Algoritmen & Heuristieken

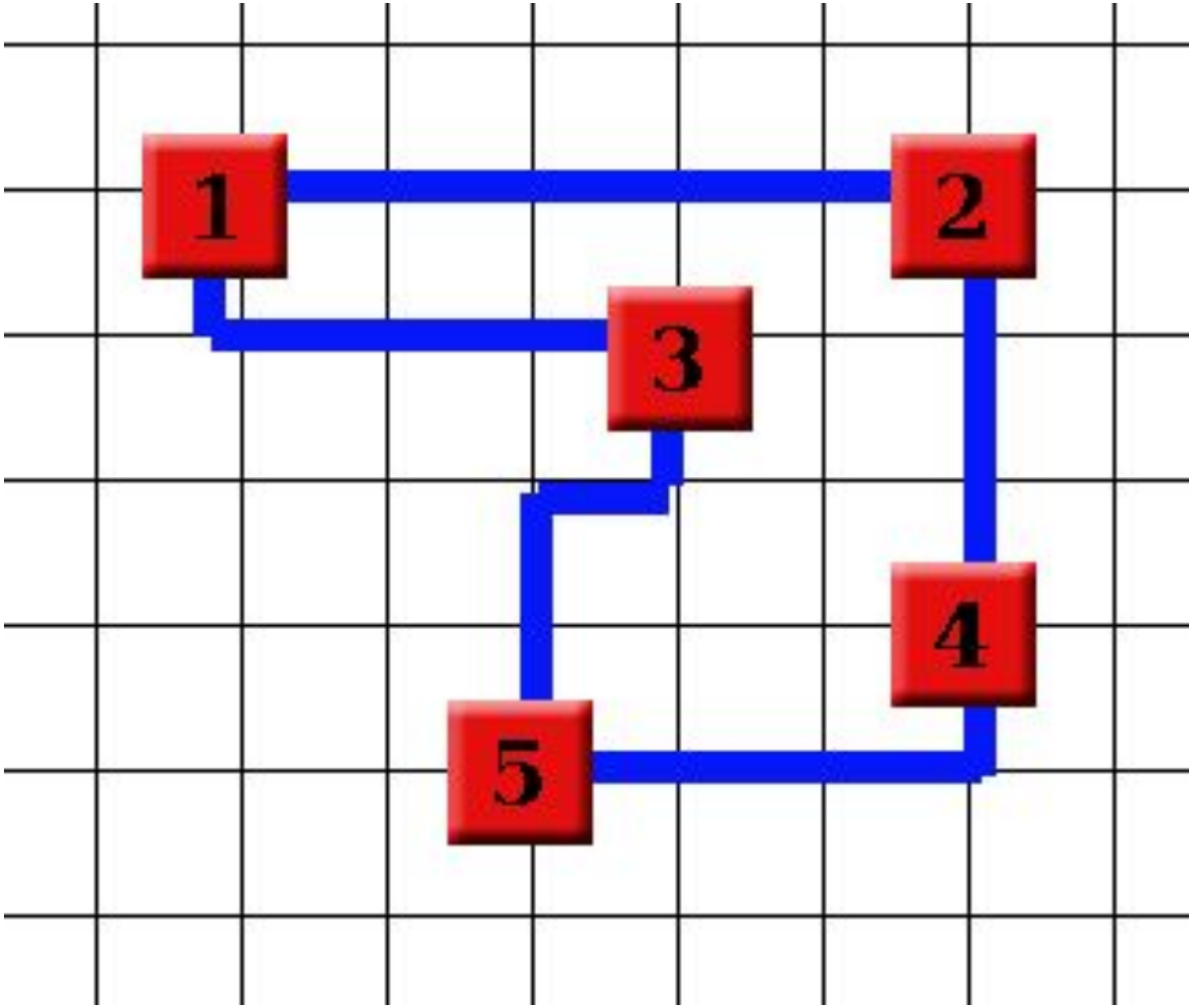
Experimenteren met optimaliseren

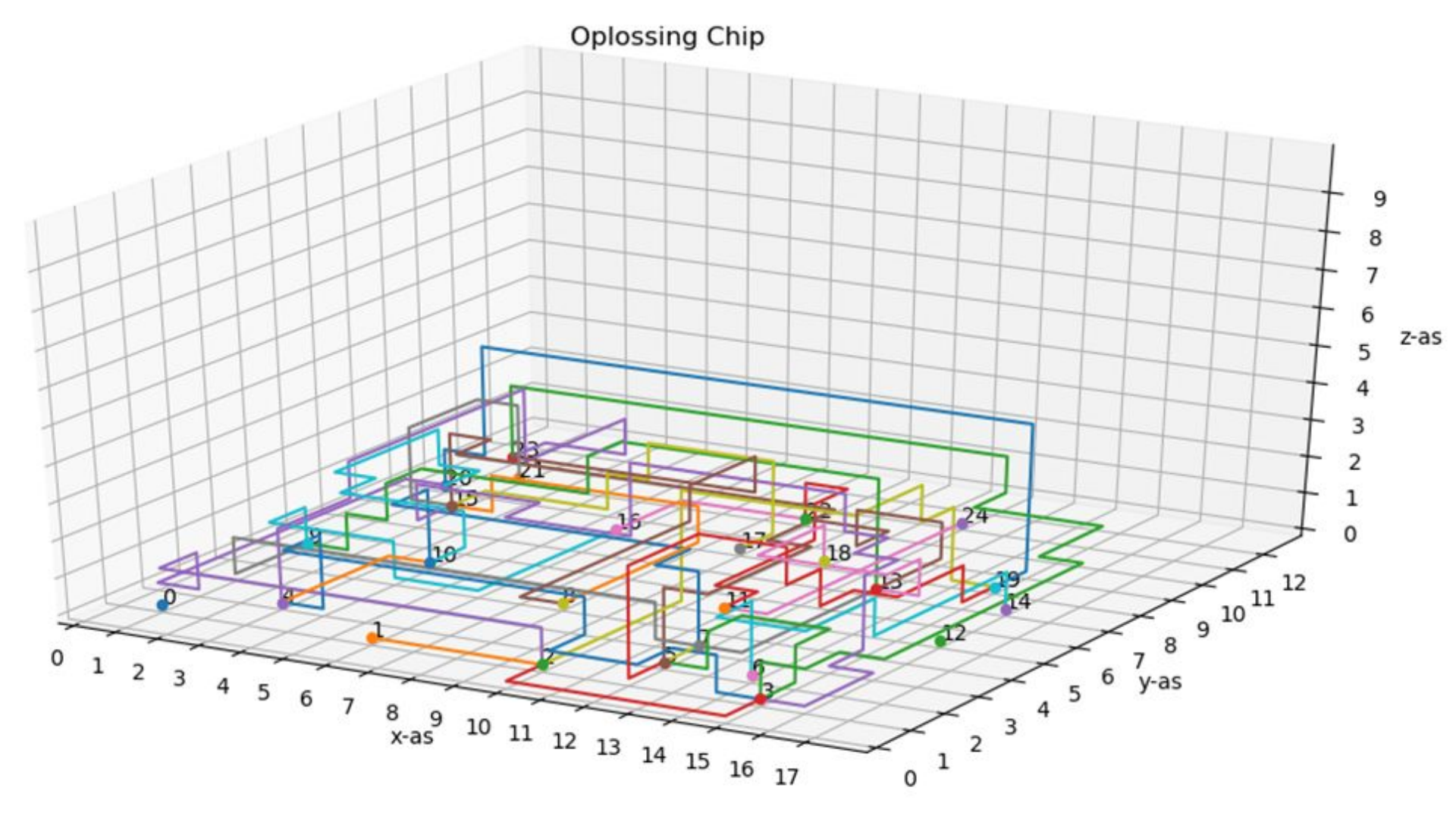
Jelle van Assema
proglab.nl

Experimenteren

Presenteren

The assignment is to implement all nets in all netlists at minimum cost.


1
2
3
4
5


Oplossing Chip
x-as
y-as
z-as

$$C = 578$$

Optimaal antwoord

Waarschijnlijk niet

$$C = 42$$

What was the ~~question~~ algorithm?

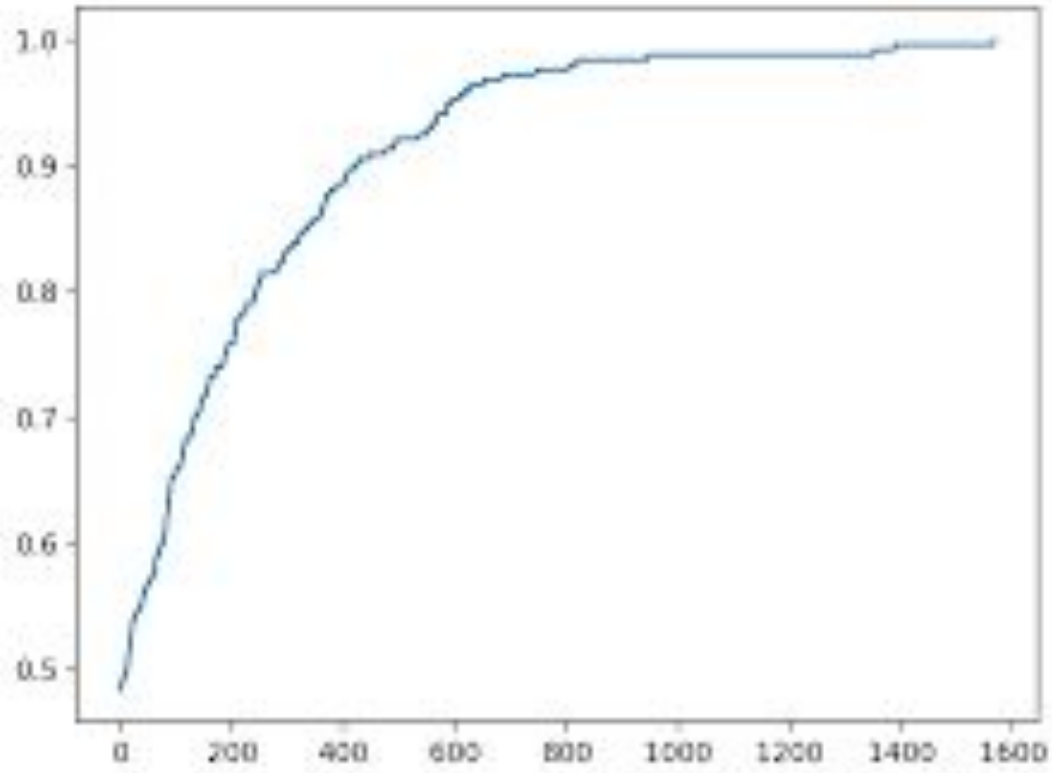
Om precies **00:37:31:678**

op **11/06/2023** produceerde

random_baseline.py

een grid met

C = 42


1.0
0.9
0.8
0.7
0.6
0.5
0
200
400
600
800
1000
1200
1400
1600

~~Global Optimum~~

∞

Random

~~The assignment is to implement all nets in all netlists at minimum cost.~~

What is a good algorithm to implement all nets in all netlists with at a minimum cost?

