hole Blues",
  "author": {
    "firstName": "Janna",
  }
}
```

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)

1,26-Jan,Introduction,—,"pdf, pptx",Dickerson,
2,31-Jan,Scraping Data with Python,Anaconda's Test Drive.,,Dickerson,
3,2-Feb,"Vectors, Matrices, and Dataframes",Introduction to pandas.,,Dickerson,
4,7-Feb,Jupyter notebook lab,,, "Denis, Anant, & Neil",
5,9-Feb,Best Practices for Data Science Projects,,,Dickerson,

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)
```

(We'll use pandas to do this much more easily and efficiently)

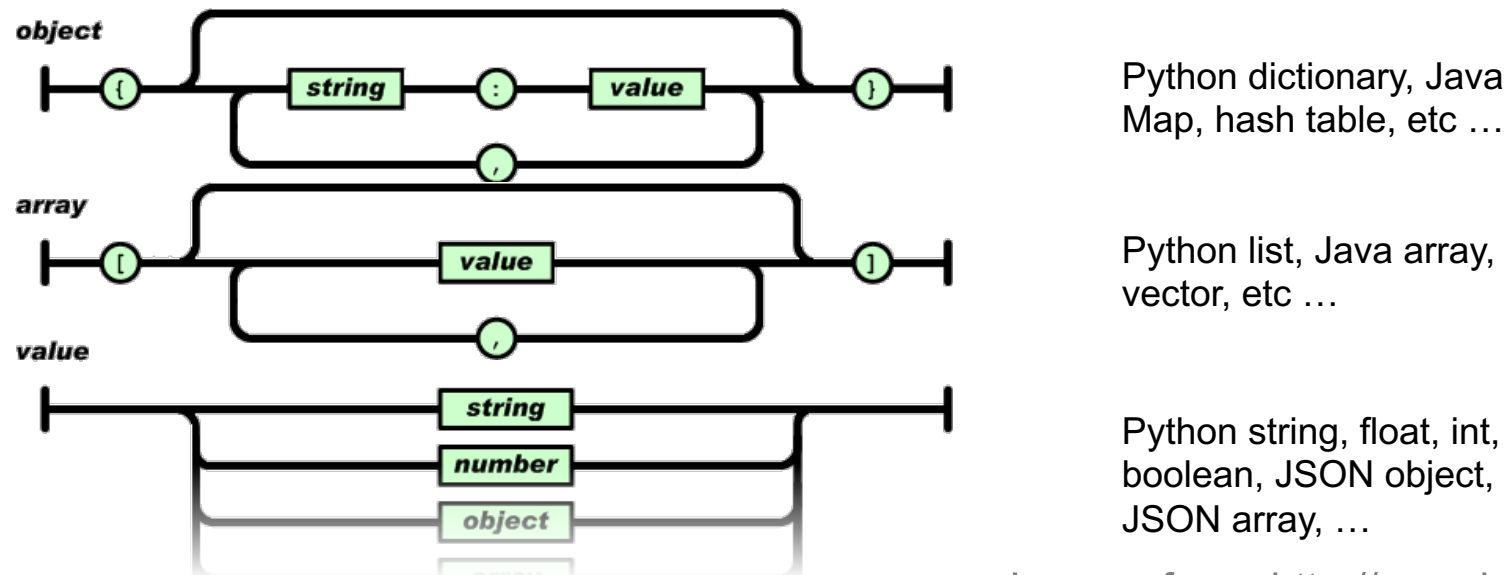
JSON FILES & STRINGS

JSON is a method for **serializing** objects:

- Convert an object into a string (done in Java in 131/132?)
- **Deserialization** converts a string back to an object

