
# COMP1730/COMP6730
## Programming for Scientists

Data analysis and visualisation

# Announcements

* Please fill out **mid-semester survey on Wattle** *once you finished your lab this week*! It's open until the end of semester break (17 Sept) and will help us to identify areas for improvement in the 2nd half of the course!

# Recap of 1st half and outline for 2nd half

So far:

* Functional decomposition
* Types and expressions
* Branching, `if else`
* Iteration, `while` & `for` loop
* Sequence, `list`, `tuple`, `str`
* Code quality
* Debugging & testing
* Data analysis & visualisation

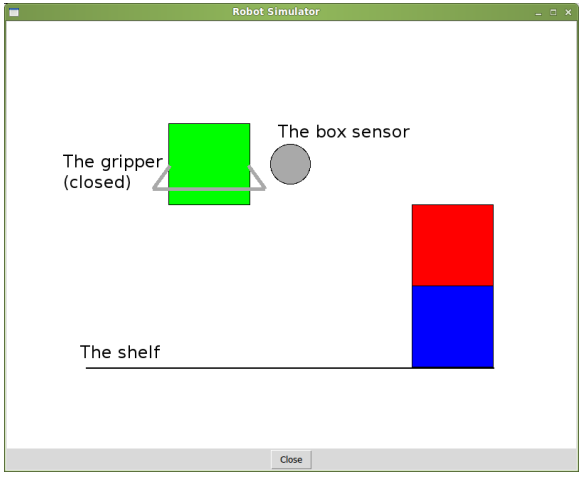
What's next?

* Numpy arrays
* Files, Input/Output
* Dictionaries and sets
* Exception handling
* Complexity, big-O notation
* Dynamic programming
* Computational Science
* Another advanced topic or 2

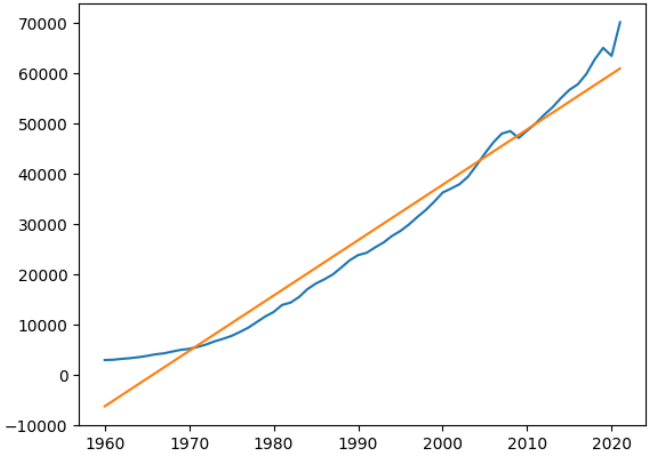
Many, if not most, concepts also apply to other programming languages, not just Python!

# Many scientific applications

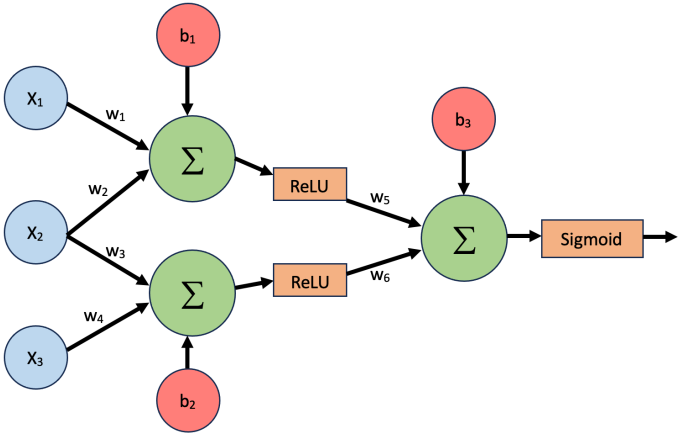
## Robot simulator:




## Linear regression:




## Neural network:




## Bioinformatics:

```
AGAGACCCCCT
AGA
 GAG
  AGA
   GAC
    ACC
     CCC
      CCC
       CCC
        CCT
```

→

k=3:

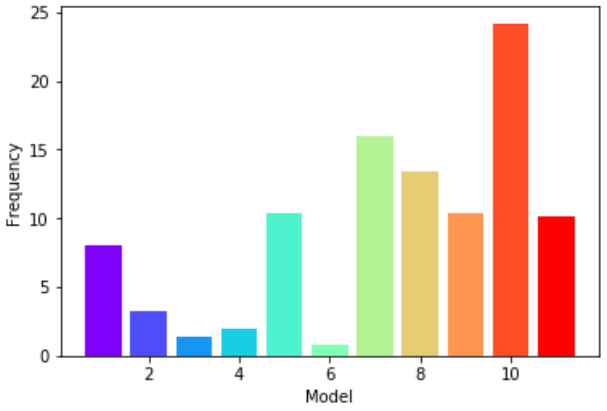
```
AGA 2
GAG 1
GAC 1
ACC 1
CCC 3
CCT 1
```

# Data science

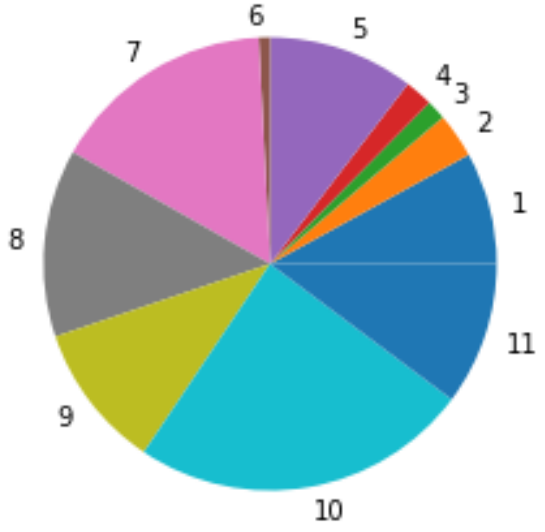
How-to:

* Represent 2-dimensional data?
* Read and write data?
* Analyse and visualise data?
* Interpret data?

Barplot:




Piechart:



# A working example

COVID-19 cases until 25th March 2022 (Source: Johns Hopkins University)

| | FIPS | Admin2 | Province_Sta | Country_Reg | Last_Update | Lat | Long_ | Confirmed | Deaths | Recovered | Active | Combined_K | Incident_Rat | Case_Fatality_Ratio |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2 | | | | Afghanistan | 26/3/22 4:20 | 33.93911 | 67.709953 | 177321 | 7657 | | | Afghanistan | 455.506183 | 4.31815747 |
| 3 | | | | Albania | 26/3/22 4:20 | 41.1533 | 20.1683 | 273318 | 3490 | | | Albania | 9497.46334 | 1.2769009 |
| 4 | | | | Algeria | 26/3/22 4:20 | 28.0339 | 1.6596 | 265612 | 6873 | | | Algeria | 605.714213 | 2.58760899 |
| 5 | | | | Andorra | 26/3/22 4:20 | 42.5063 | 1.5218 | 39713 | 153 | | | Andorra | 51398.434 | 0.38526427 |
| 6 | | | | Angola | 26/3/22 4:20 | -11.2027 | 17.8739 | 99102 | 1900 | | | Angola | 301.531041 | 1.91721661 |
| 7 | | | | Antarctica | 26/3/22 4:20 | -71.9499 | 23.347 | 11 | 0 | | | Antarctica | | 0 |
| 8 | | | | Antigua and I | 26/3/22 4:20 | 17.0608 | -61.7964 | 7482 | 135 | | | Antigua and I | 7640.30716 | 1.80433039 |
| 9 | | | | Argentina | 26/3/22 4:20 | -38.4161 | -63.6167 | 9023812 | 127846 | | | Argentina | 19966.0513 | 1.41676267 |
| 10 | | | | Armenia | 26/3/22 4:20 | 40.0691 | 45.0382 | 422423 | 8607 | | | Armenia | 14255.4722 | 2.0375311 |
| 11 | | | Australian Ca | Australia | 26/3/22 4:20 | -35.4735 | 149.0124 | 72571 | 39 | | | Australian Ca | 16951.8804 | 0.05374047 |
| 12 | | | New South W | Australia | 26/3/22 4:20 | -33.8688 | 151.2093 | 1715381 | 2055 | | | New South W | 21130.5864 | 0.11979846 |
| 13 | | | Northern Ter | Australia | 26/3/22 4:20 | -12.4634 | 130.8456 | 47660 | 33 | | | Northern Ter | 19405.5375 | 0.06924045 |
| 14 | | | Queensland | Australia | 26/3/22 4:20 | -27.4698 | 153.0251 | 721628 | 717 | | | Queensland, | 14106.6953 | 0.09935867 |
| 15 | | | South Austral | Australia | 26/3/22 4:20 | -34.9285 | 138.6007 | 227182 | 246 | | | South Austral | 12933.7888 | 0.10828323 |
| 16 | | | Tasmania | Australia | 26/3/22 4:20 | -42.8821 | 147.3272 | 78805 | 29 | | | Tasmania, Au | 14716.1531 | 0.0367997 |
| 17 | | | Victoria | Australia | 26/3/22 4:20 | -37.8136 | 144.9631 | 1233174 | 2722 | | | Victoria, Aust | 18598.3499 | 0.22073122 |
| 18 | | | Western Aust | Australia | 26/3/22 4:20 | -31.9505 | 115.8605 | 132060 | 34 | | | Western Aust | 5020.14749 | 0.02574587 |
| 19 | | | | Austria | 26/3/22 4:20 | 47.5162 | 14.5501 | 3665003 | 15619 | | | Austria | 40693.3181 | 0.42616609 |
| 20 | | | | Azerbaijan | 26/3/22 4:20 | 40.1431 | 47.5769 | 791654 | 9675 | | | Azerbaijan | 7807.87391 | 1.22212482 |
| 21 | | | | Bahamas | 26/3/22 4:20 | 25.025885 | -78.035889 | 33242 | 788 | | | Bahamas | 8453.18984 | 2.37049516 |
| 22 | | | | Bahrain | 26/3/22 4:20 | 26.0275 | 50.55 | 549718 | 1468 | | | Bahrain | 32306.2701 | 0.26704601 |