Wat is een goed algoritme?

Correct

Optimaal

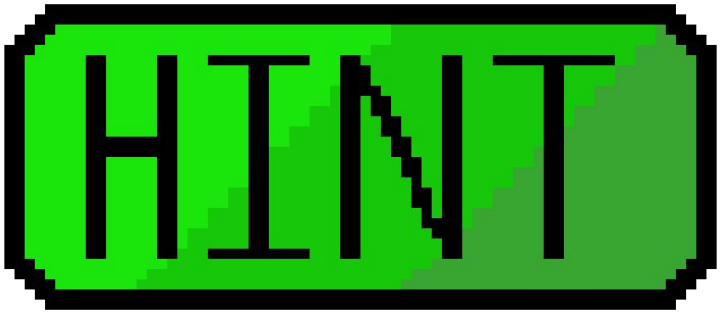
Efficiënt

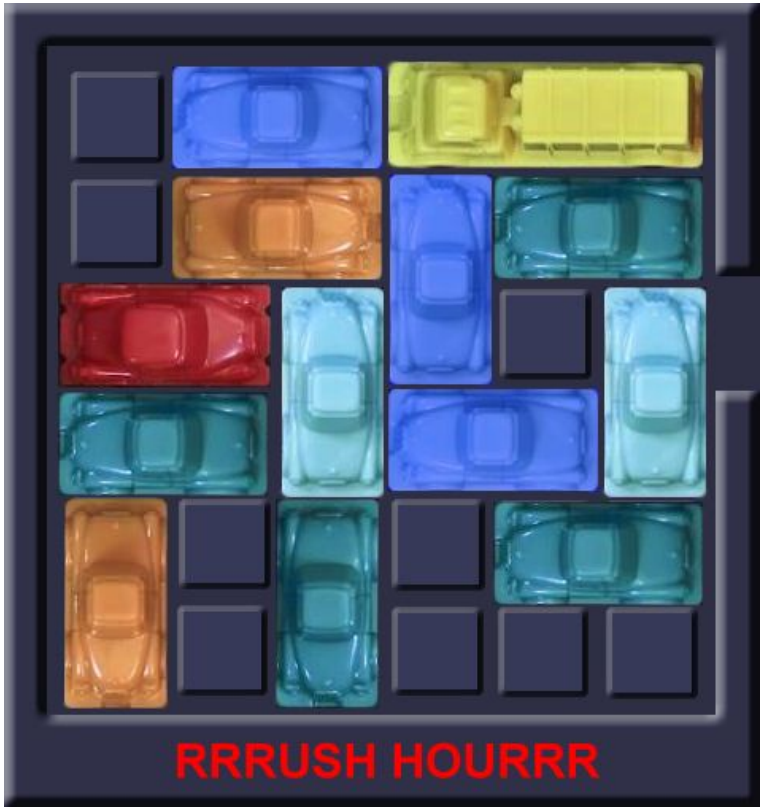
Consistent

...

Wat is een goed algoritme?

Wat is een goed algoritme?





Wat is een goed optimalisatie-algoritme?

Efficiëntie

Optimaal antwoord

Score

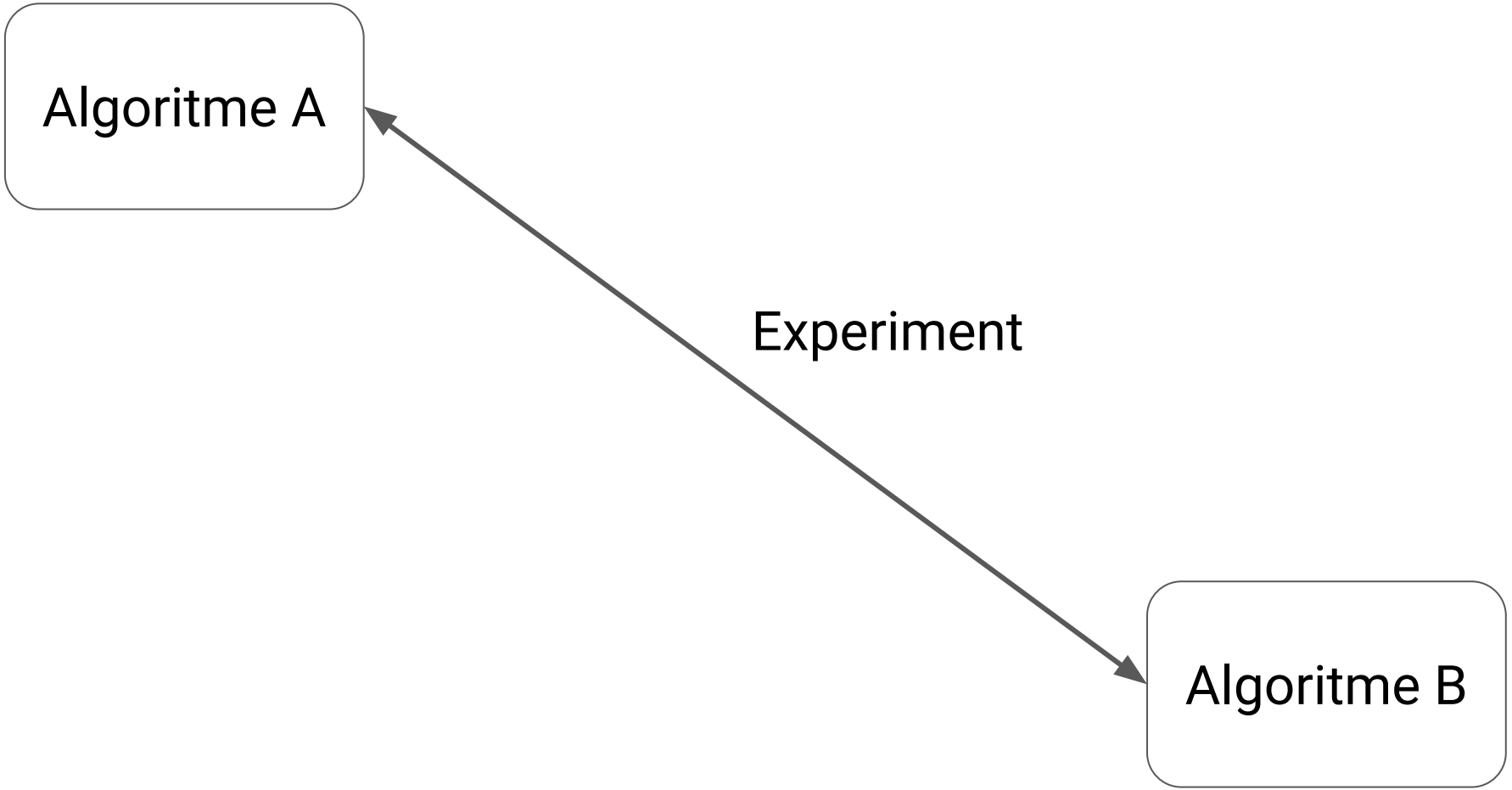
Waarschijnlijk niet

Efficiëntie

Algoritme A

Wat is een beter optimalisatie-algoritme?

Algoritme B


Algoritme A
Experiment
Algoritme B

Experiment

Resultaten

Evaluatie

Conclusie

Algoritme A

Wat is een beter optimalisatie-algoritme?

Algoritme B

Experimenteren met algoritmes

Experimenteren met algoritmes

```
while(change > 1) {
    coins += 1;
    change -= 1;
}
```

```
coins += change;
change = 0;
```

Experimenteren met algoritmes

~~Experimenteren met algoritmes~~

Experimenteren met **implementaties** van algoritmes

Implementaties van algoritmes

```
def sum_of_numbers_between(a, b):
    return sum(range(a, b))
```

