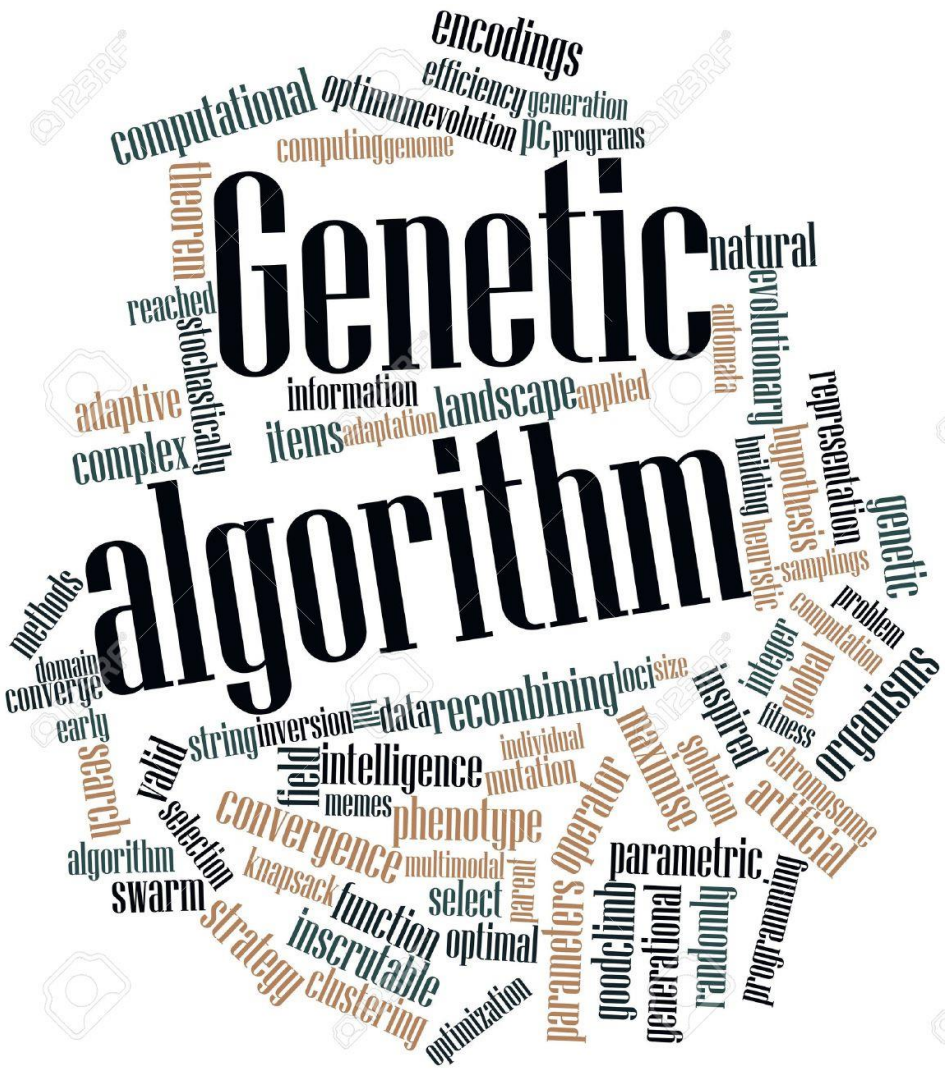
Genetics Algorithm: TSP & VRP

José Luis González Chacón:

