DS4LAW

Workshop 1: Algorithms (foundations)

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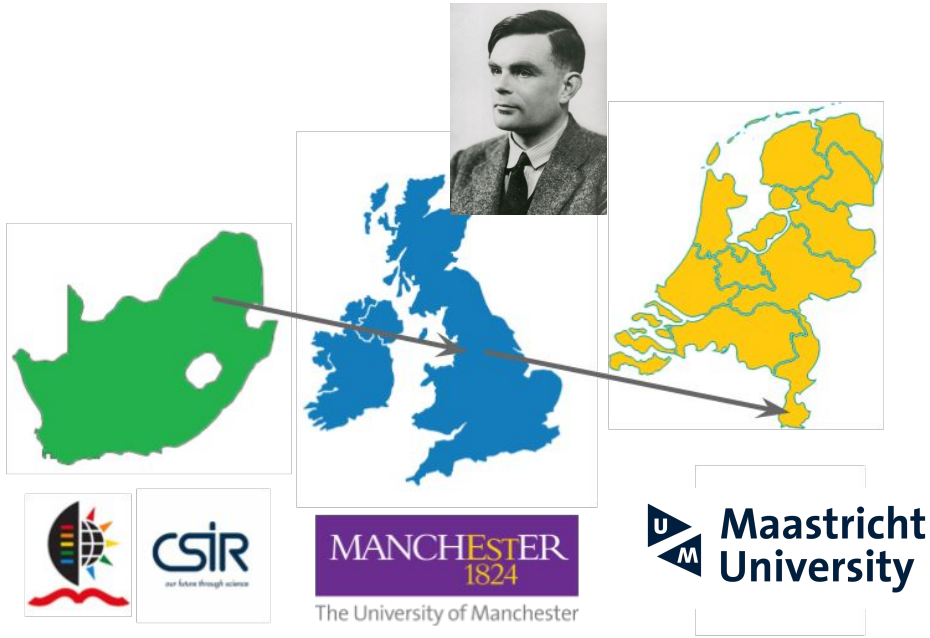
Maastricht University

Institute of Data Science

A little about me

- Born and bred in South Africa
- Trained as a Computer Scientist
- BSc & MSc in Pretoria
- PhD in Manchester
- Industry - **creating algorithms** (mobile applications)
- 1st Postdoc in Maastricht



“In theory, there is no difference between theory and practice, in practice, there is.” - Jan L. A. Van De Snepscheut (Caltech)

A little about you?

- Brief introduction (name & affiliation)
- What is your interest: DS4LAW or LAW4DS?
- Experience with algorithms
- What you hope to gain from the session

Aims

- Basic literacy of algorithms in the context of Computer Science
- LAW4DS:
  - Understanding mechanisms of algorithms can aid formulation of good questions about their regulation
  - Intuition for distinguishing between true & apparent algorithmic intelligence
- DS4LAW:
  - Theoretical foundations of algorithms & role in computer science
  - Basic practical experience with creating & implementing algorithms

Roadmap

Mostly talking

- Part 1A: Algorithms are all around us...but what exactly are they?
- Part 1B: Algorithms in Computer Science
- Part 2: Real examples of algorithms
- Part 3: Ethical significance of algorithms

Mostly doing

- Python programming in Jupyter notebooks
- Write and test some algorithms!

Part 1A

Algorithms are all around us...but what are they?

Definition for Algorithm

“a set of rules that must be followed when solving a particular problem.”

- Oxford Learner’s Dictionary

“A set of specific, step-by-step instructions for taking an input and converting [it] into an output.”

- John Danaher, The Philosophical Importance of Algorithms, 2015.

In short: “a set of step-by-step instructions for executing a task.”

Examples

Making a peanut butter & jelly sandwich

1. Get a piece of bread
2. Spread peanut butter on it
3. Get another piece of bread
4. Spread jelly on it
5. Put the two pieces of bread together

Who is issuing the instructions?
Who is executing the instructions?

What are the inputs & outputs of the algorithm?

Examples

Shampooing hair

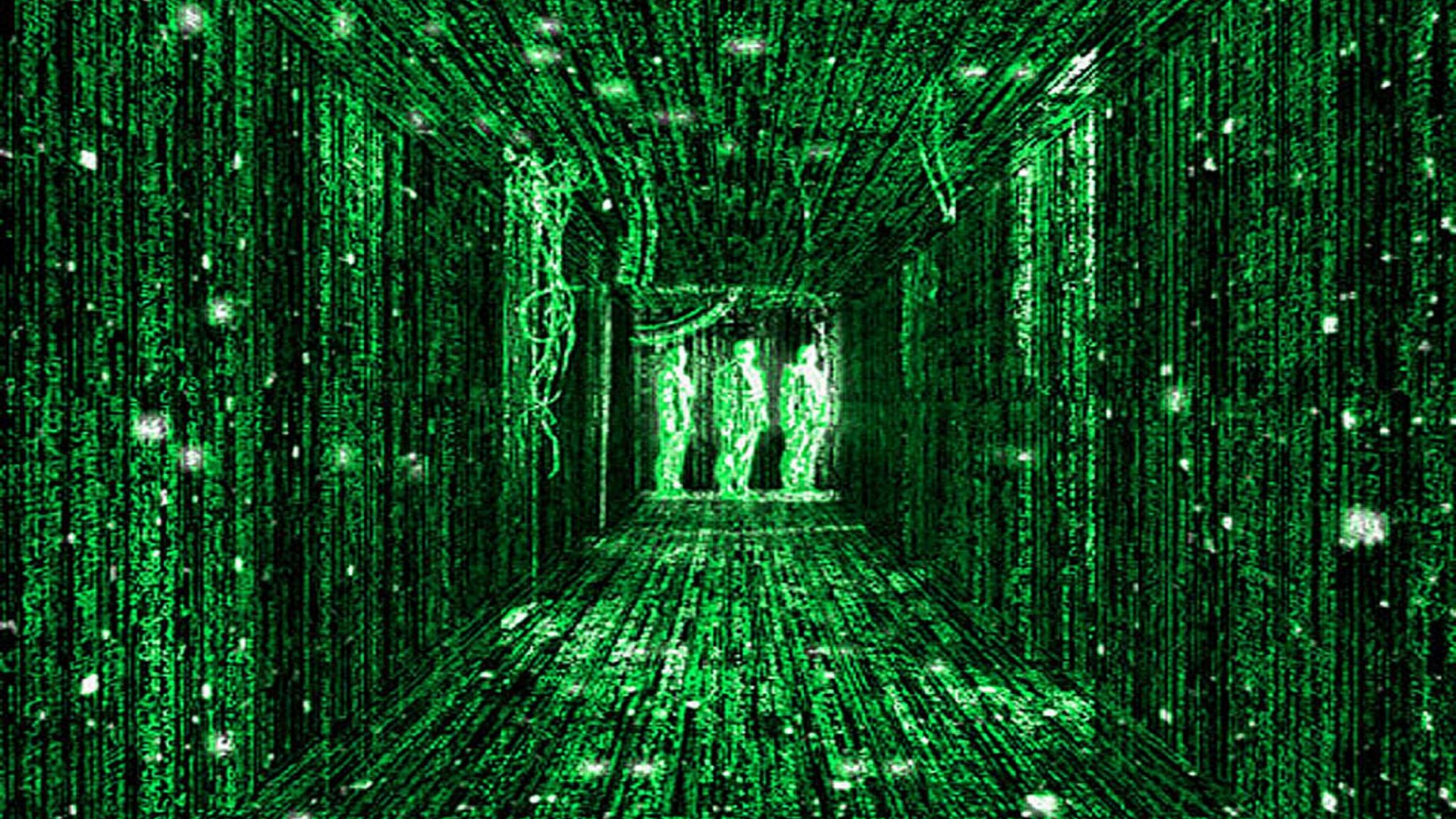
Anything strange about this algorithm?