$$C = 578$$

Praktisch onmogelijk om correctheid te bewijzen

Antwoord onbekend

Heisenbugs

Mensen

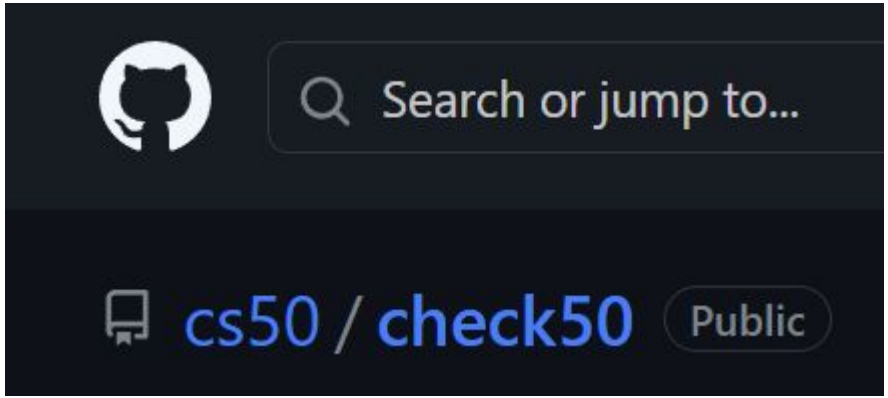
~~Experimenteren met algoritmes~~

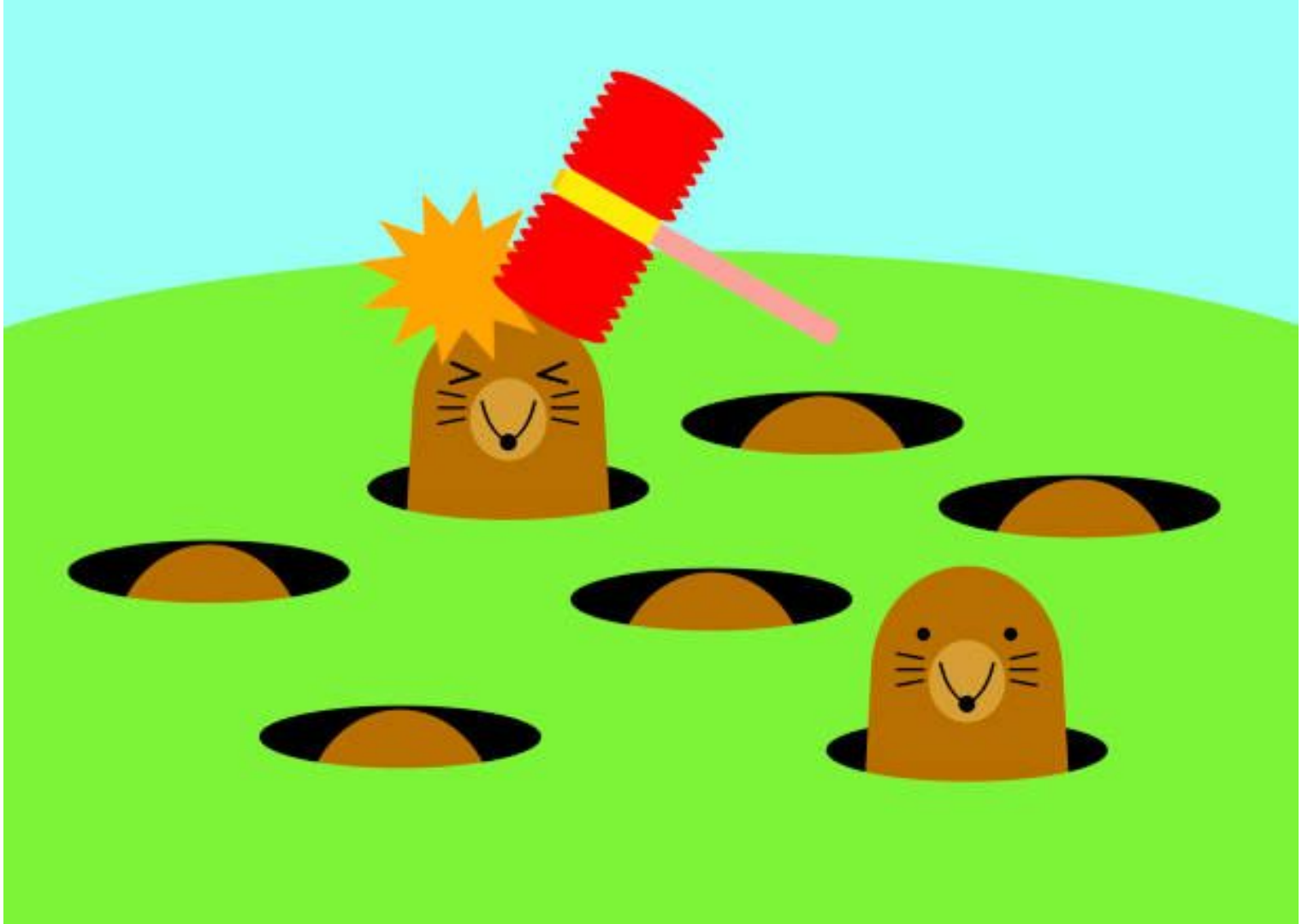
~~Experimenteren met~~
~~**implementaties** van algoritmes~~

Experimenteren met **buggy**
implementaties van algoritmes

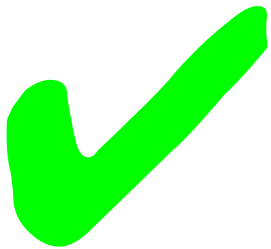
(unit)tests

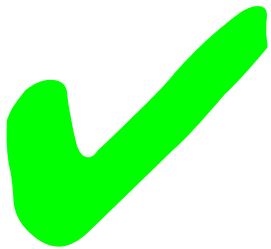

CS50

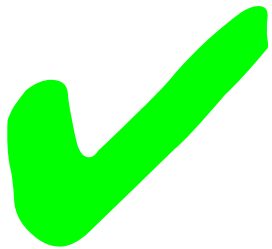

Search or jump to...
cs50 / check50
Public

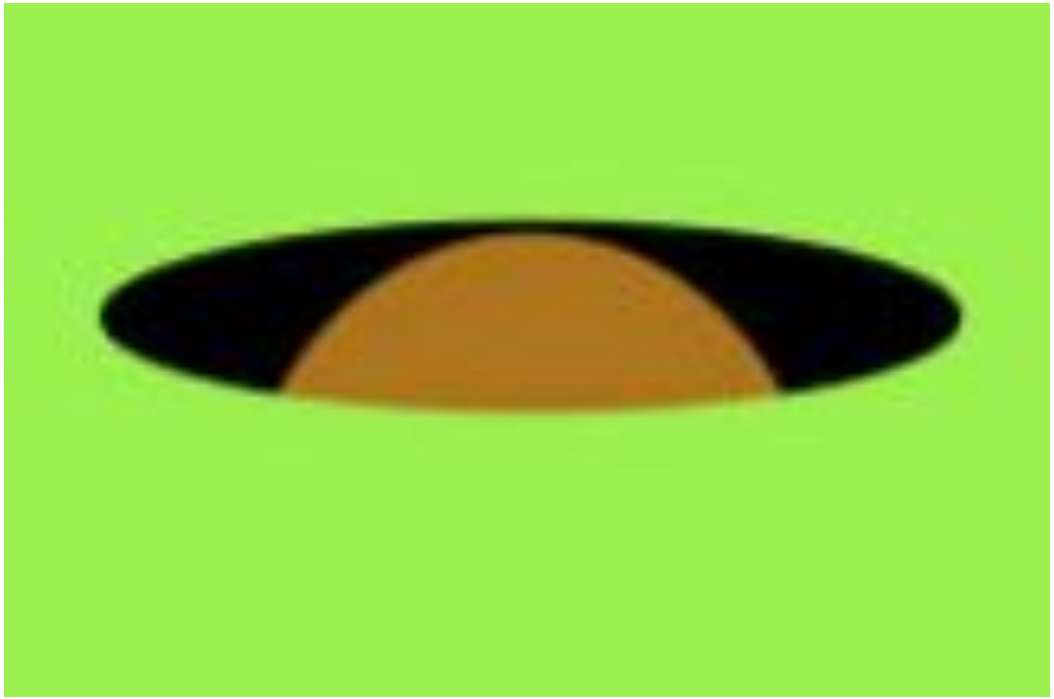


```
def spawn(self, cmd, env=None):
    """Spawns a new child process."""
    if self._valgrind:
        self.log.append("running valgrind {}...".format(cmd))
        cmd = "valgrind --show-leak-kinds=all --xml=yes --xml-file={} -- {}".format(
            os.path.join(self.dir, self._valgrind_log), cmd)
```









Vertrouwen is **niet** goed,

controle is nodig

(unit)tests

score-functie

(unit)tests

score-functie

(unit)tests

representatie

score-functie

(unit)tests

algoritmes

representatie

(unit)tests

Nu. Anders is het te laat.

check50

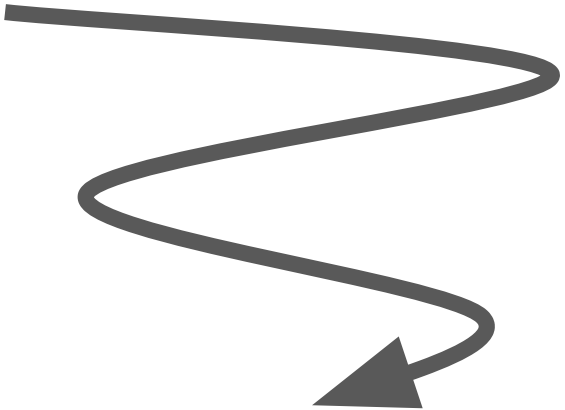
De kans dat we het allebei fout doen is kleiner toch?

check50

De kans dat we het allebei fout doen is kleiner toch?

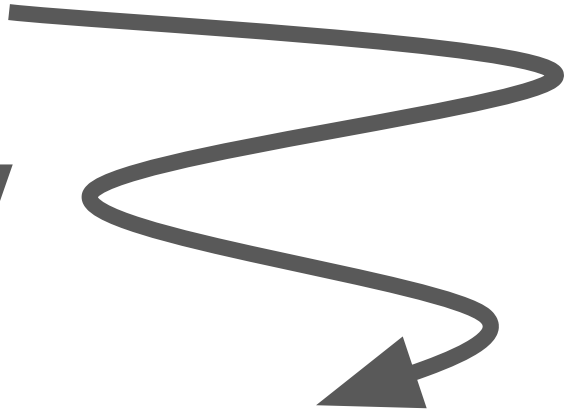
Experimenteren met **buggy**

implementaties van algoritmes



Is algoritme A beter dan algoritme B?

Repeatability



Reproducibility

Replicability

Reproducibility

- Deel de code
- Deel de input
- Documenteer hoe de code is ingezet op de input
- Geef de resultaten
- Geef de tools om de resultaten te visualiseren

Reproducibility tips

Schrijf scripts voor de experimenten.

Reproducibility tips

Liever te veel data, dan te weinig.

Reproducibility tips

”Ask yourself: If I put my data on my website and someone else downloads it, does every single file contain sufficient information to understand its content?”[1]

Reproducibility tips

Gebruik een “seed” bij random algoritmes.

Reproducibility tips

Schrijf scripts voor het visualiseren van resultaten.

Reproducibility tips

requirements.txt

numpy==1.24.3

Testing & Reproducibility

Begin nu: minder werk & beter resultaat

Code lever je in

Schrijf scripts

Efficiëntie

Score

Optimaal antwoord

Waarschijnlijk niet

Efficiëntie

Optimale algoritmes vergelijken

```
for problem in problems:
  for _ in range(X):
    algorithm_a(problem)
```

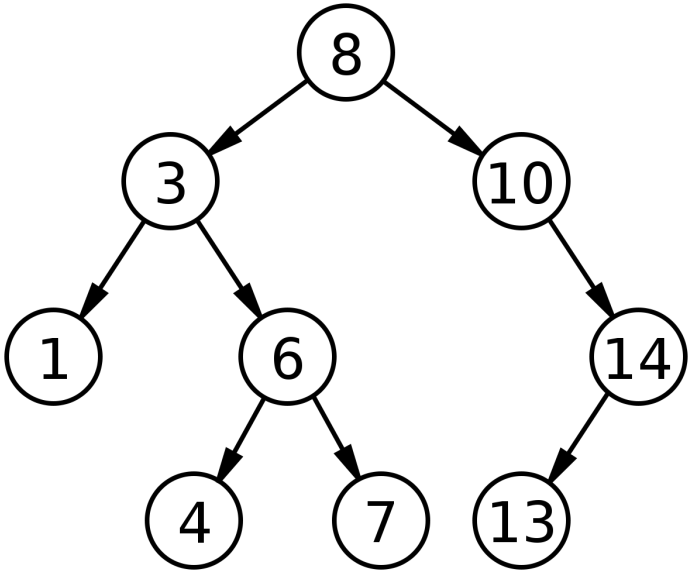
```
for problem in problems:
  for _ in range(X):
    algorithm_b(problem)
```

Optimale algoritmes vergelijken

Tijd

Ruimte

Tijd



Wall time


```
import time
start = time.time()
…
end = time.time() - start
```

Wall time

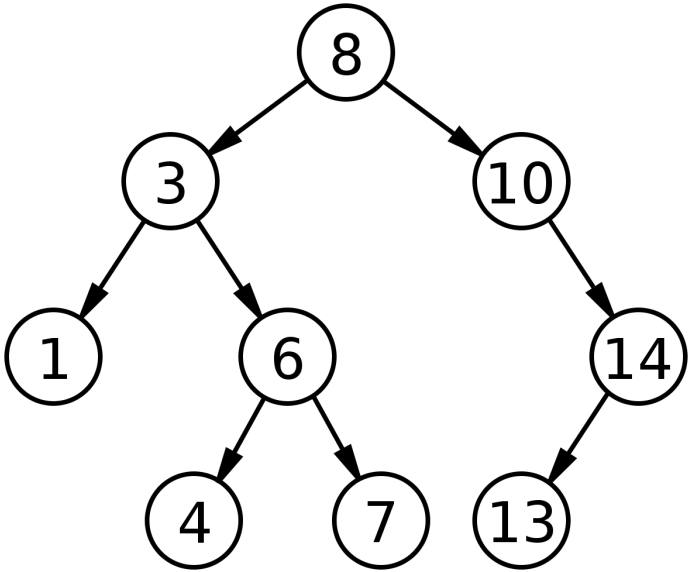
- Meet implementatie, niet algoritme
- Afhankelijk van hardware
- Makkelijk te begrijpen
- Goed in praktijk

