Python, Pandas, and a Bit of SH

Network Security and Measurement

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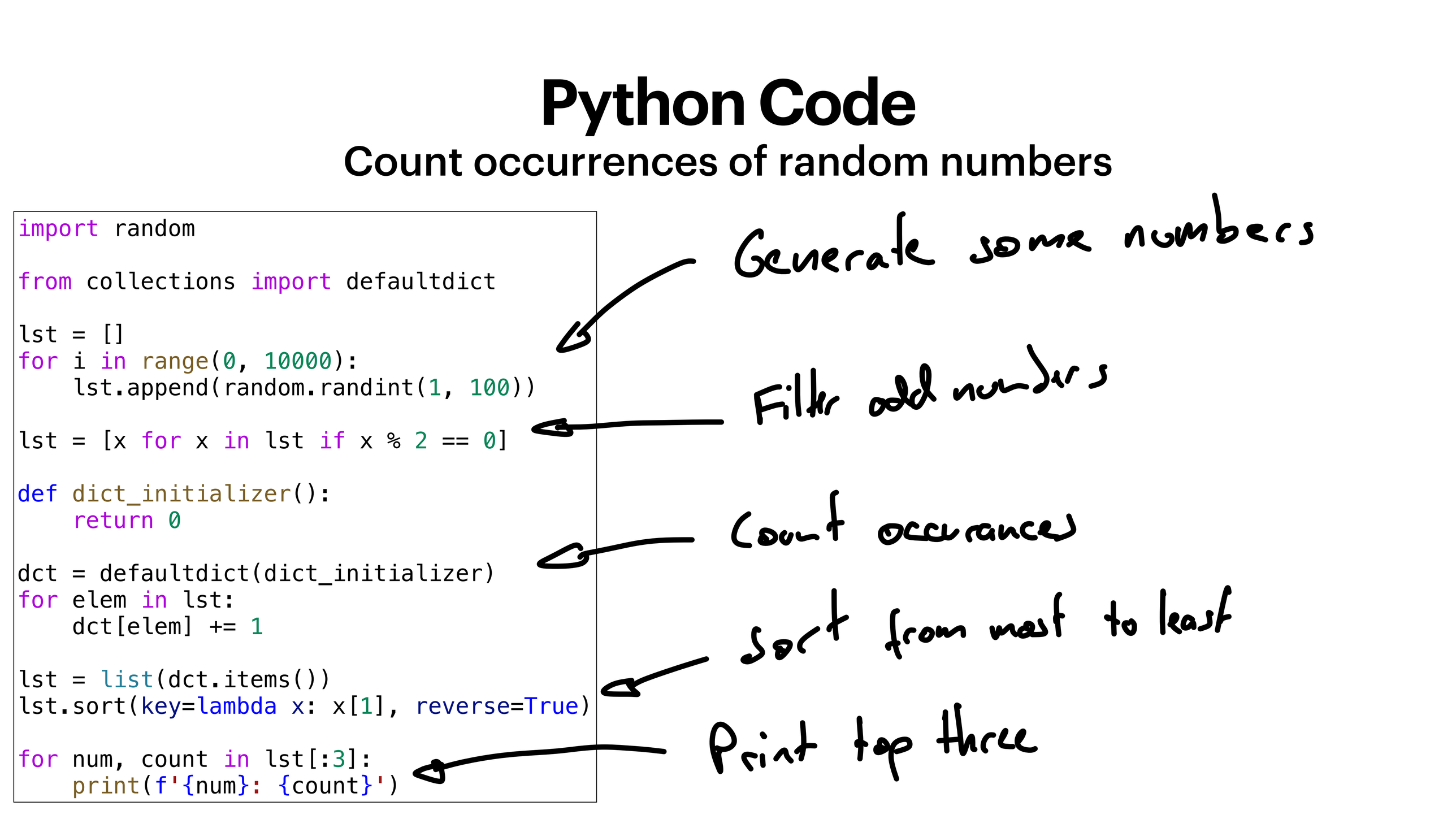
Python
A Programming Language