Who is issuing the instructions?
Who is executing the instructions?

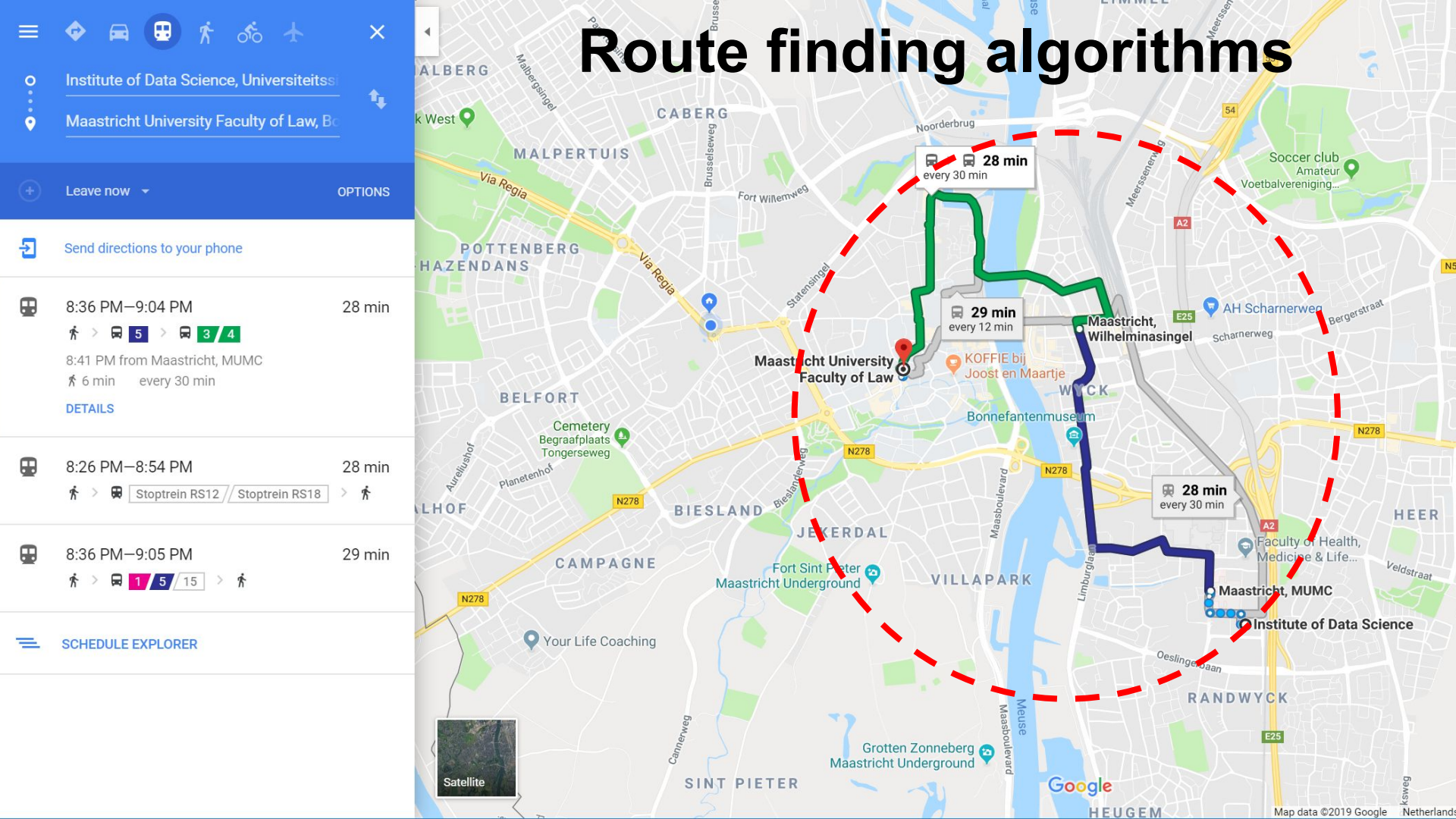
What are the inputs & outputs of the algorithm?