Wall time

- **Zelfde computer**
- **Rapporteer specs computer**
- **Deel de code**
- **Gebruik geen profiler**

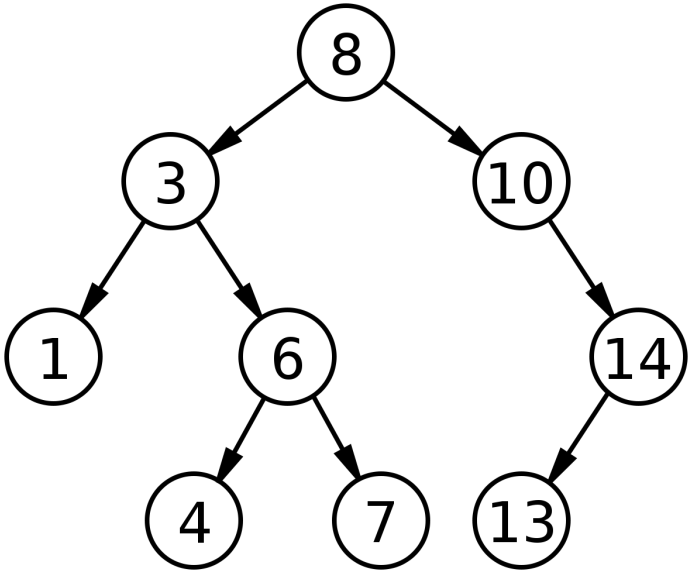
Tijd

```
evaluation_count = 0
def evaluate(state):
    evaluation_count += 1
    …
```

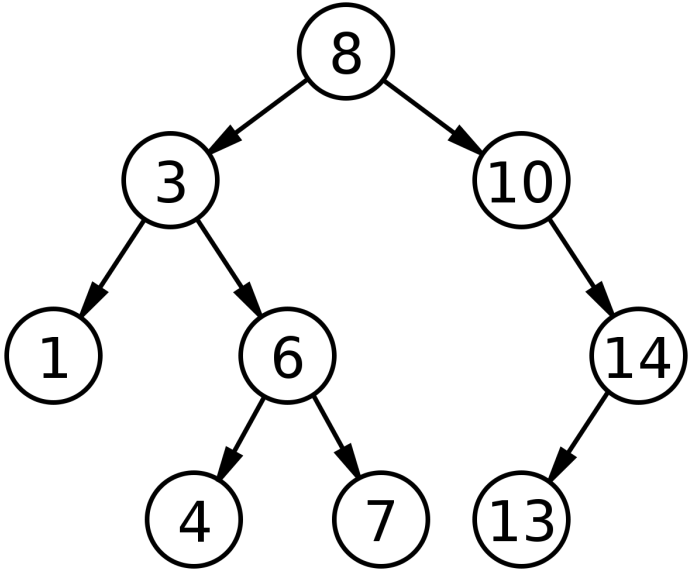


Tijd

- Meet algoritme, niet implementatie
- Onafhankelijk van hardware
- Geen directe relatie met tijd
  - Tijd per state verschilt enorm
- Goed in theorie



Tijd: doe het allebei



Optimale algoritmes vergelijken

```
for problem in problems:
  for _ in range(X):
     algorithm_a(problem)
    …
    file.write(
      f"{time} {evals}\n"
    )
```

```
for problem in problems:
  for _ in range(X):
     algorithm_b(problem)
    …
    file.write(
      f"{time} {evals}\n"
    )
```

Efficiëntie

Optimaal antwoord

Score

Waarschijnlijk niet

Efficiëntie

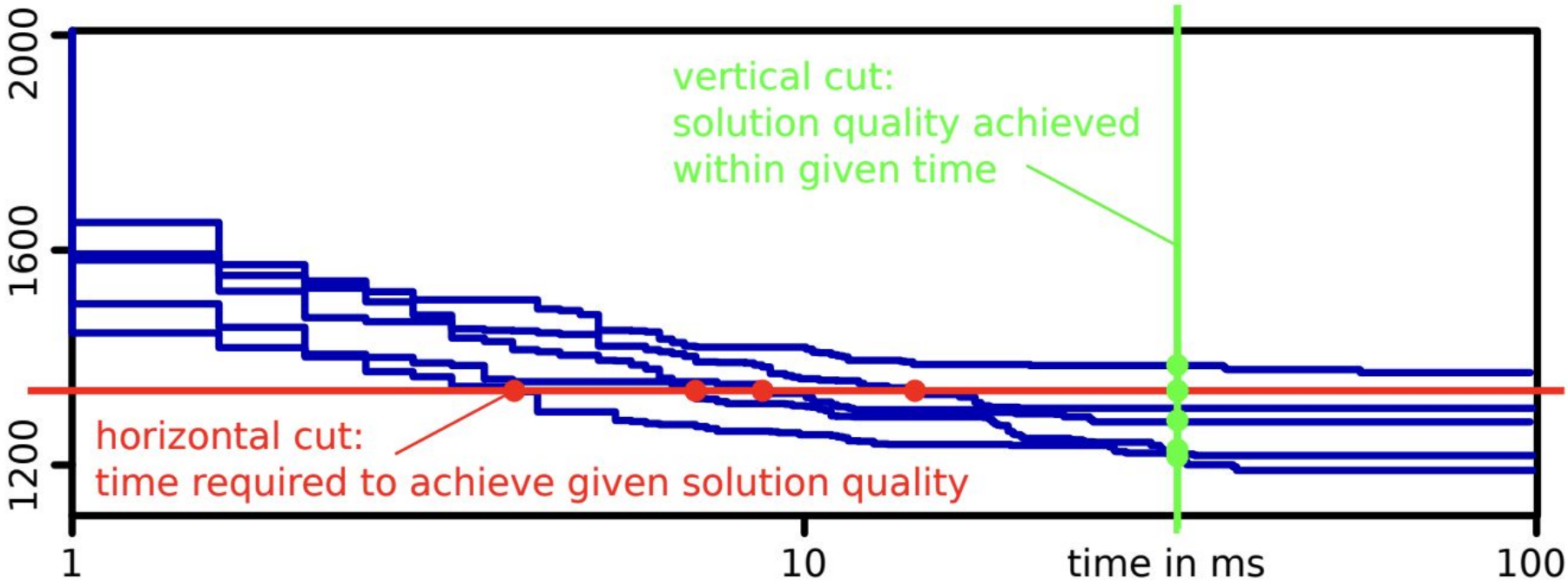
Niet optimale algoritmes vergelijken

Tijd

Versus

Score

Niet optimale algoritmes vergelijken



[1] Optimization Algorithms, Thomas Weise

Restrictie op tijd (vertical cut)

Goed voor praktijk: binnen X tijd wordt Y resultaat behaald

Vergelijken op score is lastig te interpreteren

```
if end_time - start_time >= X:
    return best_solution_so_far
```

Restrictie op kwaliteit (horizontal cut)

Goed voor theorie: X resultaat wordt in Y tijd behaald

Vergelijken met tijd is makkelijker te interpreteren

```
if evaluate(best_solution_so_far) >= X:
    return best_solution_so_far
```

Niet optimale algoritmes vergelijken

Doe zowel horizontaal als verticaal

"Cuts" zijn afhankelijk van case en context

Meerdere "cuts" ook mogelijk!

- Liever te veel data dan te weinig

Niet optimale algoritmes vergelijken

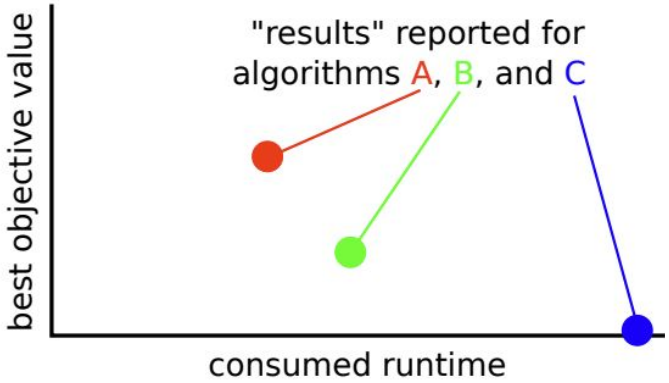


Figure 4.4: “End results” experiments with algorithms versus how the algorithms could actually have performed.

[1] Optimization Algorithms, Thomas Weise

Niet optimale algoritmes vergelijken

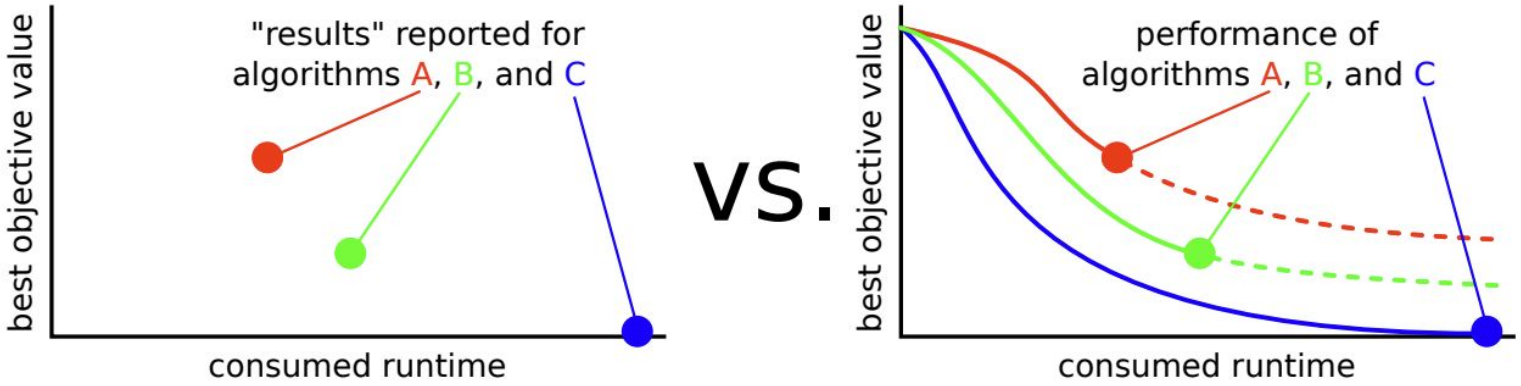


Figure 4.4: "End results" experiments with algorithms versus how the algorithms could actually have performed.