# Data files

* Many data file formats (e.g., excel, csv, json, binary). We'll use the following csv file.

```
FIPS,Admin2,Province_State,Country_Region,Last_Update,Lat,Long_,Confirmed,Deaths,Recovered,Active,Combined_Key,Incident_Rate,Case_Fatal
,,,Afghanistan,2022-03-26 04:20:23,33.93911,67.709953,177321,7657,,,Afghanistan,455.50618250081607,4.318157465838789
,,,Albania,2022-03-26 04:20:23,41.1533,20.1683,273318,3490,,,Albania,9497.463340051429,1.2769008993187423
,,,Algeria,2022-03-26 04:20:23,28.0339,1.6596,265612,6873,,,Algeria,605.7142130005892,2.587608993569568
,,,Andorra,2022-03-26 04:20:23,42.5063,1.5218,39713,153,,,Andorra,51398.43396104316,0.38526427114546874
,,,Angola,2022-03-26 04:20:23,-11.2027,17.8739,99102,1900,,,Angola,301.5310408836196,1.917216605113923
,,,Antarctica,2022-03-26 04:20:23,-71.9499,23.346999999999998,11,0,,,Antarctica,,0.0
,,,Antigua and Barbuda,2022-03-26 04:20:23,17.0608,-61.7964,7482,135,,,Antigua and Barbuda,7640.3071644473475,1.8043303929430634
,,,Argentina,2022-03-26 04:20:23,-38.4161,-63.6167,9023812,127846,,,Argentina,19966.05125297436,1.4167626719173672
,,,Armenia,2022-03-26 04:20:23,40.0691,45.0382,422423,8607,,,Armenia,14255.472230677698,2.0375311003425476
,,Australian Capital Territory,Australia,2022-03-26 04:20:23,-35.4735,149.0124,72571,39,,,"Australian Capital Territory, Australia",169
,,New South Wales,Australia,2022-03-26 04:20:23,-33.8688,151.2093,1715381,2055,,,"New South Wales, Australia",21130.58635131806,0.11979
,,Northern Territory,Australia,2022-03-26 04:20:23,-12.4634,130.8456,47660,33,,,"Northern Territory, Australia",19405.53745928339,0.069
,,Queensland,Australia,2022-03-26 04:20:23,-27.4698,153.0251,721628,717,,,"Queensland, Australia",14106.69533769915,0.09935867233533067
,,South Australia,Australia,2022-03-26 04:20:23,-34.9285,138.6007,227182,246,,,"South Australia, Australia",12933.788784514658,0.108283
,,Tasmania,Australia,2022-03-26 04:20:23,-42.8821,147.3272,78805,29,,,"Tasmania, Australia",14716.153127917834,0.03679969545079627
,,Victoria,Australia,2022-03-26 04:20:23,-37.8136,144.9631,1233174,2722,,,"Victoria, Australia",18598.349899696823,0.2207312187898869
,,Western Australia,Australia,2022-03-26 04:20:23,-31.9505,115.8605,132060,34,,,"Western Australia, Australia",5020.147494868091,0.0257
,,,Austria,2022-03-26 04:20:23,47.5162,14.5501,3665003,15619,,,Austria,40693.3180849174,0.4261660904506763
,,,Azerbaijan,2022-03-26 04:20:23,40.1431,47.5769,791654,9675,,,Azerbaijan,7807.873914790897,1.2221248171549692
,,,Bahamas,2022-03-26 04:20:23,25.025885,-78.035889,33242,788,,,Bahamas,8453.189844576451,2.370495156729439
,,,Bahrain,2022-03-26 04:20:23,26.0275,50.55,549718,1468,,,Bahrain,32306.270102604463,0.2670460126828665
,,,Bangladesh,2022-03-26 04:20:23,23.685,90.3563,1951174,29118,,,Bangladesh,1184.7600400567412,1.4923323086510993
,,,Barbados,2022-03-26 04:20:23,13.1939,-59.5432,58270,330,,,Barbados,20276.92425470907,0.5663291573708598
,,,Belarus,2022-03-26 04:20:23,53.7098,27.9534,957088,6767,,,Belarus,10128.643105679232,0.7070405229195226
,,Antwerp,Belgium,2022-03-26 04:20:23,51.2195,4.4024,592524,0,,,"Antwerp, Belgium",31890.660101852216,0.0
,,Brussels,Belgium,2022-03-26 04:20:23,50.8503,4.3517,424772,0,,,"Brussels, Belgium",35147.475222209905,0.0
```