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

Defined by three universal data structures



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"},
    "CMSC320"
}]}
```



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.twitter.com/1.1/statuses/user_timeline.json?screen_name=JohnPDickerson&count=100", auth=auth )

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:

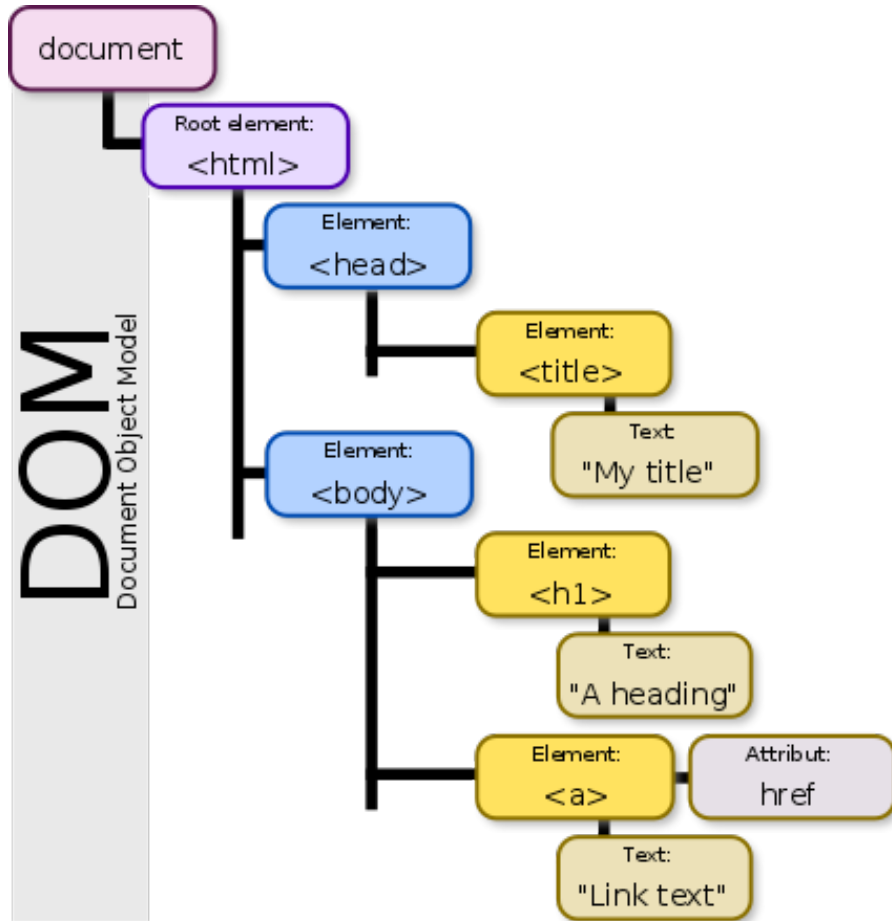
- Asynchronous browser \leftrightarrow server calls
- Many (most?) newer web APIs

XML is a hierarchical markup language:

```
<tag attribute="value1">
  <subtag>
    Some content goes 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)



XML encodes Document-Object Models (“the DOM”)

The DOM is tree-structured.

Easy to work with! Everything is encoded via links.

Can be **huge**, & mostly full of stuff you don't need ...

SAX

SAX (Simple API for XML) is an alternative “lightweight” way to process XML.

A SAX parser generates a stream of events as it parses the XML file. The programmer registers handlers for each one.

It allows a programmer to handle only parts of the data structure.

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://cm320.github.io" )

root = BeautifulSoup( r.content )
root.find("div", id="schedule")\
    .find("table")\                # find all schedule
    .find("tbody").findAll("a")  # links for CM320
```

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 CMSC320 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.find("div", id="schedule")\  
    .find("table")\                # find all schedule  
    .find("tbody").findAll("a")    # links for CMSC320
```

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?