[1] Optimization Algorithms, Thomas Weise

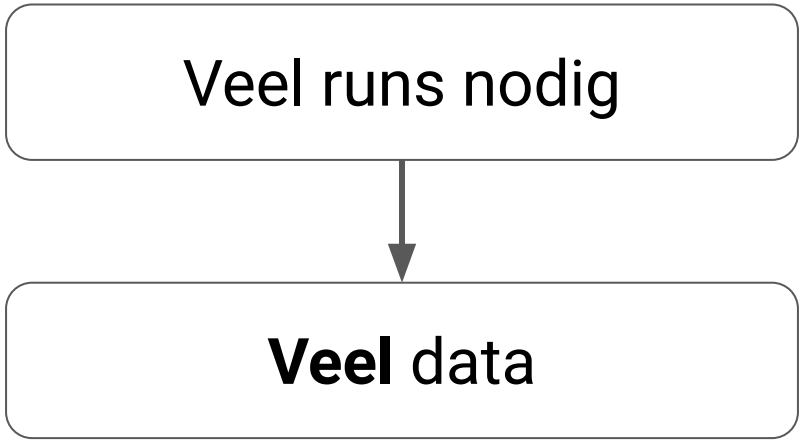
Experiment

Resultaten

Evaluatie

Conclusie

Randomness



Samenvatting nodig

Resultaten

…300 250 1000 275 190 320 195 270 280 350…

Resultaten

…300 250 1000 275 190 320 195 270 280 350…

```
best = max(results) = 1000
```

Resultaten

…300 250 1000 275 190 320 195 270 280 350…

```
best = max(results) = 1000
```

```
mean = sum(results) / len(results) = 343
```

Resultaten

```
…300 250 1000 275 190 320 195 270 280 350…

best = max(results) = 1000

mean = sum(results) / len(results) = 343

median = sort(results)[len(results // 2)] = 275
```

Resultaten - spreiding

…300 250 1000 275 190 320 195 270 280 350…

Resultaten - spreiding

…300 250 1000 275 190 320 195 270 280 350…

```
variance = 0
for result in results:
    variance += (result - mean(results))**2
variance /= len(results)
```

Resultaten - spreiding

…300 250 1000 275 190 320 195 270 280 350…

```
variance = 0
for result in results:
    variance += (result - mean(results))**2
variance /= len(results)

standard_deviation = variance**0.5
```

Resultaten - spreiding

…300 250 1000 275 190 320 195 270 280 350…

```
from statistics import variance, stdev
```

Resultaten - spreiding

…300 250 1000 275 190 320 195 270 280 350…

```
variance = 0
for result in results:
    variance += (result - mean(results))**2
variance /= len(results)

standard_deviation = variance**0.5
```

Resultaten - spreiding

```
   …300 250 1000 275 190 320 195 270 280 350…


sorted_results = sort(results)
n_results = len(results)
quartiles = [
   sorted_results[int(n_results * 0.25)]
   sorted_results[int(n_results * 0.5)]
   sorted_results[int(n_results * 0.75)]
]
```

Experiment

Resultaten

Evaluatie

Conclusie

Evaluatie

…300 250 1000 275 190 320 195 270 280 350…

…350 900 1100 760 600 260 340 750 570 350…

Evaluatie

…300 250 1000 275 190 320 195 270 280 350…

…350 900 1100 760 600 260 340 750 570 350…

```
best(res_a) = 1000
median(res_a) = 275
quintile_90(res_a) = 350
```

```
best(res_b) = 1100
median(res_b) = 570
quintile_90(res_b) = 900
```

Evaluatie

…300 250 1000 275 190 320 195 270 280 350…

…350 900 1100 760 600 260 340 750 570 350…

```
>>> from scipy.stats import mannwhiteneyu
>>> print(mannwhitneyu(res_a, res_b))
0.013875
```

Experiment

Resultaten

Evaluatie

Conclusie

Conclusie

Conclusie

- Kijk uit met claims
- Buggy implementations of algorithms
- Under promise, over deliver
- Geef een oplossing voor de case

Just one more thing…

Just one more thing…

One Factor At a Time

Grid Search

Presenteren

Case 2 min

State Space 1 min

Methode 2-3 min

Resultaten 3 min

Conclusie 1-2 min

Wat is het probleem?

Case

Wat is het probleem?

Terminologie

Case

Terminologie

Wat is het probleem?

Case

Wat is een oplossing?

Terminologie

Wat is het probleem?

Case

2 min

Wat is een oplossing?


State
Space

BFS
Beam Search
Genetic Algorithm

Methode (algoritmes)

BFS + Case = ?

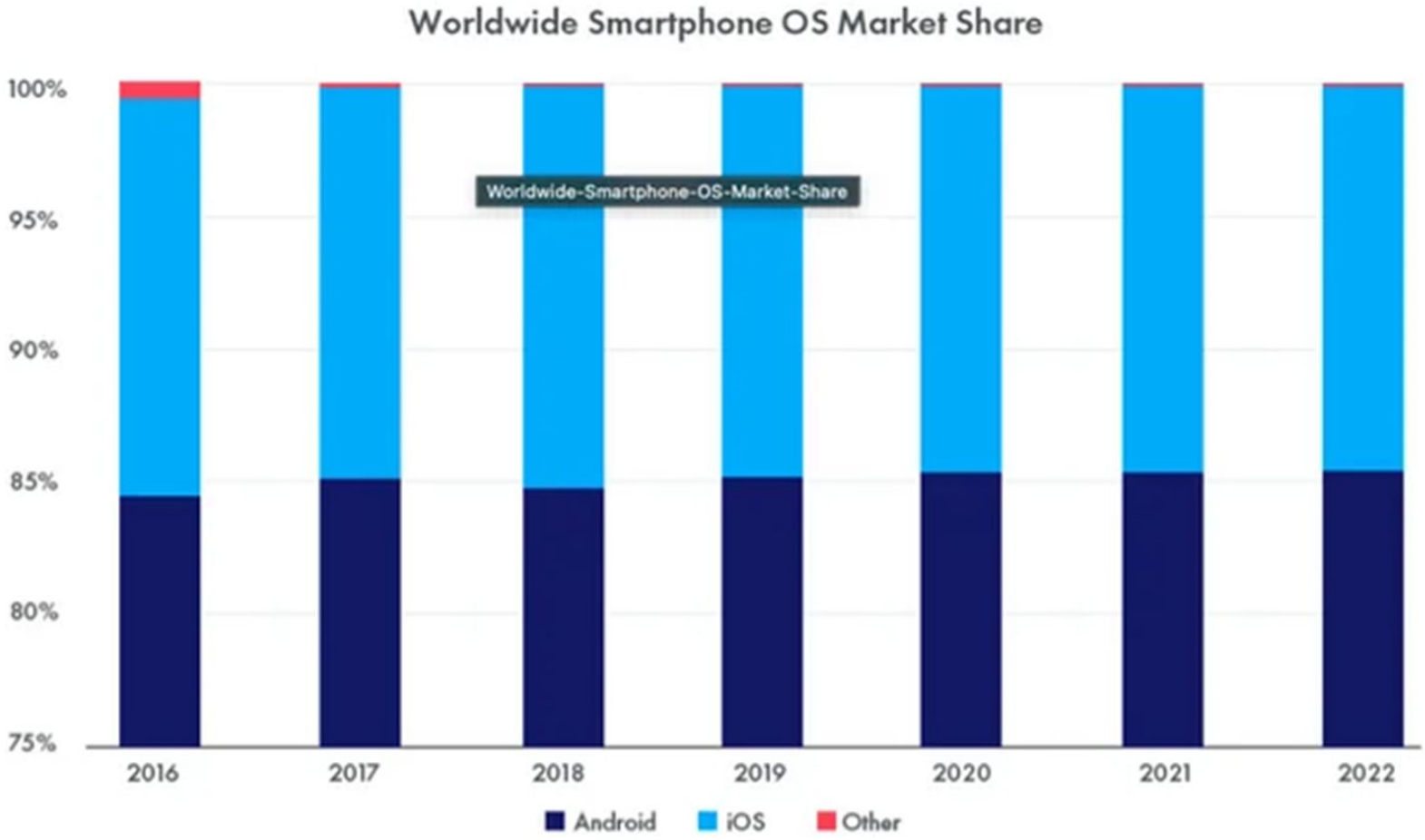
BFS
Beam Search
Genetic Algorithm

Methode (algoritmes)

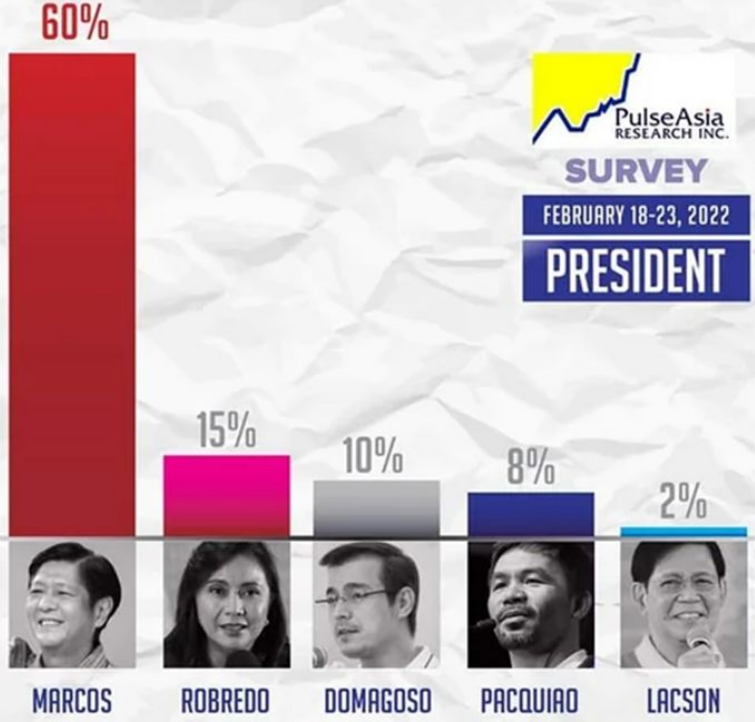
BFS + Case = ?