- Dynamically-typed and interpreted programming language
- Need to know:
  - Use python 3, version 2 is EOL
  - Indentation is part of the syntax (there are less braces here)
  - There are types, but you (usually) don’t write them in code
- Executing the python binary without arguments gives you a REPL!
- Docs: https://docs.python.org/3.8/

Python Code

Count occurrences of random numbers

```python
import random

from collections import defaultdict

lst = []
for i in range(0, 10000):
    lst.append(random.randint(1, 100))

lst = [x for x in lst if x % 2 == 0]

def dict_initializer():
    return 0

dct = defaultdict(dict_initializer)
for elem in lst:
    dct[elem] += 1

lst = list(dct.items())
lst.sort(key=lambda x: x[1], reverse=True)

for num, count in lst[:3]:
    print(f'{num}: {count}')
```



Running Python

- Jupyter Notebooks
  - Interactive environments for incremental development
  - There is a HTML document in shared-data of the example
- Virtual environments: isolation for projects

```
# Create a virtual environment
python3 -m venv my_env
source my_env/bin/activate

# Install requirements
pip install matplotlib pandas

# Do your thing
python my_script.py

# Leave the environment
deactivate
```

Data Analysis with Pandas

Pandas

- Build around DataFrames and Series
- Allows efficient processing of large datasets
- Frequently used libraries have an import name by convention, here: pd

```
import pandas as pd
```

- Docs: https://pandas.pydata.org/docs/

Read CSV into DataFrame

- pd.**read_csv(**FILENAME, ...**)**
- Options configure the format, such as:
  - Name and select columns
  - Specify the column separator
  - Read data in chunks (etc.)

```
df = pd.read_csv('shared-data/ports.csv', sep='|', index_col=0)
print(df)
```

```
      port    count
0       80  1131992
1     8080   878982
```

Table Operations

- Columns can be selected via the name which returns a Series
- Both types offer a variety of operations, such as sum, mean, etc.
- Use table and series operations when possible, they are performant!
- Avoid simple iterations of rows or columns with for loops

```
total = df['count'].sum()
df['share'] = (df['count'] / total * 100).round(2)
```

Diving Deeper into Performance

- Important characteristics: processing time & memory usage
- When in doubt, time it yourself
- Further reading:
  - https://medium.com/bigdatarepublic/advanced-pandas-optimize-speed-and-memory-a654b53be6c2
  - https://stackoverflow.com/questions/52673285/performance-of-pandas-apply-vs-np-vectorize-to-create-new-column-from-existing-c/52674448#52674448

Plotting with Pandas
Matplotlib

- DataFrames can plot via matplotlib (import matplotlib.pyplot as plt)

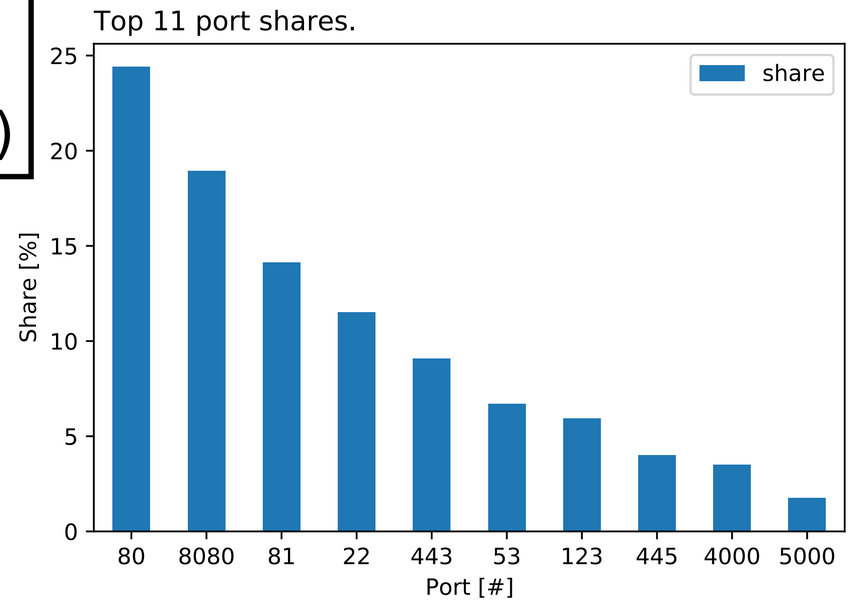
```
ax = df.plot.bar(x='port', y='share', rot=0)
```