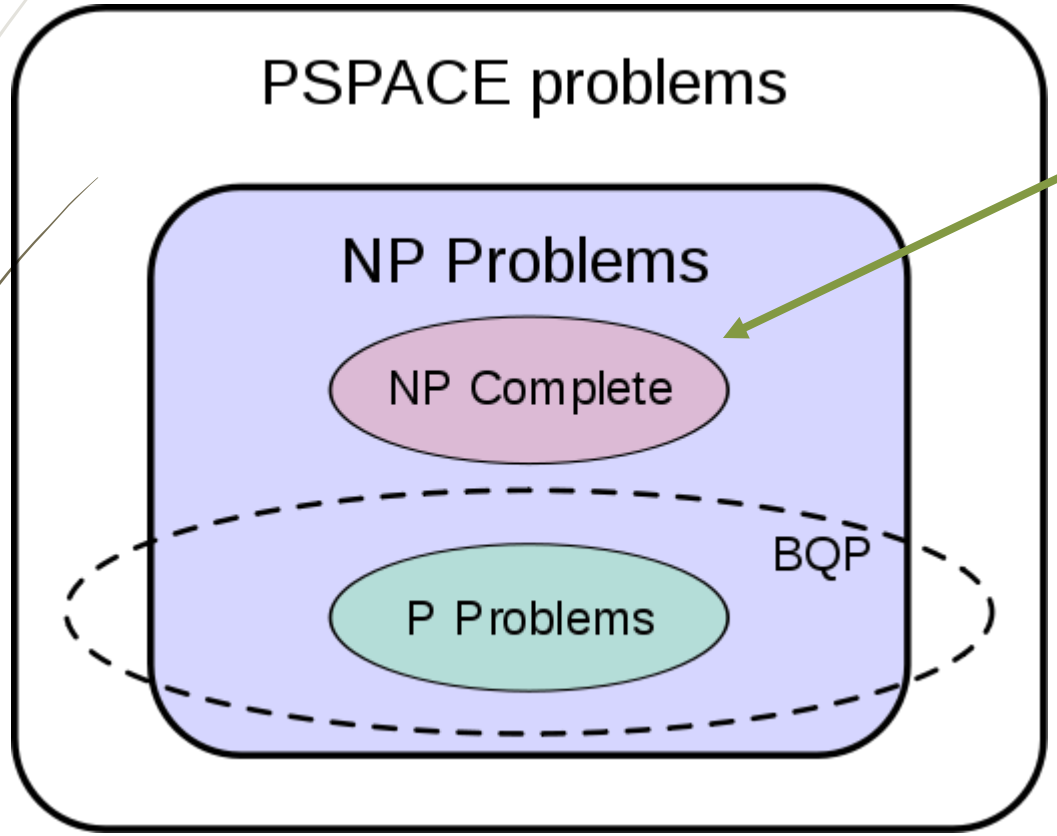
Fernando Méndez Requena: www.linkedin.com/in/fmendez1