2-3 min

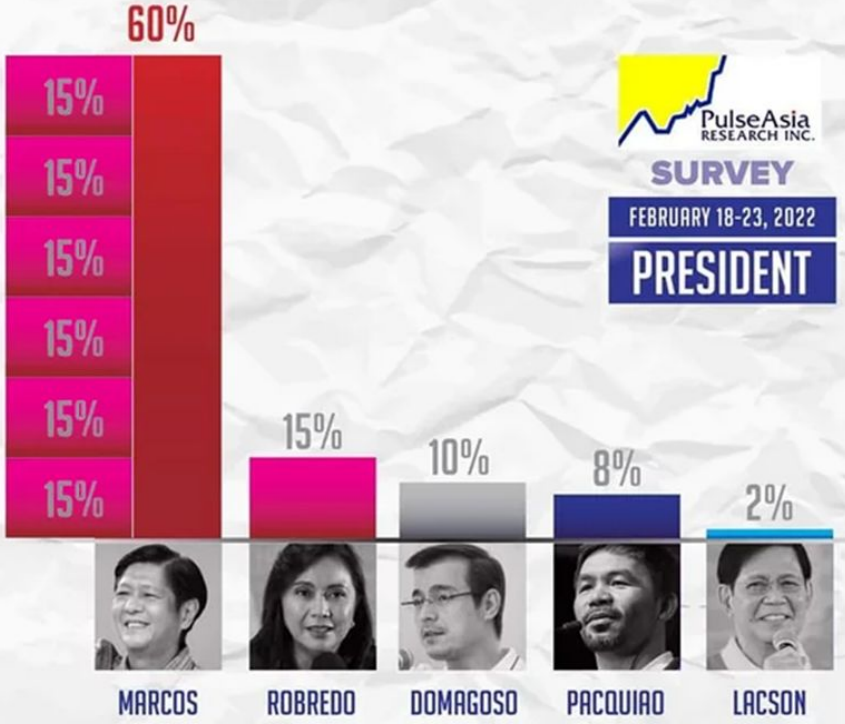
Resultaten


Worldwide Smartphone OS Market Share
100%
95%
90%
85%
80%
75%
Worldwide-Smartphone-OS-Market-Share
2016
2017
2018
2019
2020
2021
2022
Android
iOS
Other

Balita


60%
15%
10%
8%
2%
PulseAsia
RESEARCH INC.
SURVEY
FEBRUARY 18-23, 2022
PRESIDENT
MARCOS
ROBREDO
DOMAGOSO
PACQUIAO
LACSON

Balita

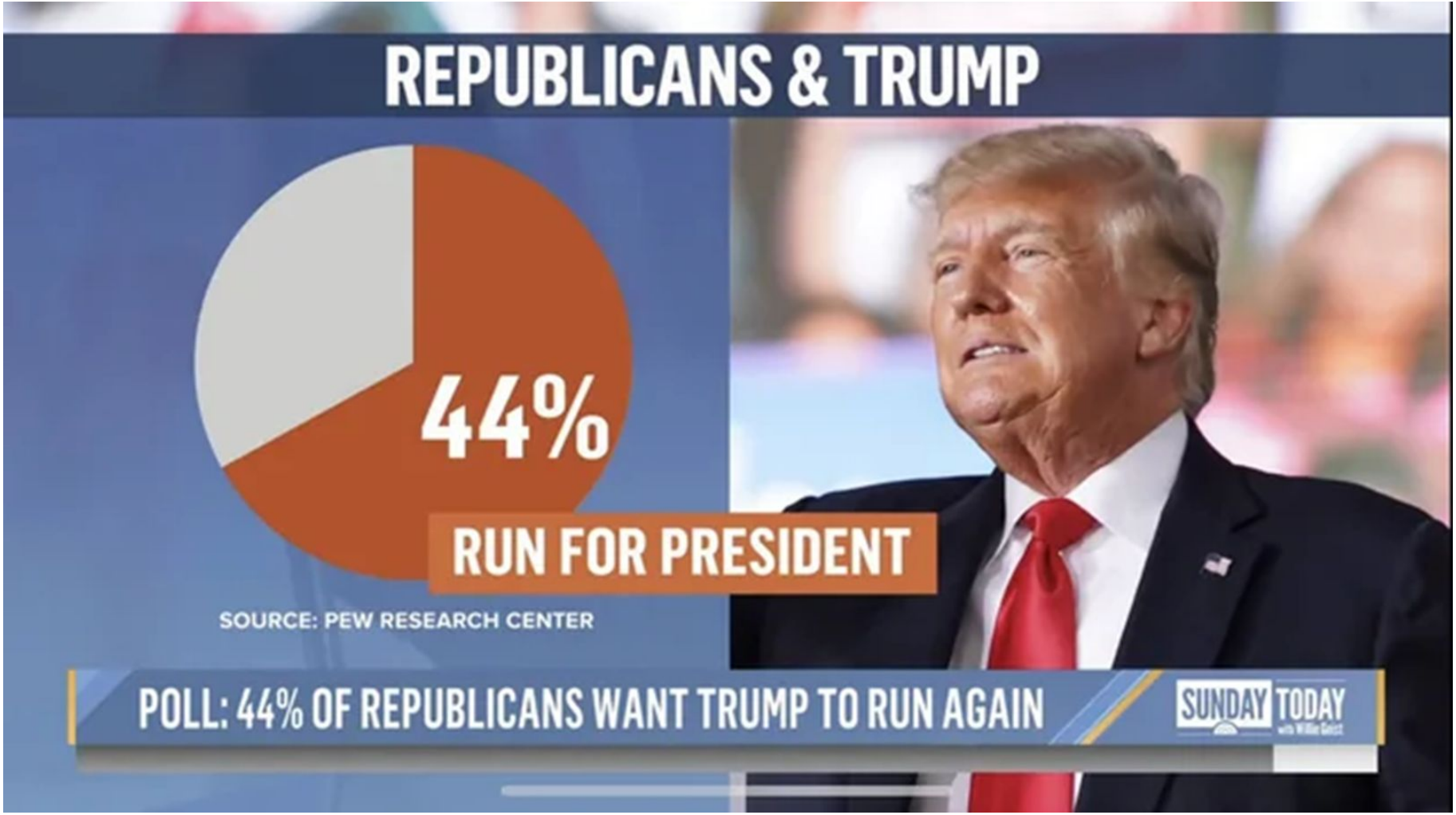


PulseAsia RESEARCH INC.

SURVEY

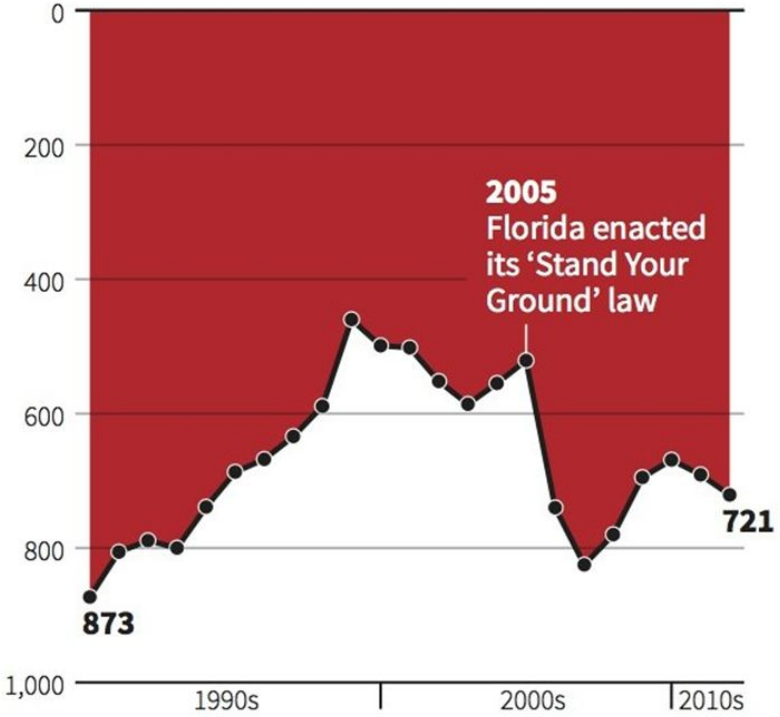
FEBRUARY 18-23, 2022

PRESIDENT


REPUBLICANS & TRUMP
44%
RUN FOR PRESIDENT
SOURCE: PEW RESEARCH CENTER
POLL: 44% OF REPUBLICANS WANT TRUMP TO RUN AGAIN
SUNDAY TODAY
with Willie Geist

Gun deaths in Florida

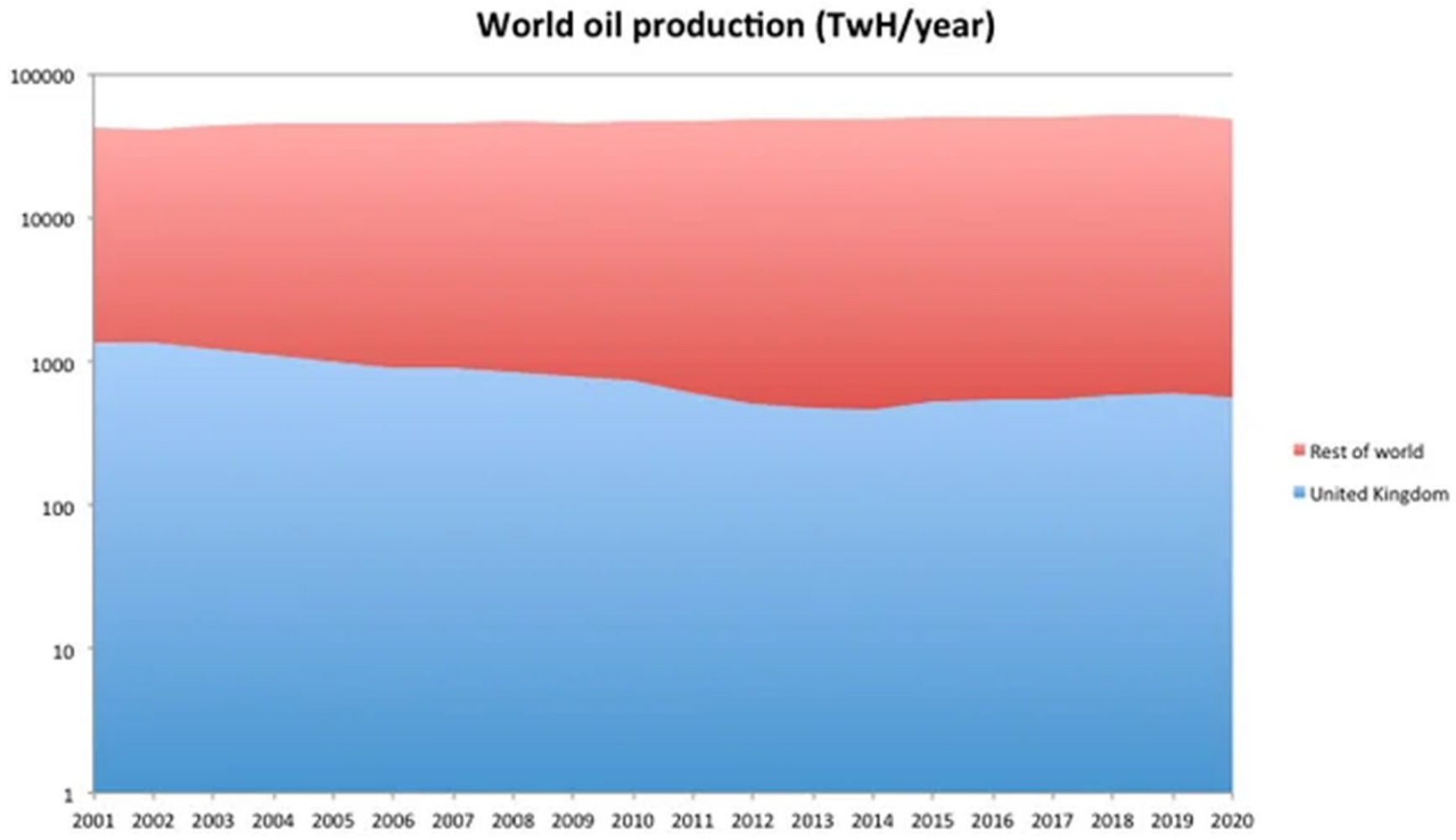
Number of murders committed using firearms