- Configure your plot (always name the axis)

```
ax.set_xlabel('Port [#]')
ax.set_ylabel('Share [%]')
ax.set_title('Top 11 port shares.', loc='left')
```

- Show plots or save them

```
plt.show()
fig = ax.get_figure()
fig.savefig("ports.pdf", bbox_inches='tight')
plt.close(fig)
```



Helpful DataFrame Functions

- df.**value_counts()** - Return a Series containing counts of unique rows in the DataFrame.
- df.**groupby()** - Group DataFrame rows using a mapper or by a Series of columns.
  - A bit complicated to use.
  - Often combined with "aggregator" functions like mean(), sum(), etc.
  - You can also group timestamps by frequency with pd.**Grouper()**

- Check the pandas docs for detailed descriptions and examples: https://pandas.pydata.org/pandas-docs/stable/reference/index.html#api

An Easy-to-use Progress Bar

- Some measurements run for minutes, hours or days
- The tqdm module shows a progress bar for iterations
- Simply wrap your iterable, such as a range:

```
from tqdm import tqdm
for i in tqdm(range(10000)):
    ...
```

- Check https://tqdm.github.io/ for details

Shell Tools

Thanks to Marcin and Clemens from FU Berlin for the slides!

UNIX tools are great!

Some key advantages:

chaining using pipe

processing of files larger than your RAM

easily parallelizable

How do you find how UNIX tools work?

1. `<tool> --help`
2. `man <tool>`
3. Search Google

```
> $ cat --help

Usage: cat [OPTION]... [FILE]...
Concatenate FILE(s) to standard output.

With no FILE, or when FILE is -, read standard input.

  -A, --show-all               equivalent to -vET
  -b, --number-nonblank        number nonempty output lines, overrides -n
  -e                           equivalent to -vE
.....
```

```
CAT(1)                                                          User Commands
                CAT(1)

NAME
                cat - concatenate files and print on the standard output

DESCRIPTION
                Concatenate FILE(s) to standard output.

                With no FILE, or when FILE is -, read standard input.

                -A, --show-all
                equivalent to -vET

                -b, --number-nonblank
                number nonempty output lines, overrides -n
.....
```

UNIX: What does my data look like?

- zcat / cat
- less
- wc
- gzip / gunzip
- grep
- cut
- sort
- uniq

zcat / cat [OPTION]... [FILE]...

cat takes a list of files and pastes their content to stdout.
zcat is for compressed files.

```
> $ ls

another_cool_test_file  cool_test_file

> $ cat cool_test_file another_cool_test_file

This is line number 1.
Some hacky lines in between.
Some hacky lines in between.
This is the last line of this wonderful file.
More lines.
Unix is user-friendly. It's just picky about who its friends are.
End of Story
```

less is more

less is used to navigate and view large files easily.