INDICE

- INTRODUCTION
- TSP
- VRP
- EXPERIMENTATION
- BIBLIOGRAPHY

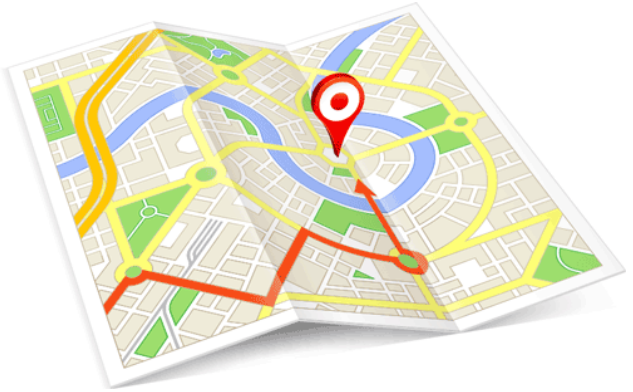


INTRODUCTION



TSP PROBLEM

VRP PROBLEM



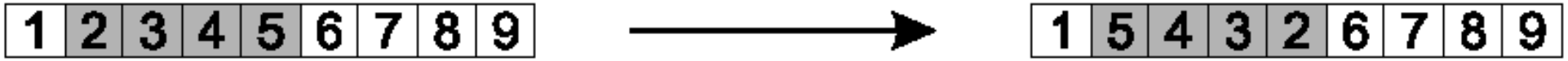
TSP- REPRESENTATION

HUELVA	GEN_0
SEVILLA	
CÁDIZ	
CÓRDOBA	
MÁLAGA	
JAÉN	
GRANADA	
ALMERÍA	GEN_7

CHROMOSOME

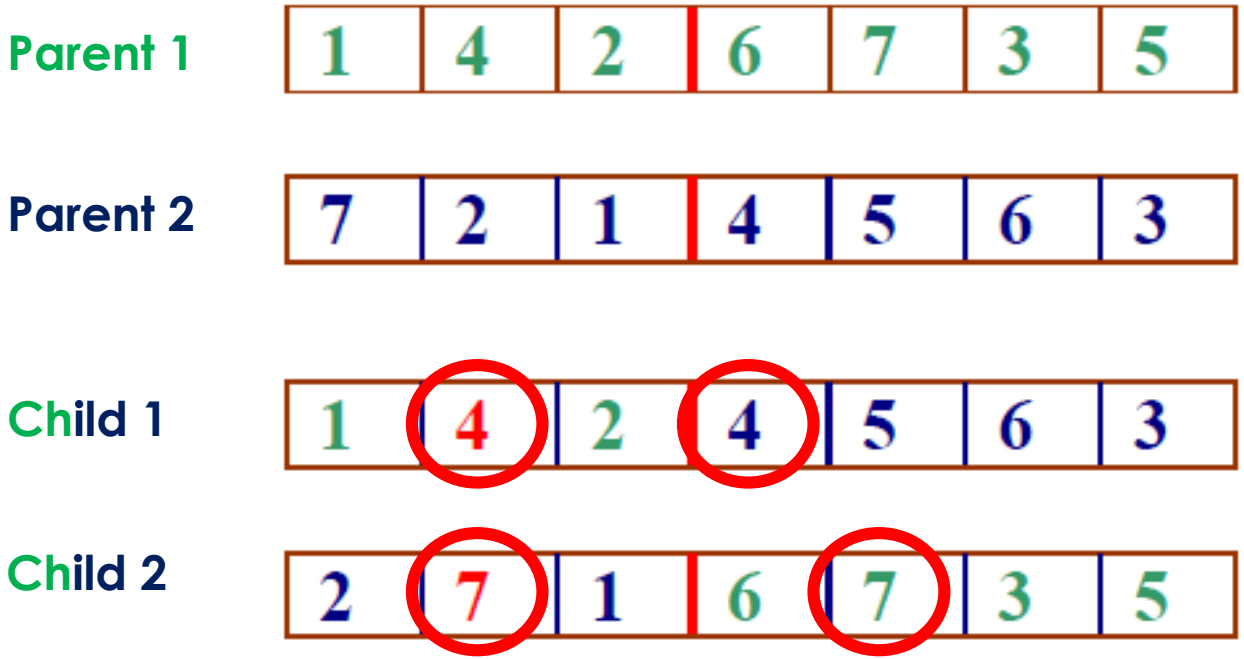
TSP- OPERATORS

- INVERSION MUTATION FOR PERMUTATIONS
- We pick to alleles at random and then we invert the positions between them



TSP- OPERATORS

- POINT CROSSOVER ("NORMAL")