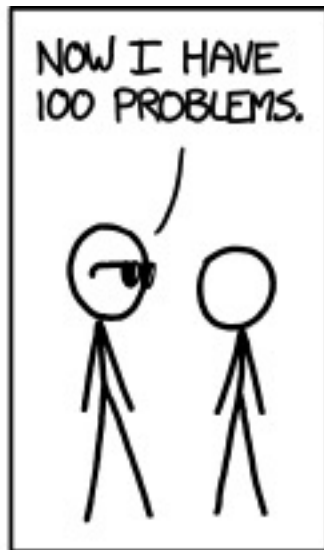
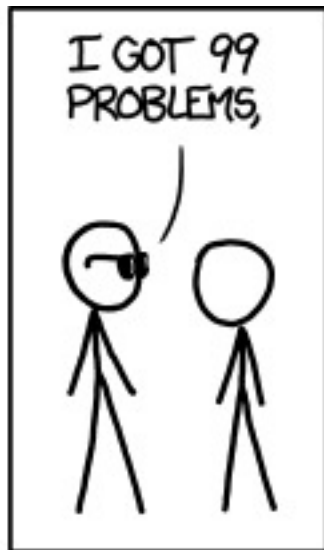
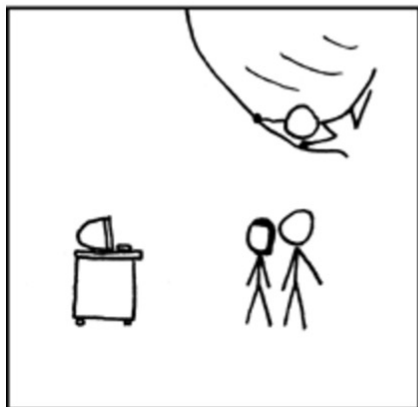
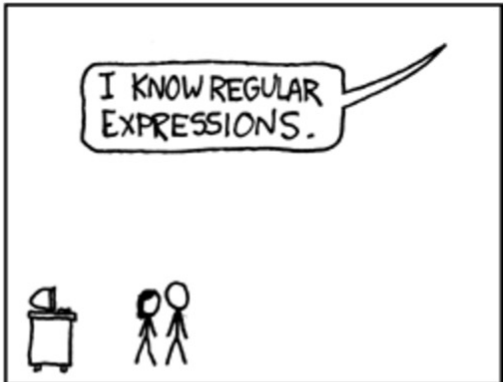
- Regular expressions!
- (Actually Python strings come with a built-in `endswith` function.)

```
"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"))
```



REGULAR EXPRESSIONS

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

Indispensable for data munging and wrangling

Many constructs to search a variety of different patterns

Many languages/libraries (including Python) allow “compiling”

Much faster for repeated applications of the regex pattern

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

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 "cmssc320"
match = re.search(r"cmssc320", text)
print( match.start() )
```

```
# Does start of text match "cmssc320"?
match = re.match(r"cmssc320", text)
```

```
# Iterate over all matches for "cmssc320" in text
for match in re.finditer(r"cmssc320", text):
    print( match.start() )
```

```
# Return all matches of "cmssc320" in the text
match = re.findall(r"cmssc320", 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\s of\s\w{3,}`

GROUPS

What if we want to know more than just “did we find a match” or “where is the first match” ...?

Grouping asks the regex matcher to keep track of certain portions – surrounded by (parentheses) – of the match

```
\s*([Uu]niversity)\s([Oo]f)\s(\w{3,})
```

```
regex = r"\s*([Uu]niversity)\s([Oo]f)\s(\w{3,})"  
m = re.search( regex, "university Of Maryland" )  
print( m.groups() )
```

```
('university', 'Of', 'Maryland')
```


NAMED GROUPS

Raw grouping is useful for one-off exploratory analysis, but may get confusing with longer regexes

- Much scarier regexes than that email one exist in the wild ...

Named groups let you attach position-independent identifiers to groups in a regex

```
(?P<some_name> ...)
```

```
regex = "\s*[Uu]niversity\s[Oo]f\s(?P<school>(\w{3,}))"  
m = re.search( regex, "University of Maryland" )  
print( m.group('school') )
```

```
'Maryland'
```

SUBSTITUTIONS

The Python `string` module contains basic functionality for find-and-replace within strings:

```
"abcabcabc".replace("a", "X")
```

```
`XbcXbcXbc`
```

For more complicated stuff, use regexes:

```
text = "I love Introduction to Data Science"  
re.sub(r"Data Science", r"Schmada Schmience", text)
```

```
`I love Introduction to Schmada Schmience`
```

Can incorporate groups into the matching

```
re.sub(r"(\w+)\s([Ss]cience", r"\1 \2hmience", text)
```

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 "cm320"
regex = re.compile(r"cm320")