Which data type can we use to represent tables?

# Representing tables

* Lists are 1-dimensional, but a list can contain values of any type, including lists.
* A table can be stored as a list of lists, by row, for example:

```
data[i]     # i:th row
data[i][j]  # j:th column of i:th row
```

* Indexing (and slicing) are *operators*
* Indexing (and slicing) associate to the left:

```
data[i][j] == (data[i])[j]
```

# Reading data files

* Use a python module that helps with reading the file format:

```
import csv
with open("filename.csv") as csvfile:
    reader = csv.reader(csvfile)
    next(reader) # skip the header
    data = [ row for row in reader ] # reader is an iterable
```

* More about (reading and writing) files later in the course.

# How to select a column of the table?

* List comprehension:

```
first_col = [ row[0] for row in data ]
last_two_cols = [ row[-2:] for row in data ]
```

* Equivalent to:

```
first_col = []
for row in data:
    first_col.append(row[0])
```

# Select rows satisfying some conditions?

* Syntax:

```
[ expression for item in iterable if condition ]
```

* Example: select rows where column-1 is $>$ 10

```
sel_rows = [ row for row in data if int(row[1]) > 10 ]
```

* Equivalent to:

```
sel_rows = []
for row in data:
    if int(row[1]) > 10:
        sel_rows.append(row)
```

# How to sort rows by some keys?

* `sorted(seq)` returns a list with values in `seq` sorted in default order (<).
  - We can sort the rows in a table.
  - Reminder: comparison of sequences is lexicographic.
* `sorted(seq, key=`*`fun`*`)` sorts value `x` by *`fun`*`(x)`.

```
def new_order(row):
    return -row[-1]  # decreasing on last col

sd = sorted(data, key=new_order)
```

# Descriptive statistics

* `min(seq)`;
* `max(seq)`;
* mean (`sum(seq) / len(seq)`);
* variance.
* No built-in function for median.

```
def median(seq):
    if len(seq) % 2 == 1:
        return sorted(seq)[len(seq) // 2]
    else:
        return sum(sorted(seq)[(len(seq)//2-1):(len(seq)//2+1)])/2
```

# Visualisation

* The purpose of visualisation is to see or show information – pretty pictures are only of secondary importance!
* Different kinds of plots show different things:
  - barplot
  - pie-chart
  - histogram or cumulative distribution
  - scatterplot
  - line and area plot
* Use one that best makes the point!
* Choose your dimensions carefully.
* Label axes, lines, etc.