TSP- OPERATORS

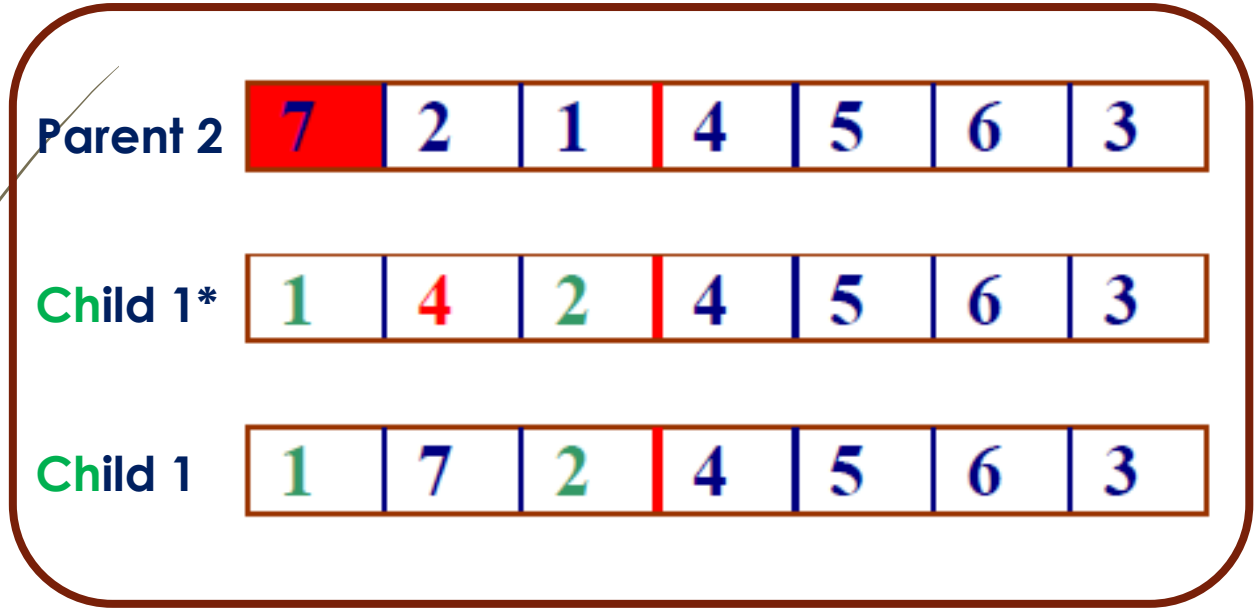
- **A PENALTY IS REQUIERED !**

$$\text{Penalty}(Path) = 100\ x\ |Genes\ -\ Path|$$

$$\text{Fitness}(Path) = 2\ x \sum_{i,j=0}^{7} (w_{i,j}) + 50\ x\ Penalty(Path)$$