- **page down / up** to navigate
- **q** to quit
- **/** to search
- **j,k** to go up and down line by line
- **G** to go to bottom
- **gg** to go to top
- **h** for help

wc [OPTION]... [FILE]...

wc counts lines, words and bytes of a file.

```
> $ cat cool_test_file

This is line number 1.
Some hacky lines in between.
Some hacky lines in between.
This is the last line of this wonderful file.

> $ wc cool_test_file

  4  24 127 cool_test_file
```

gzip / gunzip [OPTION]... [FILE]..

gzip and **gunzip** compresses and decompresses files. The data for provided on your assignment is compressed. You can either use zcat or gunzip.

```
> $ ls

another_cool_test_file  cool_test_file

> $ gzip another_cool_test_file

> $ ls

another_cool_test_file.gz  cool_test_file
```

grep [OPTION]... PATTERNS [FILE]...

grep finds lines that contain a specific pattern.

```
> $ cat cool_test_file

This is line number 1.
Some hacky lines in between.
Some hacky lines in between.
This is the last line of this wonderful file.

> $ grep "is" cool_test_file

This is line number 1.
This is the last line of this wonderful file.
```

cut OPTION... [FILE]...

cut is used to select specific parts of lines, e.g., columns.

Select columns **1,4** *from file* **sample_updates**. *The delimiter is* **'|'**.

```
> $ cat sample_updates

U|A|1579046400|2001:200:0:fe00::6249:0
U|W|1579046400|202.249.2.185
U|A|1579046400|202.249.2.185
U|A|1579046400|202.249.2.185
U|A|1579046400|202.249.2.185
U|A|1579046400|202.249.2.185
U|A|1579046400|202.249.2.185
U|A|1579046400|202.249.2.185
U|A|1579046400|202.249.2.185
U|A|1579046400|202.249.2.185
U|A|1579046400|202.249.2.185
```

```
> $ cut -f 1,4 -d '|' sample_updates

U|2001:200:0:fe00::6249:0
U|202.249.2.185
U|202.249.2.185
U|202.249.2.185
U|202.249.2.185
U|202.249.2.185
U|202.249.2.185
U|202.249.2.185
U|202.249.2.185
U|202.249.2.185
```

sort [OPTION]... [FILE]...

sort sorts

Select file **sample_updates2** *by* **column3**. *Columns are separated by* **'|'.**
Sort **numbers.**

```
> $ cat sample_updates2

U|W|1579046447|2001:200:0:fe00::12a9:0
U|W|1579046453|2001:200:0:fe00::12a9:0
U|A|1579046400|2001:200:0:fe00::6249:0
U|A|1579046400|2001:200:0:fe00::6249:0
U|A|1579046418|202.249.2.169
U|A|1579046402|202.249.2.185
U|A|1579046447|202.249.2.185
U|A|1579046447|202.249.2.185
U|A|1579046447|2001:200:0:fe00::12a9:0
U|A|1579046400|2001:200:0:fe00::6249:0
U|A|1579046447|202.249.2.185
U|W|1579046400|202.249.2.185
```

```
> $ sort -n -k 3,3 -t '|' sample_updates2

U|A|1579046400|2001:200:0:fe00::6249:0
U|A|1579046400|2001:200:0:fe00::6249:0
U|A|1579046400|2001:200:0:fe00::6249:0
U|W|1579046400|202.249.2.185
U|A|1579046402|202.249.2.185
U|A|1579046418|202.249.2.169
U|A|1579046447|2001:200:0:fe00::12a9:0
U|A|1579046447|202.249.2.185
U|A|1579046447|202.249.2.185
U|A|1579046447|202.249.2.185
U|W|1579046447|2001:200:0:fe00::12a9:0
U|W|1579046453|2001:200:0:fe00::12a9:0
```

uniq [OPTION]... [INPUT [OUTPUT]]

uniq removes duplicate rows from a file.
uniq -c also counts how often each line occured.

```
> $ cat sample_updates

U|A|1579046400|2001:200:0:fe00::6249:0
U|W|1579046400|202.249.2.185
U|A|1579046400|202.249.2.185
U|A|1579046400|202.249.2.185
U|A|1579046400|202.249.2.185
U|A|1579046400|202.249.2.185
U|A|1579046400|202.249.2.185
U|A|1579046400|202.249.2.185
U|A|1579046400|202.249.2.185
U|A|1579046400|202.249.2.185
U|A|1579046400|202.249.2.185
```

```
> $ uniq sample_updates

U|A|1579046400|2001:200:0:fe00::6249:0
U|W|1579046400|202.249.2.185
U|A|1579046400|202.249.2.185

> $ uniq -c sample_updates

                1 U|A|1579046400 2001:200:0:fe00::6249:0
                1 U|W|1579046400|202.249.2.185
                8 U|A|1579046400|202.249.2.185
```

The output of these tools goes to stdout. Let's save the results!