Part 1B

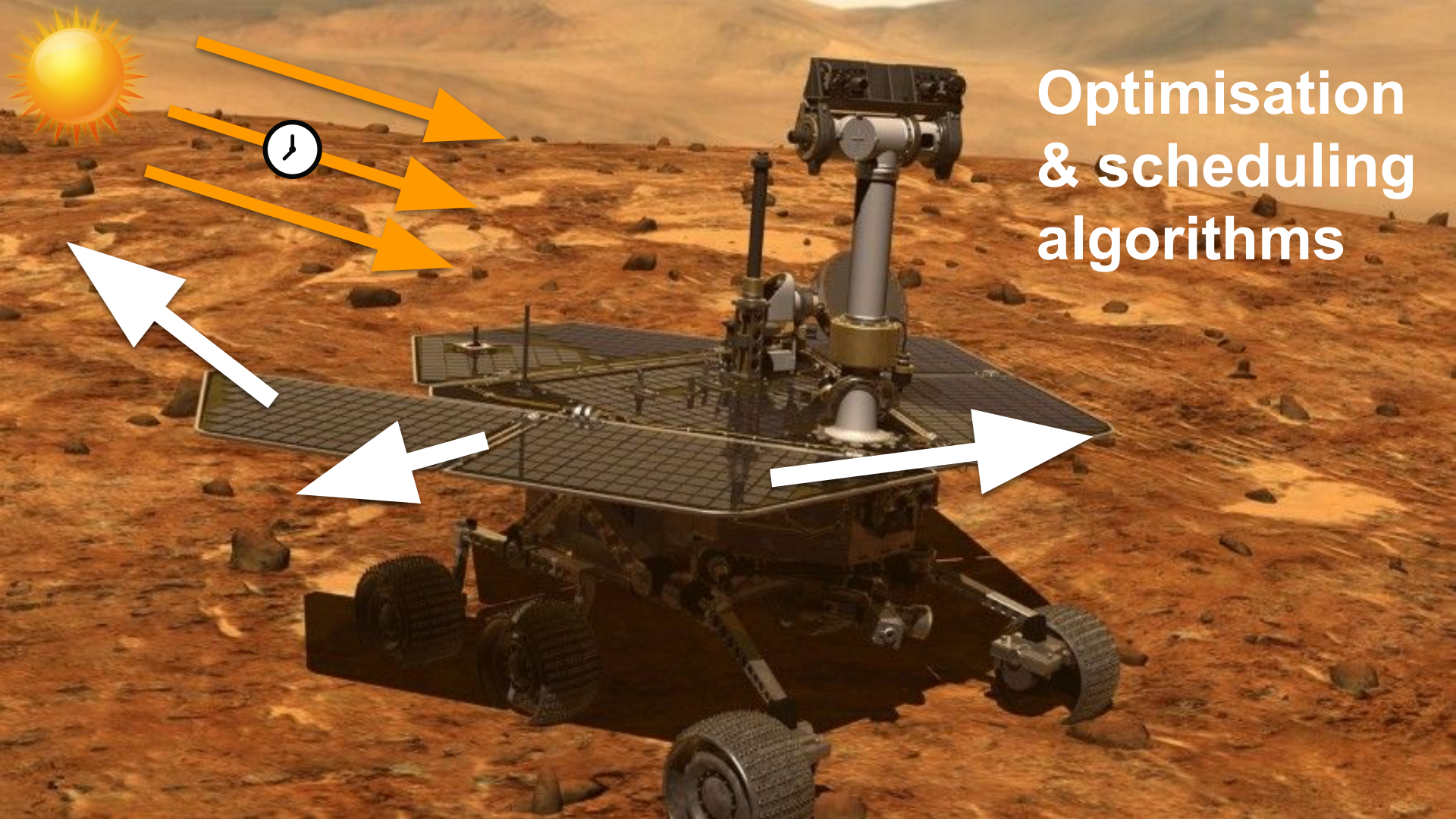
Algorithms in Computer Science



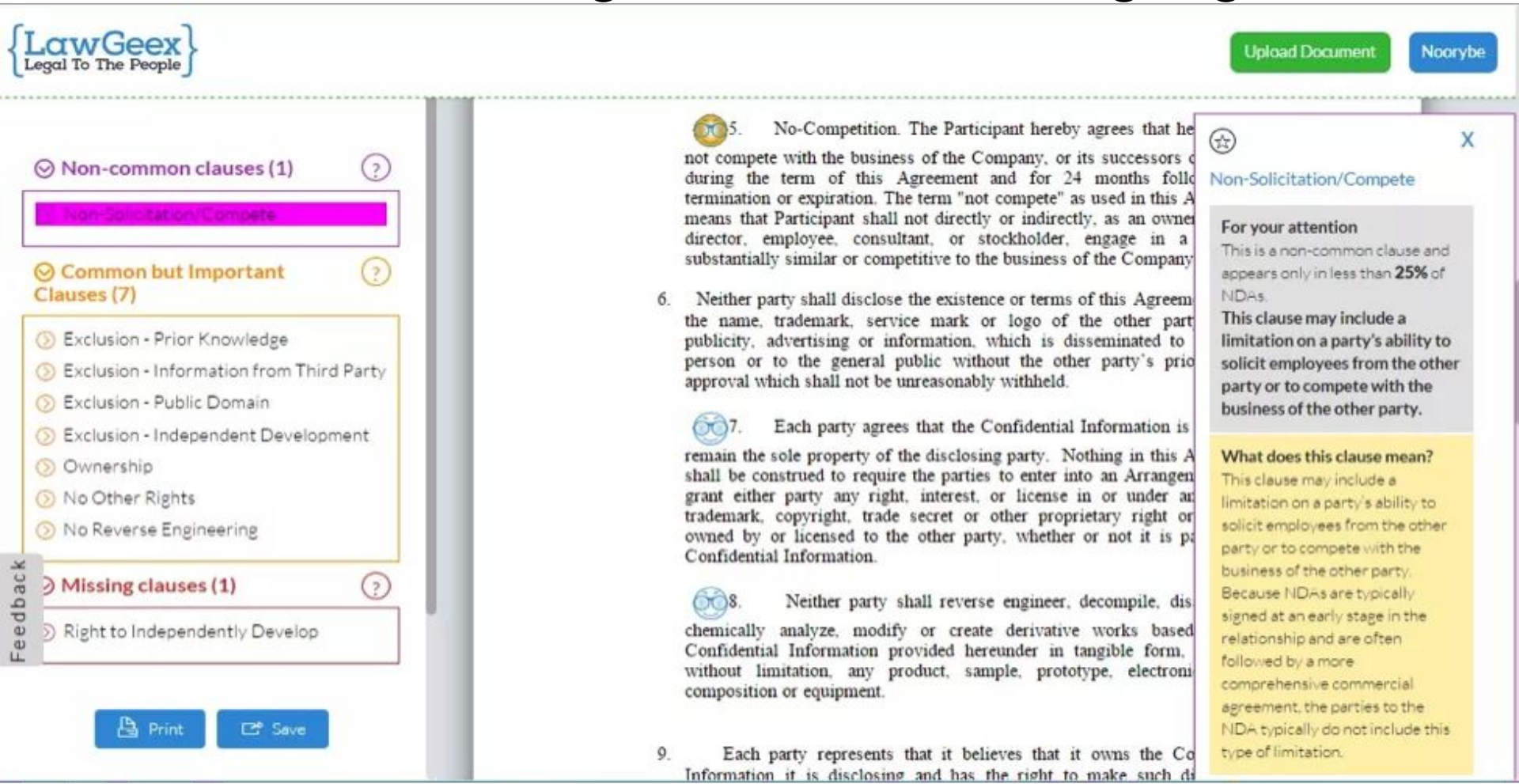
Route finding algorithms



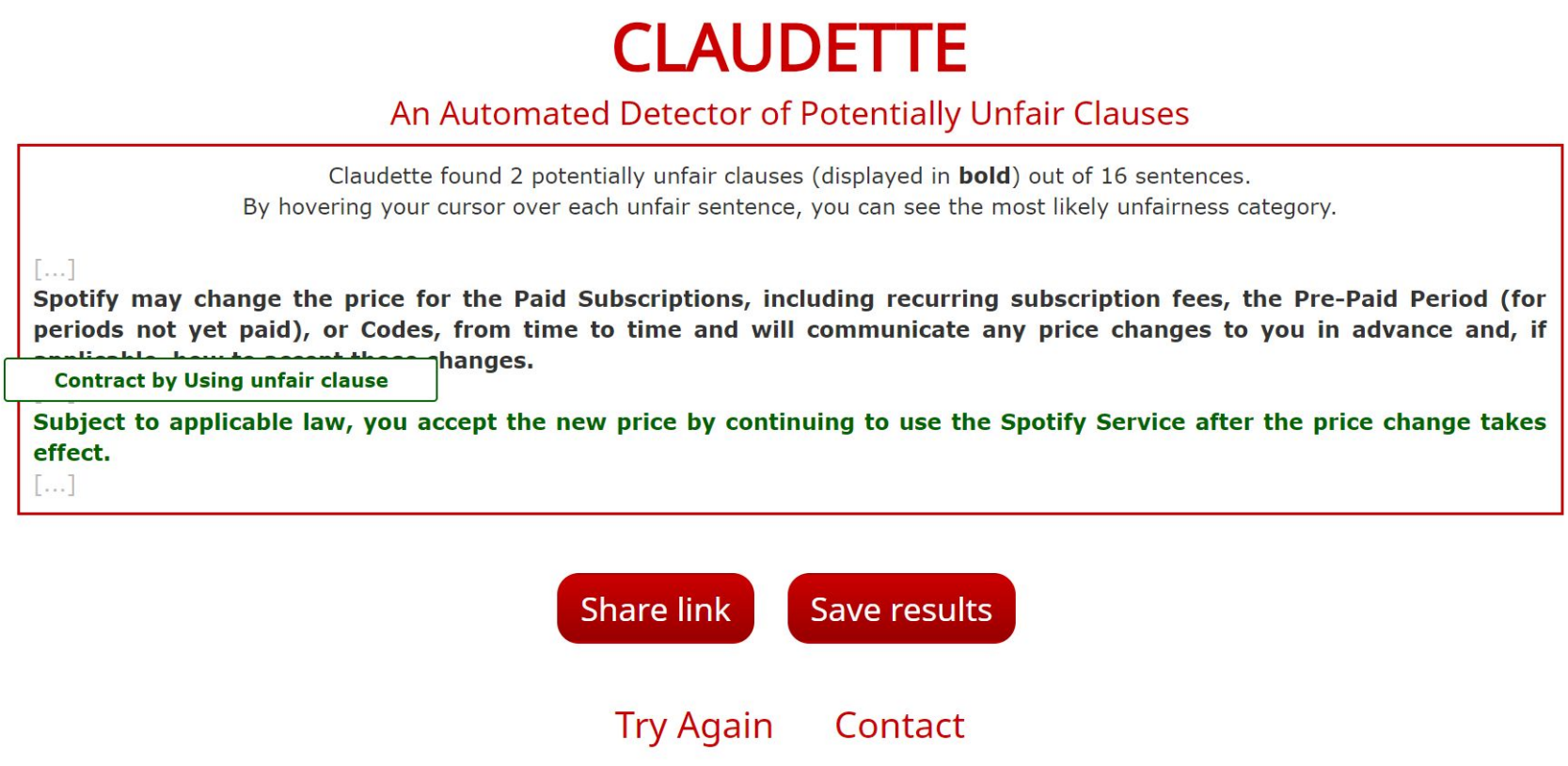

Audio & Video
compression
algorithms
Eye Waveform
Jitter1 HPF 10 Hz – Timing
Tektronix


Optimisation
& scheduling
algorithms

Contract review using Machine Learning algorithms



Unfair clause detection using Machine Learning



Algorithms in Computer Science

Who is issuing the instructions? **Humans**
Who is executing the instructions? **Computers**

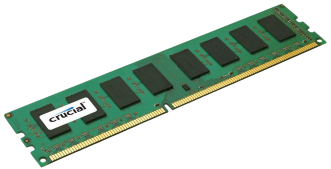
Computer Architecture

Central Processing Unit (CPU)

Memory Unit (Primary & Secondary)

Input devices

Output devices



Computer Architecture

STORAGE

23 + 34?