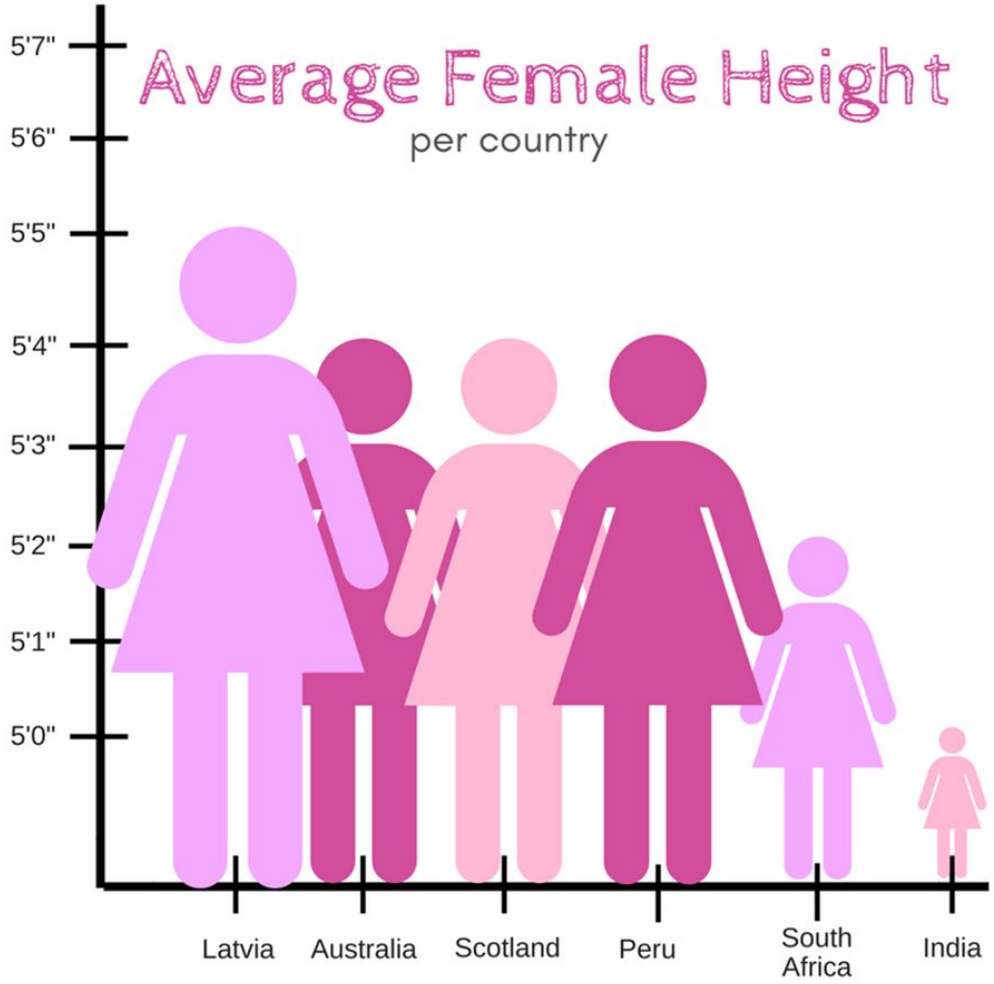


Source: Florida Department of Law Enforcement

C. Chan 16/02/2014

REUTERS


World oil production (TwH/year)
100000
10000
1000
100
10
1
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
Rest of world
United Kingdom


Average Female Height
per country
5'7"
5'6"
5'5"
5'4"
5'3"
5'2"
5'1"
5'0"
Latvia
Australia
Scotland
Peru
South Africa
India

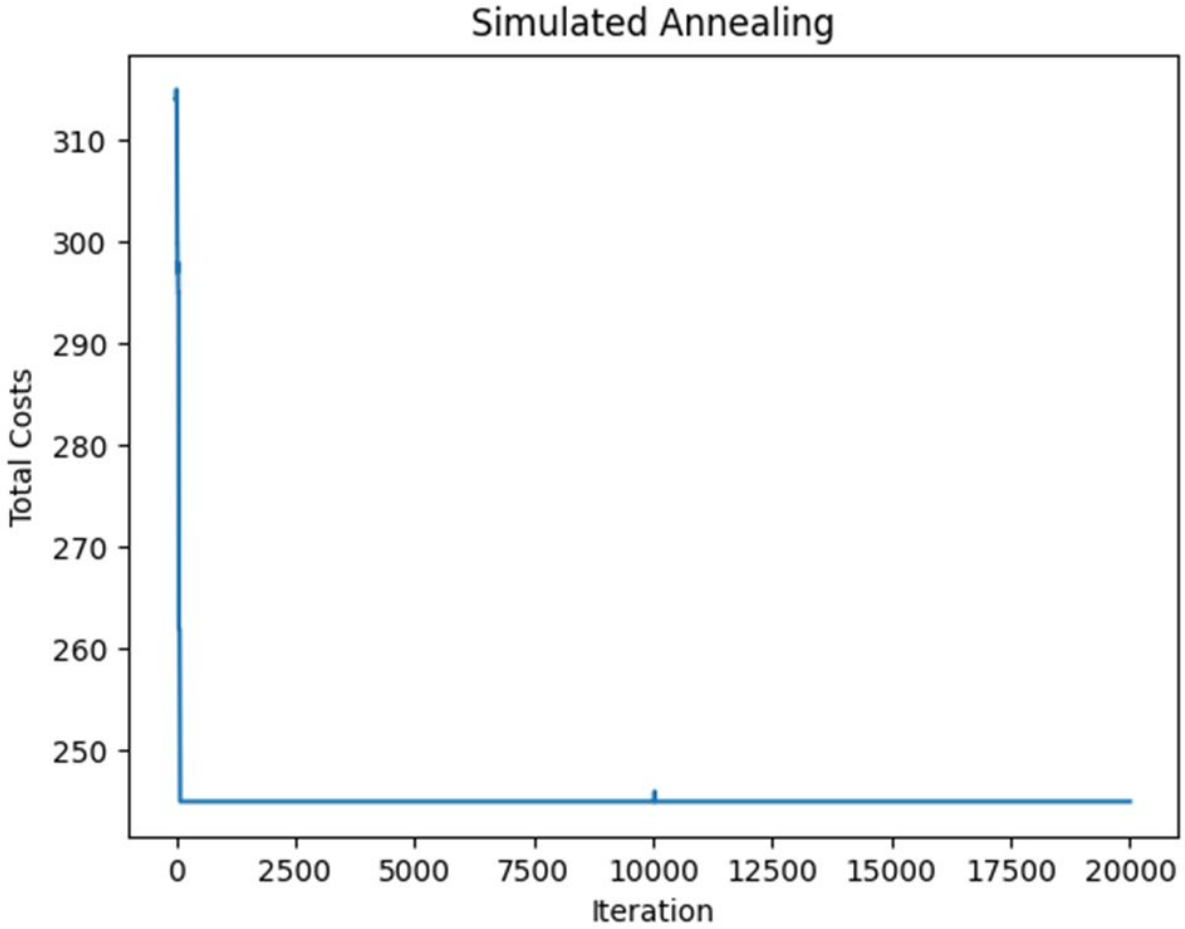
Top Goal Scorers of FIFA World Cup History

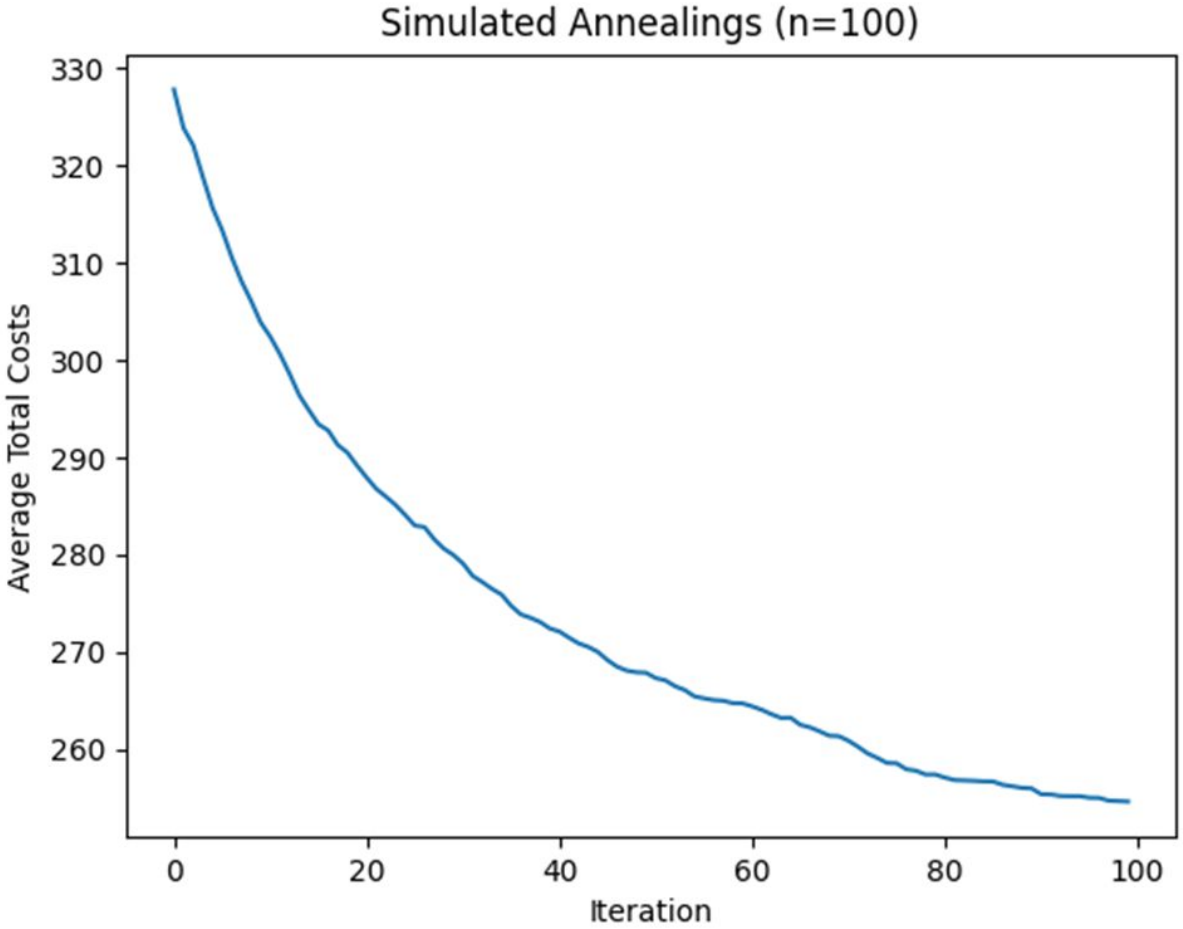
German striker Miroslav Klose holds the record for most FIFA World Cup goals in history, having scored 16 times in 24 appearances across four editions (2002, 2006, 2010 and 2014). He won the tournament in 2014.