TSP- OPERATORS

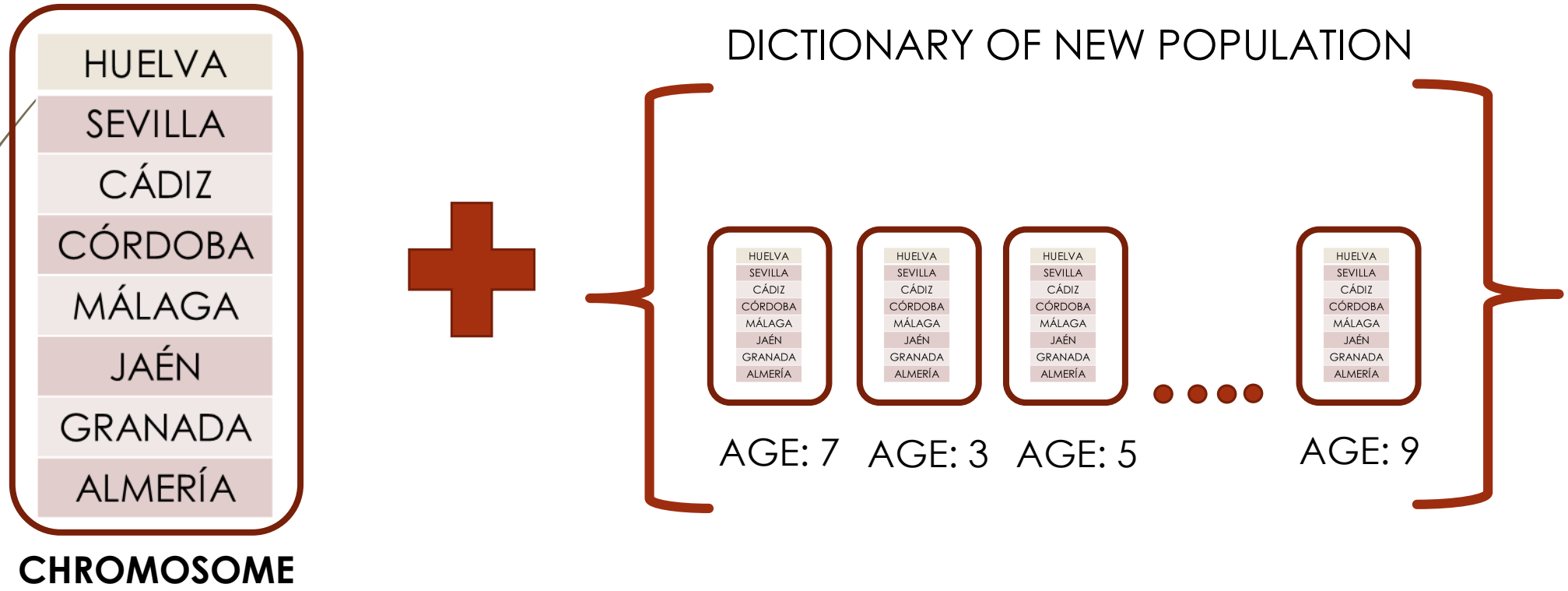
- POINT CROSSOVER: ANOTHER SOLUTION



The city that is repeated in the side of parent's heredity, is replaced by the other side that its not selected to inherit

TSP- OPERATORS: VARIANTS

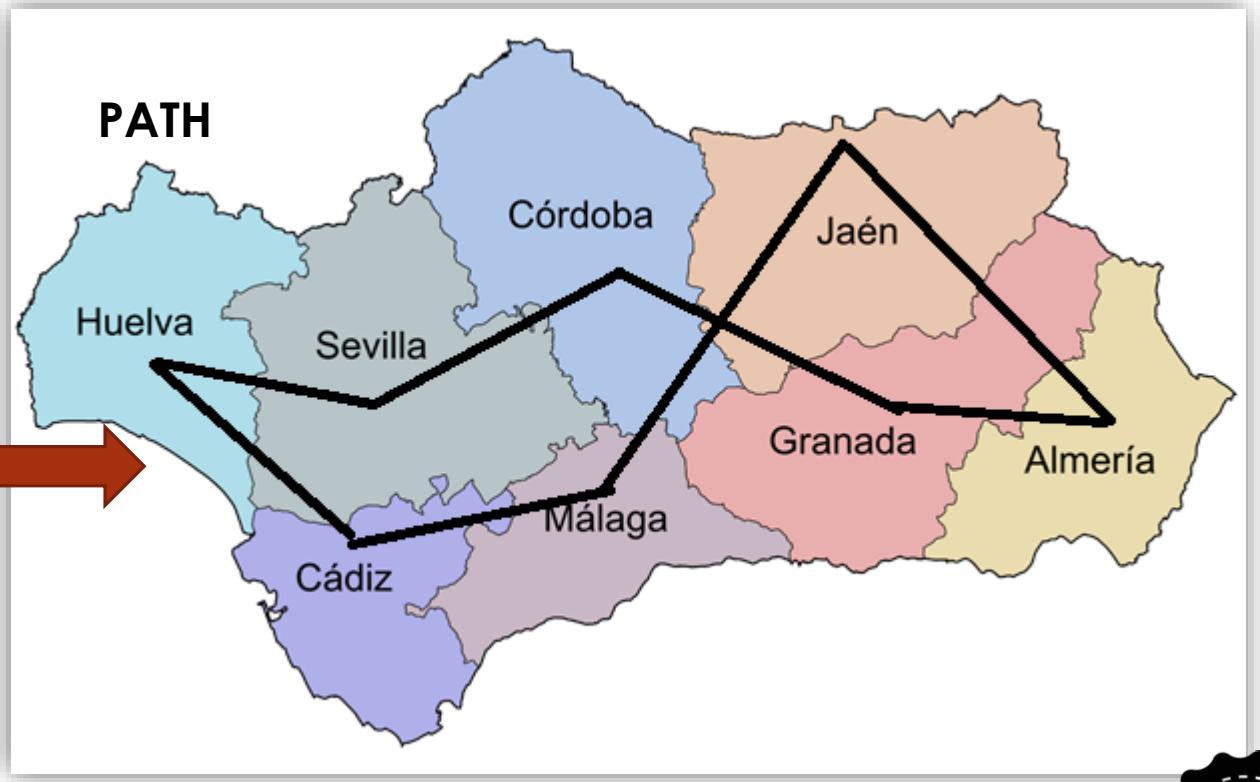
- *Genetic Algorithm with Varying Population Size*