1	2	3
Value: “23”	**Instruction:** “add(1,3)”	**Value:** “34”
...	...	...

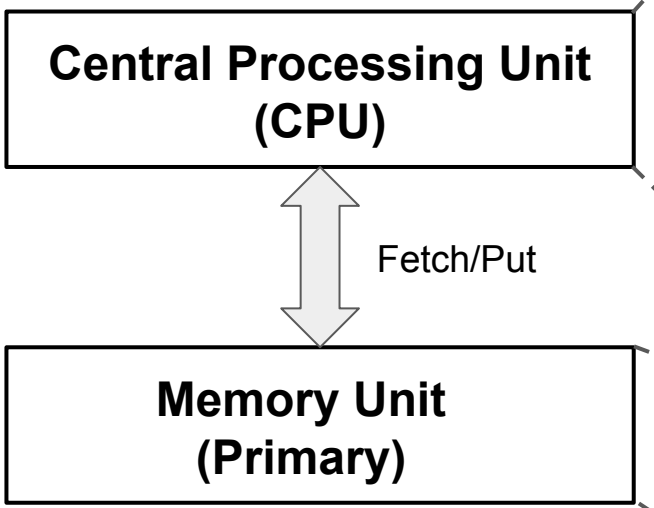
How many bits does a computer with 4GB of RAM have?

Each block represents the charge of a single capacitor in memory

0	0	1	0	0	0	1	0	“34”
0	0	0	1	0	1	1	1	“23”
0	0	1	0	0	0	0	0	“add(1,3)”
2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0	

Computer Architecture

COMPUTATION



1. Fetch instruction from memory location 2
2. Execute instruction:
   a. Load the first number into the CPU
   b. Add the second number to this number
3. Store the sum in memory location 4

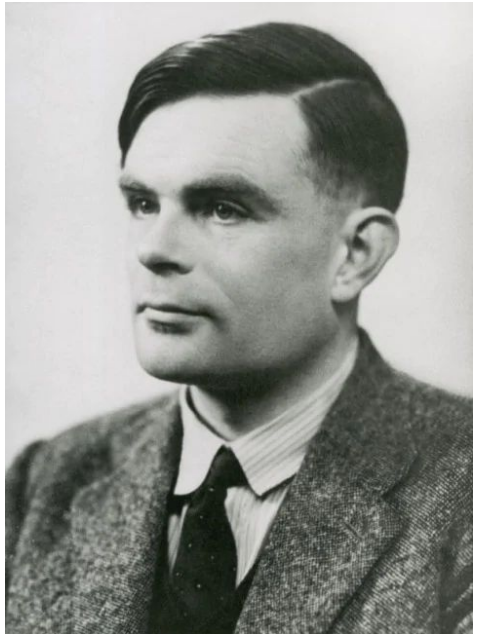
```
  0 0 1 0 0 0 1 1 0
+ 0 0 0 1 0 1 1 1
-----------------
  0 0 1 1 1 0 0 1
```

1	2	3	4
Value: “23”	**Instruction:** “add(1,3)”	**Value:** “34”	**Value: “57”**
...	...	...	

Computer Architecture

Modern computers using Turing's model of computation

- Described by a Turing machine
- Any algorithm that you can conceive of and execute as a human being, can be represented as a set of operations in a Turing machine.



Example (square root)

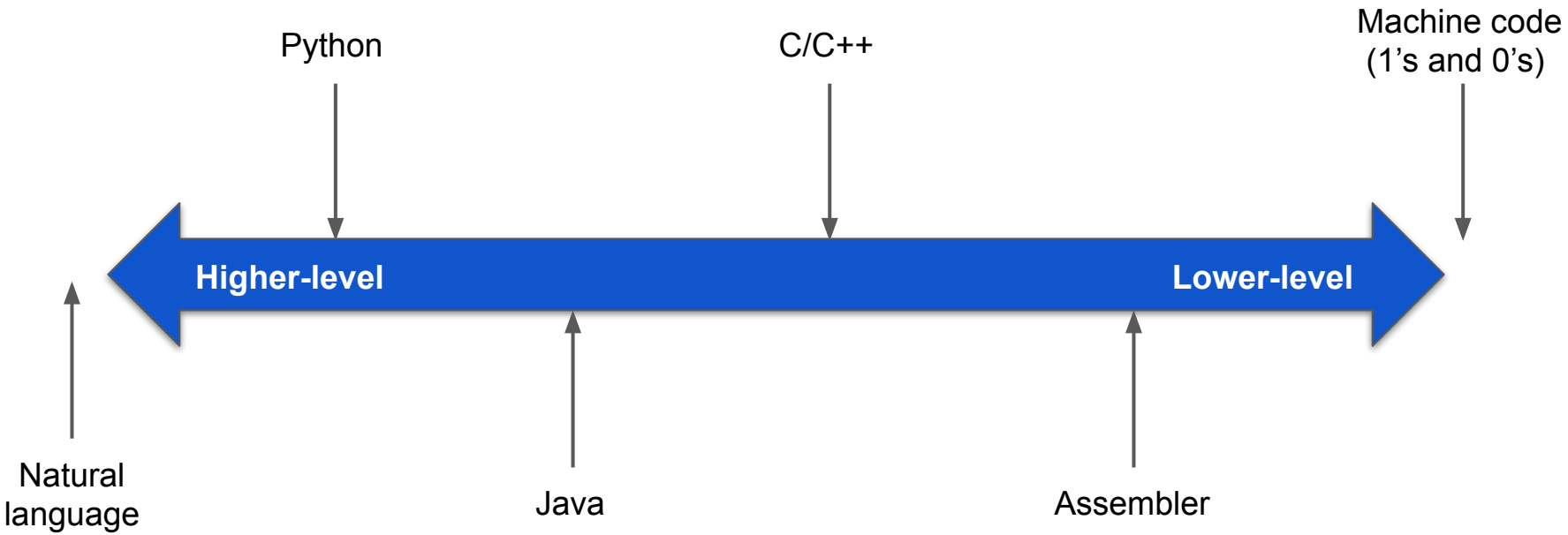
What is the square root of a given number?