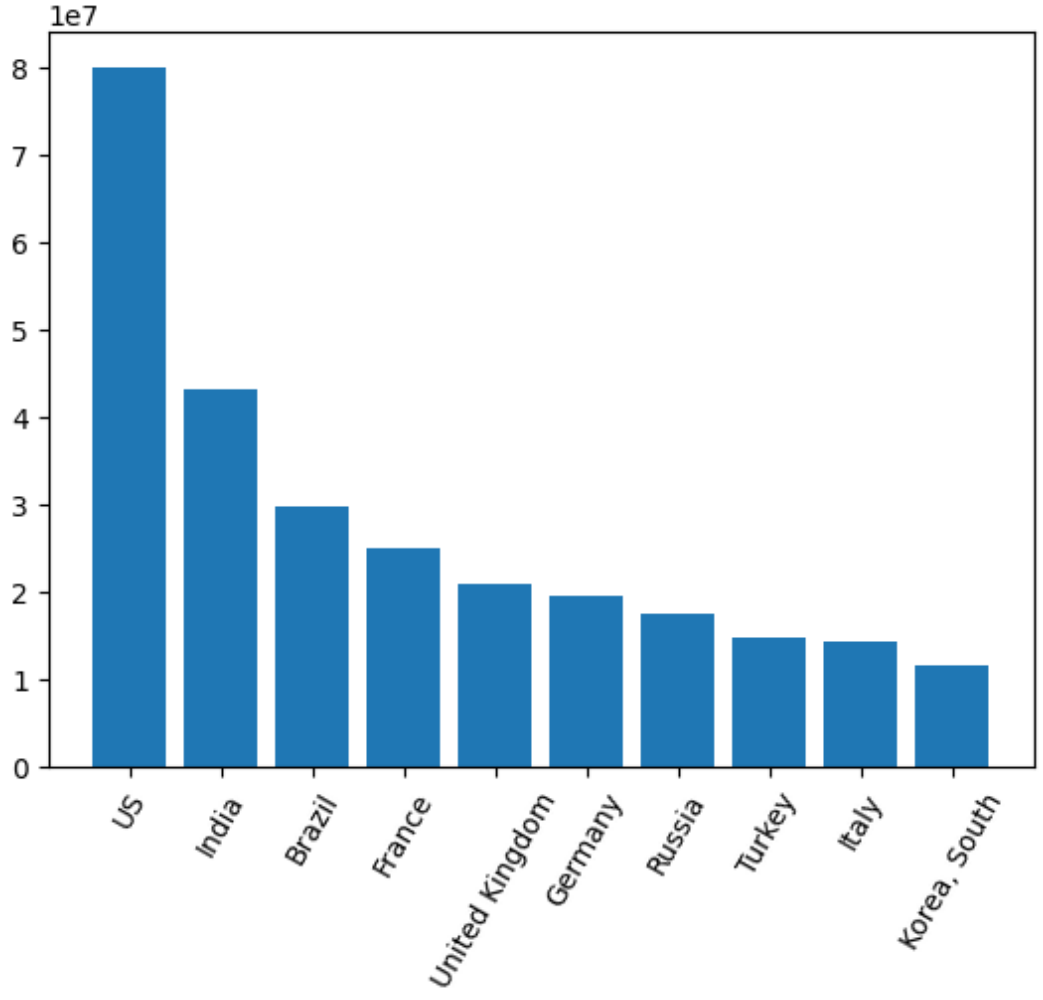
# Matplotlib

* Matplotlib is a Python 2D plotting library, which produces publication quality figures.
* "*Matplotlib makes easy things easy and hard things possible*".
* Documentation: `matplotlib.org`

Programming problem:

* How many COVID-19 positive cases worldwide until 2022-03-25?
* How many COVID-19 deaths worldwide until 2022-03-25?
* What are the top-10 countries with the most cases until 2022-03-25?
* How to visualise this result?

(added after lecture)
The code was live demo in the lecture. And visualisation with barplot:



# Take home message

* Python is powerful in data analysis.
* Think carefully about visualisation: How can people quickly interpret the results?
* We have only scratched the surface of Matplotlib. Extensive documentation: `https://matplotlib.org` or just **google it**!