TSP – DECODE & FITNESS

HUELVA
SEVILLA
CÁDIZ
CÓRDOBA
MÁLAGA
JAÉN
GRANADA
ALMERÍA

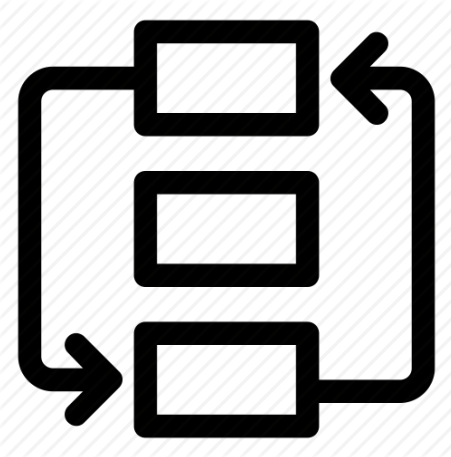
CHROMOSOME



$$\text{Fitness}(path) = \min\{\Sigma_{i,j=0}^{7}(w_{i,j})\}$$

G.A – TSP PSEUDOCODE

- GENETIC_ALGORITHM(….)
  - INITIAL_POPULATION(….)
  - NEW_GENERATION(….)
    - TOURNAMENT_SELECTION(…)
    - CROSS_PARENTS(..)
    - MUTATE(….)
  - WHILE GENERATIONS :
    - NEW_POPULATION = NEW_GENERATION(….)
  - RETURN GENOTYPE(BEST_CRHOMOSOME(…))



VRP - REPRESENTATION

$n-1$ *Distributors* as **Frontiers.** The chromosome will be divided into as many paths as **frontiers -1**

HUELVA	GEN_0
SEVILLA	
CÁDIZ	
CÓRDOBA	
MÁLAGA	
JAÉN	
GRANADA	
ALMERÍA	GEN_7

+

TRUCK1
TRUCK2
…

CHROMOSOME

VRP - REPRESENTATION

Example Final Result: 2 Trucks

HUELVA	GEN_0	PATH 1
SEVILLA		
FRONTIER1		
CADIZ		PATH 2
MÁLAGA		
GRANADA		
ALMERÍA		
JAÉN		
CORDOBA	GEN_8	

CHROMOSOME

FRONTIER = N – 1 TRUCKS

VRP - REPRESENTATION

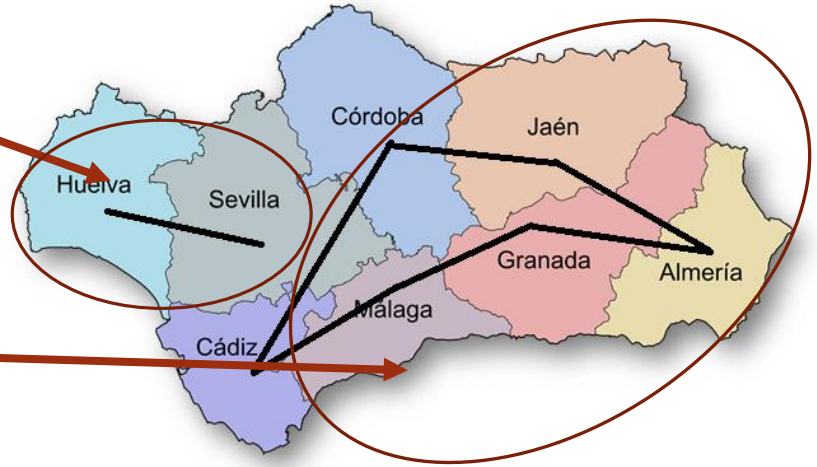
Example Final Result: 2 Trucks

HUELVA	GEN_0
SEVILLA	
FRONTIER1	
CADIZ	
MÁLAGA	
GRANADA	
ALMERÍA	
JAÉN	
CORDOBA	GEN_8

PATH 1

PATH 2

CHROMOSOME



TSP- PENALTY & FITNESS

CONSTRAINTS:

$$Capacity_{city} = (w_{i,j}) \leq Capacity\_trucks$$

$$\text{Penalty}_{capacity}(Path) = 100 * Overloads$$

$$\text{Fitness}(Path) = 2\ x \sum_{i,j=0}^{7} (w_{i,j}) + 50\ x\ Penalty_{capacity}(Path)$$