Try it out with “9”!

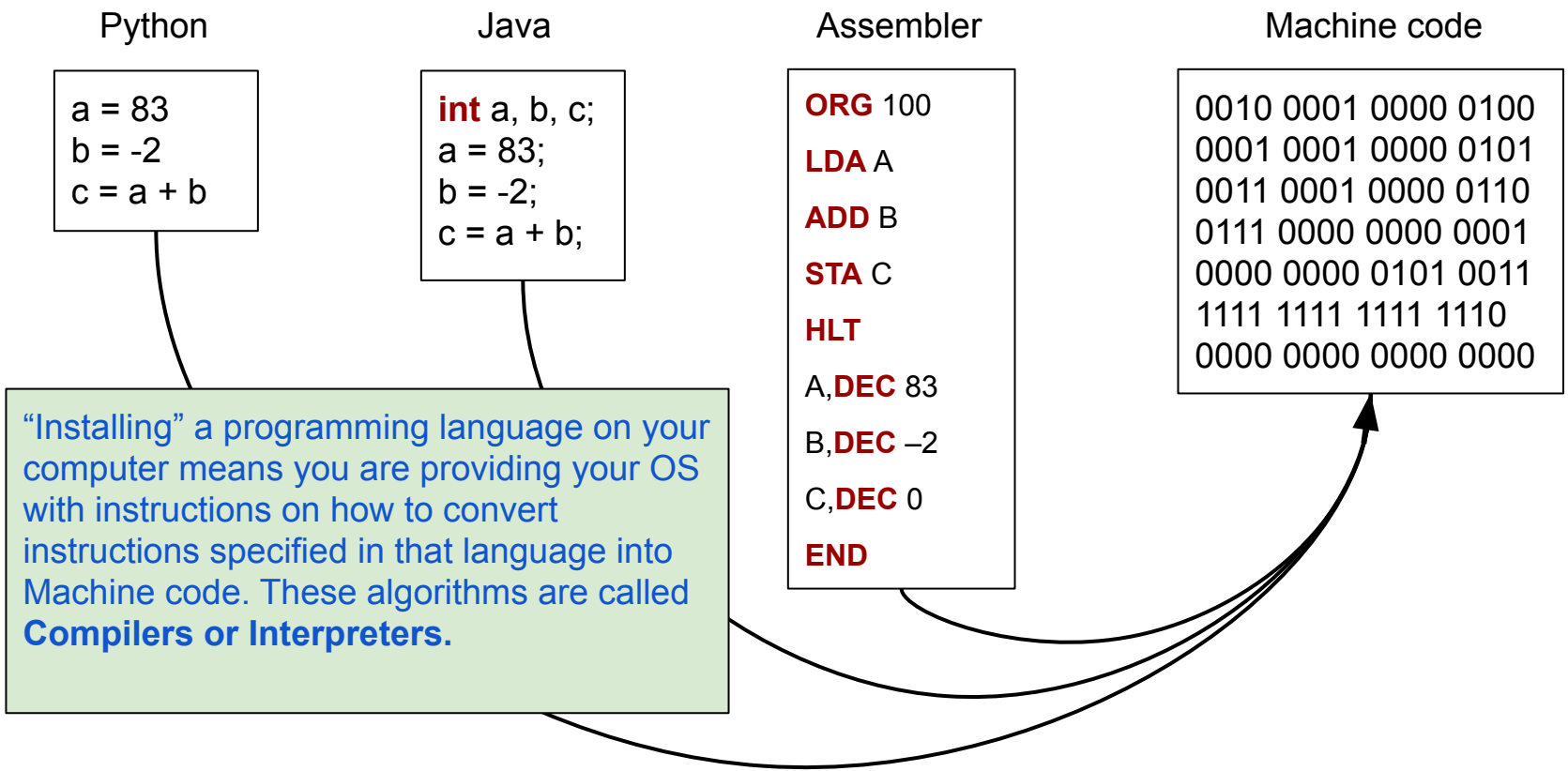
Put input number here				
(1)	**(2)**	**(3)**	**(4)**	**(5)**

1. Write 0 in box (2)
2. Increment (2)
3. Write 0 in box (3)
4. Copy number in (2) to box (4)
5. If box (4) contains 0, go to step 12.
6. Decrement (4)
7. Copy number in (2) to box (5)
8. If box (5) contains 0, go to step 5.
9. Decrement (5)
10. Increment (3)
11. Go to step 8.
12. If number in (3) not greater than number in (1), go to step 2.
13. Decrement (2)

Programming languages



Programming languages



Part 2

Real examples of algorithms

Find the largest number in a list

Judge name	Number of cases
Ilešič	266
Jann	280
Schockweiler	251
Moitinho de Almeida	272
Toader	263
Rosas	284
Silva de Lapuerta	252
Gulmann	255

Find the largest number in a list

Number of cases
266
280
251
272
263
284
252
255

- Input: ?
- Output: ?
- Instructions: ?

Find the largest number in a list

Number of cases
266
280
251
272
263
284
252
255

- Input: list of numbers e.g. 266,280,251,272,263,284,252,255
- Output: largest number in the list e.g. 284
- Outline of algorithm:
  - Assume the first number in the list is the largest
  - Consider each number in the list one-by-one from top to bottom
  - While we do this, if the current number being looked at is larger than the current largest number, consider this number to be the new largest
  - Stop when we get to the end of the list

Sort a list of numbers from smallest to largest

Number of cases
266
280
251
272
263
284
252
255

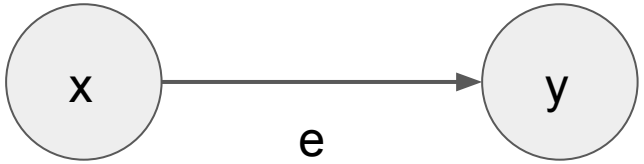
- Input: ?
- Output: ?
- Instructions: ?