> and >>

> overwrites an existing file or creates a new file with the supplied text.
>> appends to a file if it exists. Otherwise like **>**.

```
> $ cat sample_updates

U|A|1579046400|2001:200:0:fe00::6249:0
U|W|1579046400|202.249.2.185
U|A|1579046400|202.249.2.185
U|A|1579046400|202.249.2.185
U|A|1579046400|202.249.2.185
U|A|1579046400|202.249.2.185
U|A|1579046400|202.249.2.185
U|A|1579046400|202.249.2.185
U|A|1579046400|202.249.2.185
U|A|1579046400|202.249.2.185
```

```
> $ uniq sample_updates > test_output

> $ cat test_output

U|A|1579046400|2001:200:0:fe00::6249:0
U|W|1579046400|202.249.2.185
U|A|1579046400|202.249.2.185

> $ uniq sample_updates >> test_output

> $ cat test_output

U|A|1579046400|2001:200:0:fe00::6249:0
U|W|1579046400|202.249.2.185
U|A|1579046400|202.249.2.185
U|A|1579046400|2001:200:0:fe00::6249:0
U|W|1579046400|202.249.2.185
U|A|1579046400|202.249.2.185
```

Let's chain these tools!

The mighty Pipe

The mighty pipe **takes stdout** from one program and **pipes it into stdin** of another program.

How often does each IP occur in this file?

```
> $ cat sample_updates2

U|W|1579046447|2001:200:0:fe00::12a9:0
U|W|1579046453|2001:200:0:fe00::12a9:0
U|A|1579046400|2001:200:0:fe00::6249:0
U|A|1579046400|2001:200:0:fe00::6249:0
U|A|1579046418|202.249.2.169
U|A|1579046402|202.249.2.185
U|A|1579046447|202.249.2.185
U|A|1579046447|202.249.2.185
U|A|1579046447|2001:200:0:fe00::12a9:0
U|A|1579046400|2001:200:0:fe00::6249:0
U|A|1579046447|202.249.2.185
U|W|1579046400|202.249.2.185
```

```
> $ cat sample_updates2 | cut -d '|' -f 4 | sort | uniq -c

      3 2001:200:0:fe00::12a9:0
      3 2001:200:0:fe00::6249:0
      1 202.249.2.169
      5 202.249.2.185
```

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BREATHE!

You always need basic domain knowledge.

The best data science stack does not exist.

Data is too large to fit into memory.

Use UNIX tools to prep!

Data is noisy and from multiple sensors.

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Data does not lie but is sometimes biased.

Awesome! Let's look at a few more tools

Capturing Network Traffic

- **tshark** [-i INTERFACE] [-f FILTER] [-T fields -e FIELD_NAME -e ANOTHER_FIELD_NAME]
  - Captures traffic and prints field values in the shell
  - The outbound interface on mobi8 is **bond0**
- **tcpdump** [-i INTERFACE] [-w DST_FILE] [-r SRC_FILE] [FILTER]
  - Captures traffic
  - Writes and reads pcap files

DNS Lookups

- **dig** [OPTIONS] [@server] [name] [type] [class] [queryopt...]
  - Queries DNS records
  - Look for the ";; ANSWER SECTION:"
- **drill** [OPTIONS] name [@server] [type] [class]
  - *"The name* drill *is a pun on* dig. *With* drill *you should be able get even more information than with* dig."
  - Specifically designed to be used with DNSSEC, enabled with "-D"
  - From the man page: -S shows tree of signatures, -DT performs a trace

Data processing and data visualization are two separate steps.