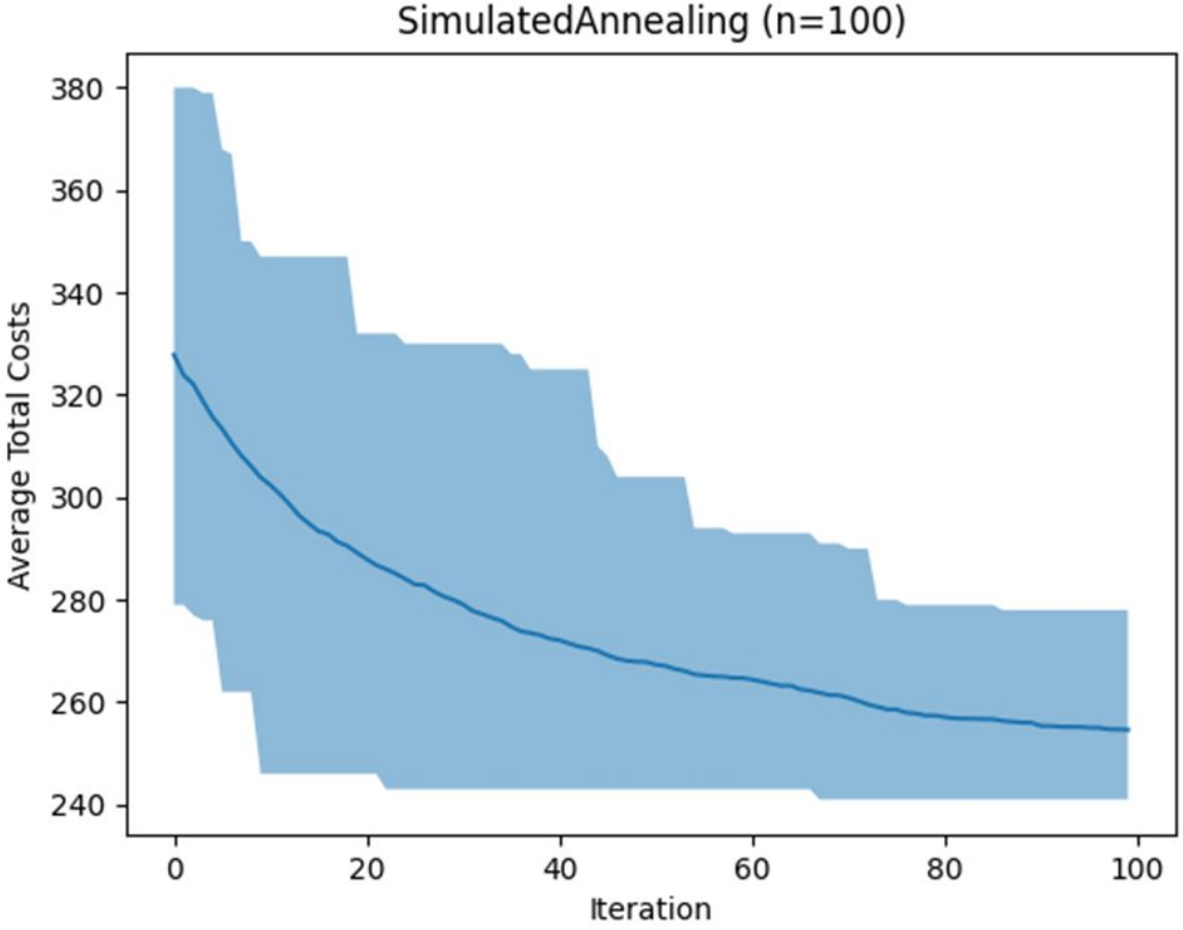
FIFA match reports do not include exact information about players' appearances before 1970

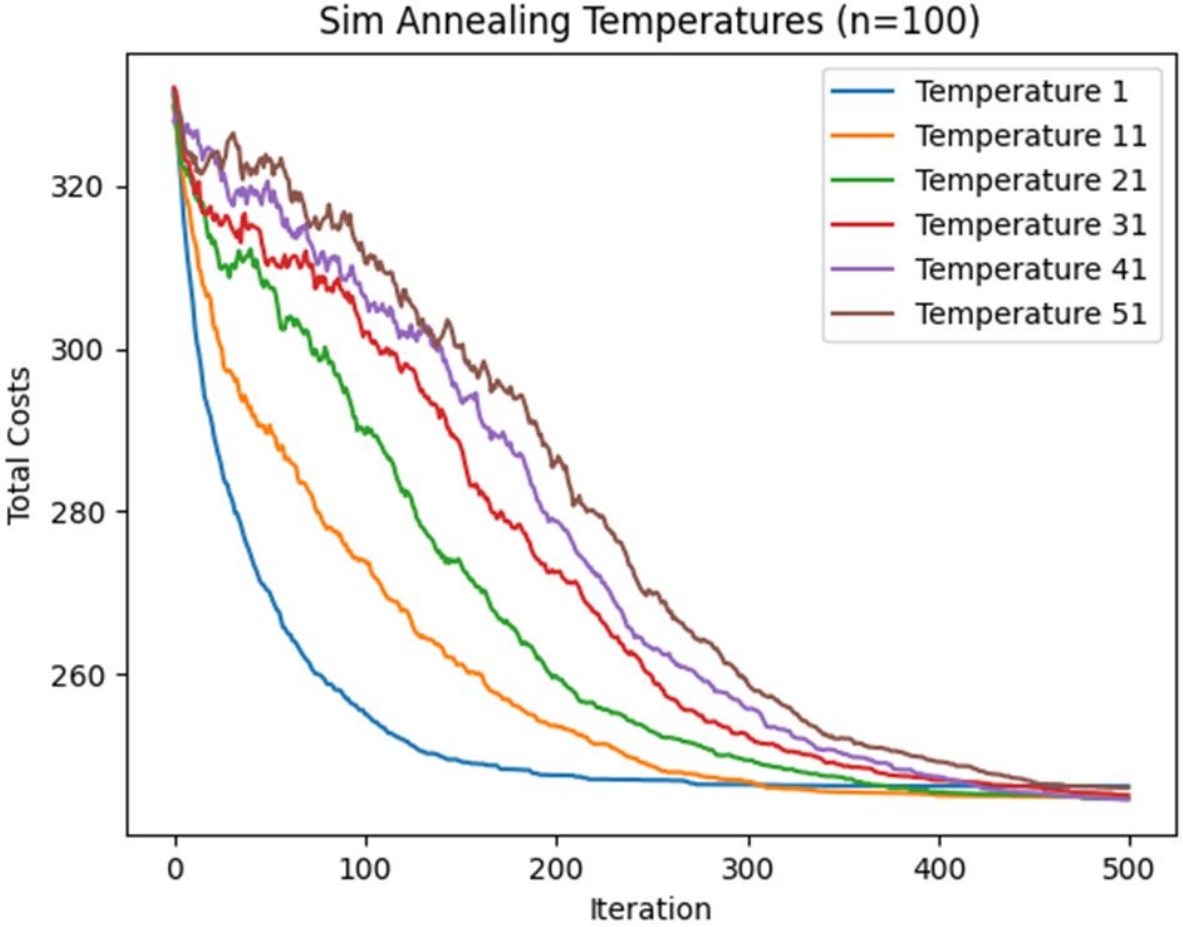
Source : FIFA

RankingRoyals

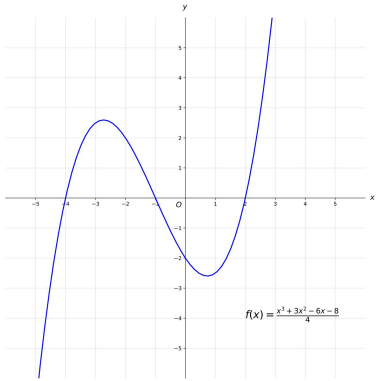

Simulated Annealing
Total Costs
310
300
290
280
270
260
250
0
2500
5000
7500
10000
12500
15000
17500
20000
Iteration


Simulated Annealings (n=100)
Average Total Costs
330
320
310
300
290
280
270
260
0
20
40
60
80
100
Iteration


SimulatedAnnealing (n=100)
Average Total Costs
380
360
340
320
300
280
260
240
0
20
40
60
80
100
Iteration


Sim Annealing Temperatures (n=100)
Temperature 1
Temperature 11
Temperature 21
Temperature 31
Temperature 41
Temperature 51
Total Costs
320
300
280
260
0
100
200
300
400
500
Iteration

Problem	Algorithm	Time Complexity	Space Complexity	Best Case	Worst Case	Advantages/Disadvantages
Sorting	QuickSort	O(n log n)	O(log n)	O(n log n)	O(n^2)	QuickSort is efficient in practice and has good average case performance. It's also an in-place sorting algorithm.
	MergeSort	O(n log n)	O(n)	O(n log n)	O(n log n)	MergeSort is a stable and efficient sorting algorithm. It's not an in-place sorting algorithm.
	BubbleSort	O(n^2)	O(1)	O(n)	O(n^2)	BubbleSort is easy to understand and implement, but it's not efficient for large datasets.
Searching	Binary Search	O(log n)	O(1)	O(1)	O(log n)	Binary search is efficient and has a good average case performance. It requires that the data is sorted.
	Linear Search	O(n)	O(1)	O(1)	O(n)	Linear search is simple and easy to understand but not efficient for large datasets.
	Ternary Search	O(log n)	O(1)	O(1)	O(log n)	Ternary search is similar to binary search but with a slightly worse average case performance. It also requires that the data is sorted.



Problem	Algorithm 1	Algorithm 2	Algorithm 3
Sorting	**QuickSort**	MergeSort	BubbleSort
Searching	**Binary Search**	Linear Search	Ternary Search
Graph traversal	DFS	BFS	**Dijkstra's**
String matching	KMP	**Boyer Moore**	Rabin-Karp
Shortest Path	Bellman Ford	Dijkstra's	**A***

Resultaten

Conclusie

De oplossing voor de case

Inzichten in algoritmen & case

Future work

Pro Tips

```
public static void
main(String[]
args) {
System.out.println
("Geen code");
}
```

Afbeelding > Tekst

Goed dat je het vraagt!

Hebben we een slide voor…

The end

https://thomasweise.github.io/oa/