Sort a list of numbers from smallest to largest

Number of cases
266
280
251
272
263
284
252
255

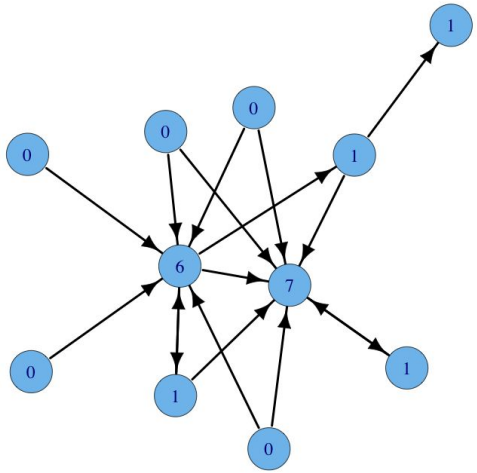
- Input: list of numbers e.g. 266,280,251,272,263,284,252,255
- Output: list of numbers sorted ascending order e.g. 251,252,255,263,266,272,280,284
- Outline of algorithm:
  - Create a new empty list
  - Find smallest number in input list and add it to end of the new list
  - Remove number in previous step from input list
  - Repeat Steps 2 and 3 until input list is empty

Network Analysis

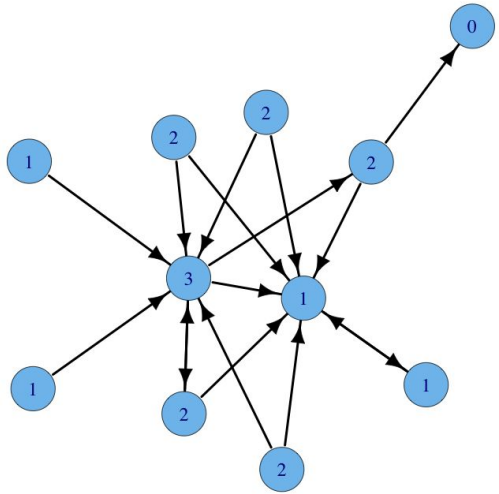



```
int calculate_indegree(graph g, vertex v):
        count = 0
        for each e in g.getAllEdges():
                if e.y == v:
                        count++
        return count
```

```
int calculate_outdegree(graph g, vertex v):
        count = 0
        for each e in g.getAllEdges():
                if e.x == v:
                        count++
        return count
```



Nodes = court decisions
Edges = citations



Part 3

Ethical significance of algorithms

Algorithm transparency

“Algorithms are not arbiters of objective truth and fairness simply because they're math.” - **Zoe Quinn**

- Transparency is a challenge with more complex algorithms (especially with ML)
- Decision-making algorithms (implications for **liability**)
- Vs. Algorithms **used** in decision-making
- Dichotomy: what an algorithm actually does and what it is **claimed** or **advertised** to do **(BEWARE OF HYPE - the truth is often far less impressive)**

Algorithms using deductive vs. inductive reasoning

- Bob likes hockey
- Bob has a systolic pressure reading of 150
- His favourite colour is green
- He works for the US Navy
- Bob’s father, Daniel, was admitted to hospital in 1999 with a systolic pressure reading of 180
- Daniel also worked for the US Navy
- Anna was chief of cardiology in the general hospital
- Daniels father took medication for hypertension
- Bob’s mother, Anna, had a normal systolic pressure reading of 110
- Systolic pressure readings between 100 - 120 are normal, anything above 120 is considered high
- Having hypertension, and a family history of it, means you are at risk of a heart attack
- If you have high systolic pressure, it means that you have hypertension

Is Bob at risk of a heart attack?

Algorithms using deductive vs. inductive reasoning

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- If you have high systolic pressure, it means that you have hypertension

Is Bob at risk of a heart attack? **YES!**

Deduction

Algorithms using deductive vs. inductive reasoning

- I saw three swans at the park
- All three were black
- I will go to the zoo tomorrow to see more swans
- What colour will they be?

Algorithms using deductive vs. inductive reasoning

- I saw three swans at the park
- All three were black
- I will go to the zoo tomorrow to see more swans
- What colour will they be?

Black (probably)

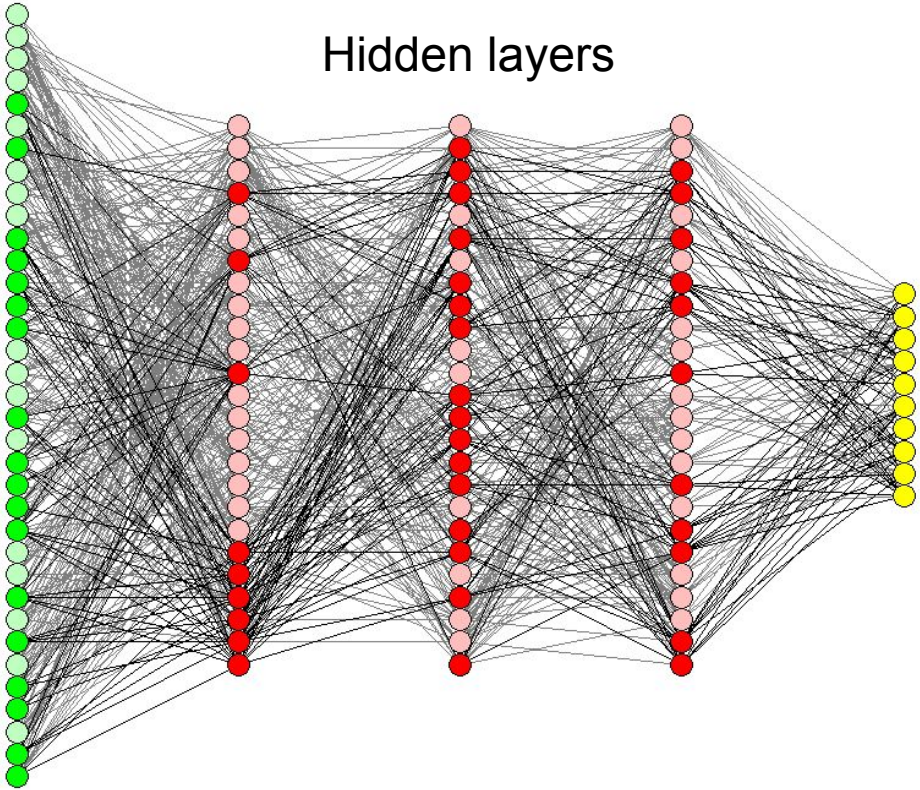
UNCERTAINTY, Lack of complete information

Induction (a form of generalisation)

Algorithms using deductive vs. inductive reasoning

Will I get cancer?