# 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
```

Interested? CMSC330, CMSC430, CMSC452, talk to me.

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']

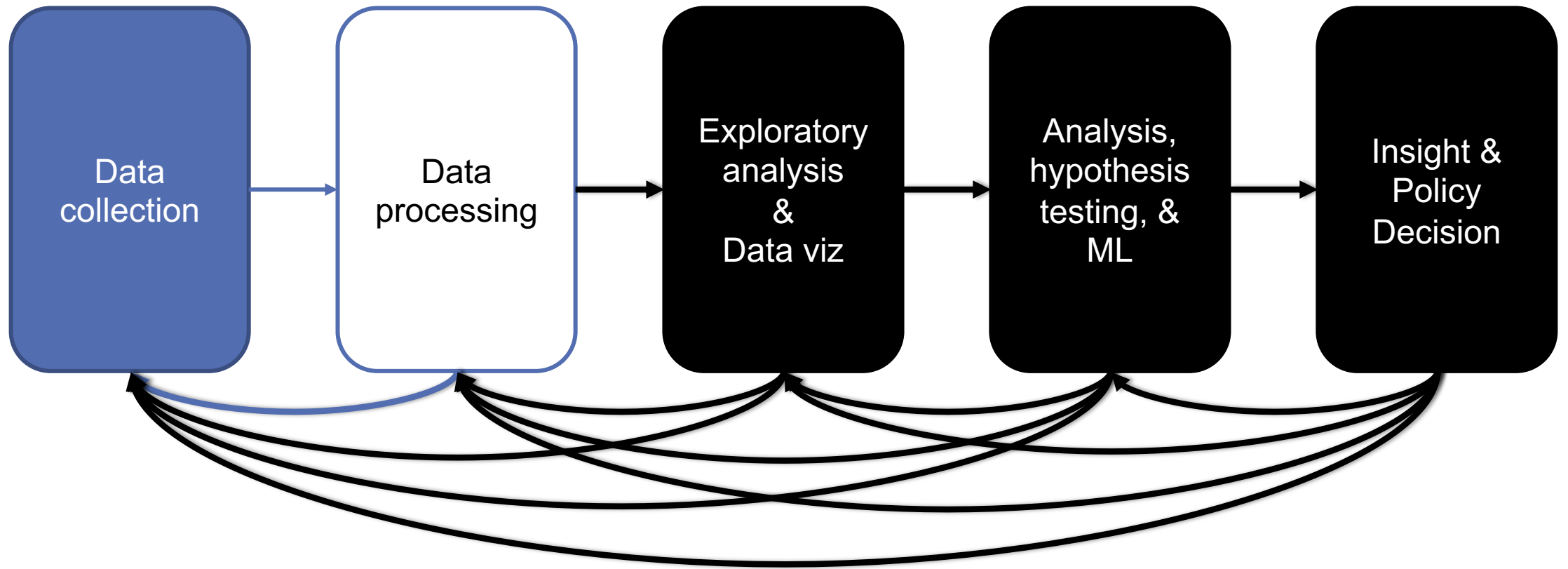
    # If it's a PDF/PPTX link, queue a download
    if href.lower().endswith(('.pdf', '.pptx')):
```

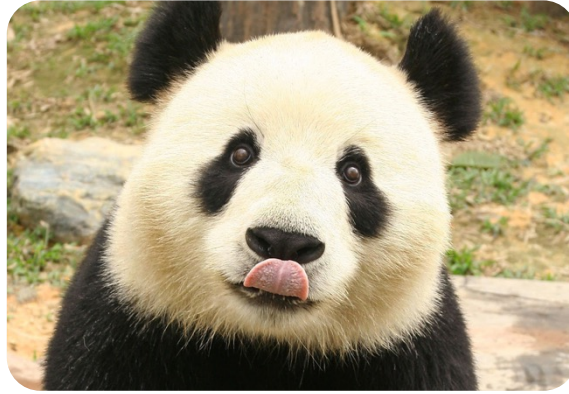
Get some more data?!

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

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

THE DATA LIFECYCLE





NEXT CLASS:
NUMPY, SCIPY, AND DATAFRAMES

pandas

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