EXPERIMENTATION - TSP

Parameters	Values
K	2
Opt	**Min**
N generations	200
Size	100
Ratio_cross	0,8
Prob_mutate	0,05

```
344 #---------------------------------------- AUXILIARY DATA FOR TESTING ------------------------------
345
346
347 cities = {0:'Almeria',1:'Cadiz',2:'Cordoba',3:'Granada',4:'Huelva',5:'Jaen',6:'Malaga',7:'Sevilla'}
348
349 #Distance between each pair of cities
350
351 w0=[999,454,317,165,528,222,223,410]
352 w1=[453,999,253,291,210,325,234,121]
353 w2=[317,252,999,202,226,108,158,140]
354 w3=[165,292,201,999,344,94,124,248]
355 w4=[508,210,235,346,999,336,303,94]
356 w5=[222,325,116,93,340,999,182,247]
357 w6=[223,235,158,125,302,185,999,206]
358 w7=[410,121,141,248,93,242,199,999]
359
360 distances = {0:w0,1:w1,2:w2,3:w3,4:w4,5:w5,6:w6,7:w7}
361
362
363 if __name__ == "__main__":
364
365     # Constant that is an instance object
366     genetic_problem_instances = 10
367     TSP(genetic_problem_instances)
```

NUMBER OF INSTANCES = 10

EXPERIMENTATION - TSP

```
EXECUTING  10  INSTANCES

-----------------------------------------------------------Executing FIRST PART: TSP -----------------------------------

Chromosome:  [5, 3, 0, 6, 1, 4, 7, 2]
Solution: (['Jaen', 'Granada', 'Almeria', 'Malaga', 'Cadiz', 'Huelva', 'Sevilla', 'Cordoba'], 1269)
Chromosome:  [0, 3, 5, 2, 4, 7, 1, 6]
Solution: (['Almeria', 'Granada', 'Jaen', 'Cordoba', 'Huelva', 'Sevilla', 'Cadiz', 'Malaga'], 1273)
Chromosome:  [6, 1, 4, 7, 2, 5, 3, 0]
Solution: (['Malaga', 'Cadiz', 'Huelva', 'Sevilla', 'Cordoba', 'Jaen', 'Granada', 'Almeria'], 1269)
Chromosome:  [4, 7, 1, 6, 0, 3, 5, 2]
Solution: (['Huelva', 'Sevilla', 'Cadiz', 'Malaga', 'Almeria', 'Granada', 'Jaen', 'Cordoba'], 1273)
Chromosome:  [1, 6, 0, 3, 5, 2, 7, 4]
Solution: (['Cadiz', 'Malaga', 'Almeria', 'Granada', 'Jaen', 'Cordoba', 'Sevilla', 'Huelva'], 1275)
Chromosome:  [2, 5, 3, 0, 6, 7, 4, 1]
Solution: (['Cordoba', 'Jaen', 'Granada', 'Almeria', 'Malaga', 'Sevilla', 'Huelva', 'Cadiz'], 1351)
Chromosome:  [1, 4, 7, 2, 5, 0, 3, 6]
Solution: (['Cadiz', 'Huelva', 'Sevilla', 'Cordoba', 'Jaen', 'Almeria', 'Granada', 'Malaga'], 1299)
Chromosome:  [4, 7, 2, 5, 3, 0, 6, 1]
Solution: (['Huelva', 'Sevilla', 'Cordoba', 'Jaen', 'Granada', 'Almeria', 'Malaga', 'Cadiz'], 1269)
Chromosome:  [3, 0, 6, 1, 4, 7, 2, 5]
Solution: (['Granada', 'Almeria', 'Malaga', 'Cadiz', 'Huelva', 'Sevilla', 'Cordoba', 'Jaen'], 1269)
Chromosome:  [3, 0, 6, 1, 4, 7, 2, 5]
Solution: (['Granada', 'Almeria', 'Malaga', 'Cadiz', 'Huelva', 'Sevilla', 'Cordoba', 'Jaen'], 1269)
Chromosome:  [0, 6, 1, 4, 7, 2, 5, 3]
Solution: (['Almeria', 'Malaga', 'Cadiz', 'Huelva', 'Sevilla', 'Cordoba', 'Jaen', 'Granada'], 1269)

Total time:  16.25  secs.
```

