

# Search Algorithms

February 2021

## Exhaustive Search

File: `exhaustivesearch.py`

### 6 cities

Shortest distance in km: 5018.8099999999995

Shortest route of cities: ['Belgrade', 'Barcelona', 'Brussels', 'Berlin', 'Budapest', 'Bucharest']

Time used: 0.006972241999999999

After performing **exhaustive search**, we see that the shortest distance for 6 cities is  $\approx 5018.8$  km, and best route is **Belgrade, Barcelona, Brussels, Berlin, Budapest, Bucharest**.

### 10 cities

Shortest distance in km: 7486.309999999999 Shortest route of cities: ['Hamburg', 'Brussels', 'Dublin', 'Barcelona', 'Belgrade', 'Istanbul', 'Bucharest', 'Budapest', 'Berlin', 'Copenhagen'] Time used: 50.983705300000004

After performing **exhaustive search** on 10 cities this time, we see that the shortest distance  $\approx 7486.3$  km, and best route is **Hamburg, Brussels, Dublin,**

**Barcelona, Belgrade, Istanbul, Bucharest, Budapest, Berlin, Copenhagen.**

## Hill Climbing

**File:** hillclimbing.py

### 10 cities

Shortest distance in km: 7486.309999999995 Shortest route of cities: ['Bucharest', 'Budapest', 'Berlin', 'Copenhagen', 'Hamburg', 'Brussels', 'Dublin', 'Barcelona', 'Belgrade', 'Istanbul']

Longest distance in km: 10450.58

Longest route of cities: ['Belgrade', 'Istanbul', 'Bucharest', 'Copenhagen', 'Dublin', 'Brussels', 'Budapest', 'Barcelona', 'Berlin', 'Hamburg']

Time used: 0.019142093

stdev: 749.4065038134474

mean: 8957.710000000001

With **Hill Climbing** it took 2663 times faster to run the program for 10 cities:

$$\frac{50.983705300000004}{0.019142093} = 2663.43420$$

The shortest distance is  $\approx 7486.3$  km and the route is **Bucharest, Budapest, Berlin, Copenhagen, Hamburg, Brussels, Dublin, Barcelona, Belgrade, Istanbul**

and

the longest distance is  $\approx 10450.6$  km and the route is **Belgrade, Istanbul, Bucharest, Copenhagen, Dublin, Brussels, Budapest, Barcelona, Berlin, Hamburg**

and

we get  $\approx 749.4$  on standard deviation and  $\approx 8957.7$  on mean

## 24 cities

Shortest distance in km: 20026.429999999997

Shortest route of cities: ['Rome', 'Milan', 'Prague', 'Bucharest', 'Istanbul', 'Sofia', 'Vienna', 'Kiev', 'Moscow', 'Stockholm', 'Saint Petersburg', 'Copenhagen', 'London', 'Berlin', 'Warsaw', 'Hamburg', 'Budapest', 'Belgrade', 'Paris', 'Brussels', 'Barcelona', 'Madrid', 'Dublin', 'Munich']

Longest distance in km: 28042.789999999997

Longest route of cities: ['Paris', 'Dublin', 'London', 'Stockholm', 'Istanbul', 'Belgrade', 'Berlin', 'Kiev', 'Barcelona', 'Hamburg', 'Warsaw', 'Budapest', 'Copenhagen', 'Moscow', 'Saint Petersburg', 'Sofia', 'Madrid', 'Brussels', 'Vienna', 'Milan', 'Rome', 'Prague', 'Munich', 'Bucharest']

Time used: 0.22721064500000002

stdev: 2103.3118699409442

mean: 24330.1885

The shortest distance here is  $\approx 20026$  and the longest is  $\approx 28042$ , where the standard deviation is  $\approx 2103$  and the mean  $\approx 24330$ .

## GA Cross

File: GA\_cross.py

24 cities

### 100 and offsprings of 50

results with population of 100 and offsprings of 50

Shortest distance in km: 16237.51

The city route: ['Bucharest', 'Warsaw', 'Prague', 'Rome', 'Milan', 'Barcelona', 'Madrid', 'Dublin', 'Brussels', 'Budapest', 'Vienna', 'Istanbul', 'Sofia', 'Belgrade', 'Munich', 'Paris', 'London', 'Hamburg', 'Berlin', 'Copenhagen', 'Stockholm', 'Saint Petersburg', 'Moscow', 'Kiev']

Longest route of cities: 18096.51

The city route: ['Bucharest', 'Rome', 'Madrid', 'Barcelona', 'Milan', 'Paris', 'Brussels', 'Dublin', 'Prague', 'Budapest', 'Vienna', 'Istanbul', 'Sofia', 'Belgrade', 'Munich', 'London', 'Warsaw', 'Stockholm', 'Copenhagen', 'Hamburg', 'Berlin', 'Saint Petersburg', 'Moscow', 'Kiev']

Standard Deviation: 348.12467335833674

Mean Distance: 17729.0854

Time used: [0.16901431400000001]

### 200 and offsprings of 160

results with population of 200 and offsprings of 160

Shortest distance in km: 13085.110000000002

The city route: ['Stockholm', 'Copenhagen', 'Hamburg', 'Berlin', 'Prague', 'Munich', 'Vienna', 'Budapest', 'Belgrade', 'Bucharest', 'Istanbul', 'Sofia', 'Rome',

'Milan', 'Barcelona', 'Madrid', 'Paris', 'London', 'Dublin', 'Brussels', 'Warsaw',  
'Kiev', 'Moscow', 'Saint Petersburg']

Longest route of cities: 13882.9

The city route: ['Stockholm', 'Saint Petersburg', 'Moscow', 'Kiev', 'Warsaw',  
'Budapest', 'Vienna', 'Munich', 'Milan', 'Rome', 'Istanbul', 'Bucharest', 'Sofia',  
'Belgrade', 'Barcelona', 'Madrid', 'Paris', 'London', 'Dublin', 'Brussels', 'Prague',  
'Berlin', 'Hamburg', 'Copenhagen']

Standard Deviation: 143.65915536294753

Mean Distance: 13576.49495

Time used: [0.5608228030000001]

## 500 and offsprings of 250

results with population of 500 and offsprings of 250

Shortest distance in km: 12962.870000000003

The city route: ['Hamburg', 'Munich', 'Milan', 'Rome', 'Barcelona', 'Madrid',  
'Paris', 'Brussels', 'London', 'Dublin', 'Copenhagen', 'Stockholm', 'Saint Peters-  
burg', 'Moscow', 'Kiev', 'Warsaw', 'Bucharest', 'Istanbul', 'Sofia', 'Belgrade',  
'Budapest', 'Vienna', 'Prague', 'Berlin']

Longest route of cities: 13256.570000000002

The city route: ['Hamburg', 'Munich', 'Milan', 'Rome', 'Barcelona', 'Madrid',  
'Paris', 'Brussels', 'London', 'Dublin', 'Copenhagen', 'Stockholm', 'Saint Peters-  
burg', 'Moscow', 'Warsaw', 'Kiev', 'Istanbul', 'Bucharest', 'Sofia', 'Belgrade',  
'Budapest', 'Vienna', 'Prague', 'Berlin']

Standard Deviation: 50.16499319889602

Mean Distance: 13215.134200000002

Time used: [1.1717333609999998]

Compared to exhaustive search, GA took a lot shorter time on 10 cities. But for 24 cities it was not possible to run with exhaustive search, while for GA it took less than a second.

Compared to exhaustive search, GA did not need to search for every route possible, but rather took crossover of the selected parents. Which will decrease the time dramatically.