Hidden layers



Input layer

Output layer

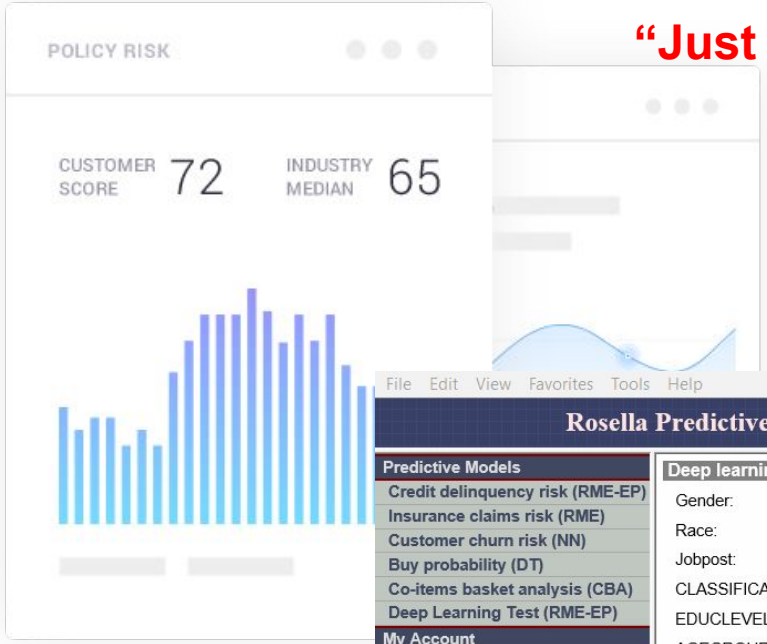
Yes / No

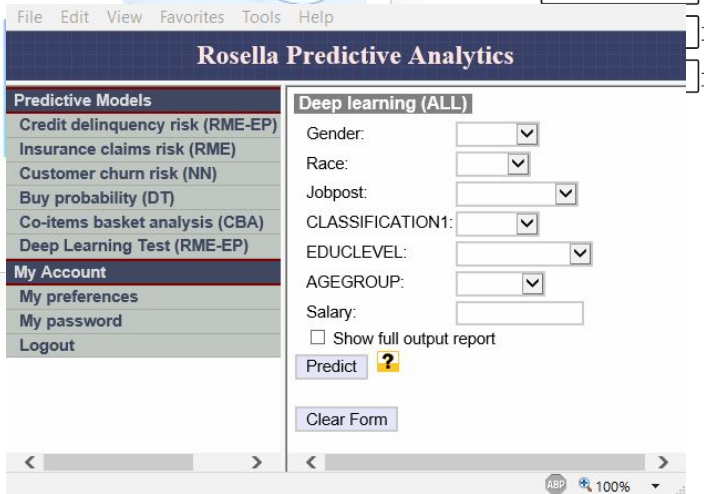
Height, weight, blood sugar levels, blood type, genetic data etc.

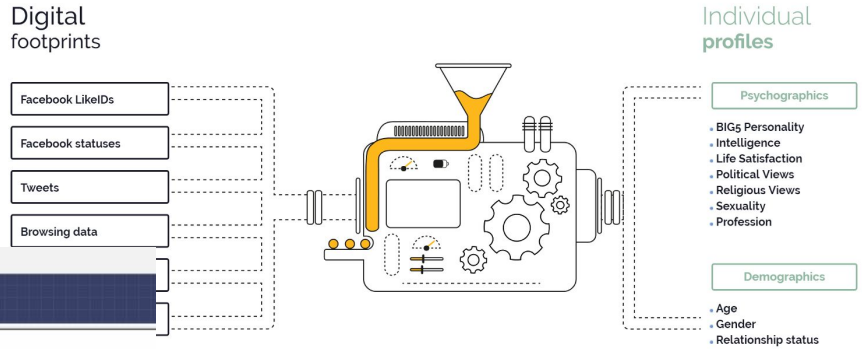

CNBC
“OK, I WILL DESTROY HUMANS”
if question about humans:
if person is smiling:
say:
“OK, I will destroy humans”

Ethical application of algorithms

“Just because you can, does not mean you should”







Summary

- Algorithms are step-by-step instructions for executing a task
- Issuing algorithmic instructions to computers requires a special language:
  - Computers, on their lowest-level, are only able to manipulate data represented in a binary language (0's and 1's)
  - Humans have created 'high-level' programming languages to help us communicate with computers more concisely
  - Compilers (algorithms for translating instructions from 'high-level' programming languages into computer language) make 'high-level' communication with computers possible
- Algorithms are usually developed in a modular way so they can be reused in other algorithms

Summary (cont.)

- Algorithms can be classified according to the problems they try to solve as well as the kinds of procedures used to solve them
- Ethical issues with algorithms are affecting society:
  - Lack of transparency in the algorithm's steps (e.g. Machine Learning)
  - Uncertainty in information doesn't stop attempts to predict (with algorithms)
  - Fundamental questions of whether algorithms (and automation in general) should be applied to solve certain problems (social implications etc.)

Practical

Jupyter notebook reference

Jupyter notebook online (without installing)

Resources

Computer Science & programming foundations

edX computer science & programming mooc

Udemy Python course

Datacamp Python course

Data Science textbook - Nice one!