EXPERIMENTATION - TSP

```
----------------------------------------------------------Executing SECOND PART: TSP ----------------------------------------------------------

Chromosome:  [0, 3, 1, 4, 7, 2, 5, 6]
Solution: (['Almeria', 'Granada', 'Cadiz', 'Huelva', 'Sevilla', 'Cordoba', 'Jaen', 'Malaga'], 1415) 1  generations of winners parents.
Chromosome:  [5, 1, 4, 7, 2, 6, 0, 3]
Solution: (['Jaen', 'Cadiz', 'Huelva', 'Sevilla', 'Cordoba', 'Malaga', 'Almeria', 'Granada'], 1410) 1  generations of winners parents.
Chromosome:  [7, 4, 1, 6, 0, 5, 3, 2]
Solution: (['Sevilla', 'Huelva', 'Cadiz', 'Malaga', 'Almeria', 'Jaen', 'Granada', 'Cordoba'], 1416) 4  generations of winners parents.
Chromosome:  [3, 0, 6, 2, 4, 1, 7, 5]
Solution: (['Granada', 'Almeria', 'Malaga', 'Cordoba', 'Huelva', 'Cadiz', 'Sevilla', 'Jaen'], 1438) 1  generations of winners parents.
Chromosome:  [0, 3, 7, 4, 1, 6, 2, 5]
Solution: (['Almeria', 'Granada', 'Sevilla', 'Huelva', 'Cadiz', 'Malaga', 'Cordoba', 'Jaen'], 1438) 7  generations of winners parents.
Chromosome:  [4, 2, 3, 0, 5, 6, 1, 7]
Solution: (['Huelva', 'Cordoba', 'Granada', 'Almeria', 'Jaen', 'Malaga', 'Cadiz', 'Sevilla'], 1455) 3  generations of winners parents.
Chromosome:  [5, 6, 0, 3, 1, 4, 7, 2]
Solution: (['Jaen', 'Malaga', 'Almeria', 'Granada', 'Cadiz', 'Huelva', 'Sevilla', 'Cordoba'], 1415) 3  generations of winners parents.
Chromosome:  [2, 4, 7, 1, 6, 5, 3, 0]
Solution: (['Cordoba', 'Huelva', 'Sevilla', 'Cadiz', 'Malaga', 'Jaen', 'Granada', 'Almeria'], 1435) 5  generations of winners parents.
Chromosome:  [2, 0, 3, 5, 6, 1, 7, 4]
Solution: (['Cordoba', 'Almeria', 'Granada', 'Jaen', 'Malaga', 'Cadiz', 'Sevilla', 'Huelva'], 1442) 1  generations of winners parents.
Chromosome:  [3, 0, 6, 7, 4, 1, 2, 5]
Solution: (['Granada', 'Almeria', 'Malaga', 'Sevilla', 'Huelva', 'Cadiz', 'Cordoba', 'Jaen'], 1351) 4  generations of winners parents.
Chromosome:  [6, 1, 4, 7, 2, 5, 0, 3]
Solution: (['Malaga', 'Cadiz', 'Huelva', 'Sevilla', 'Cordoba', 'Jaen', 'Almeria', 'Granada'], 1299) 2  generations of winners parents.

Total time:  31.377000093460083  secs.
```

EXPERIMENTATION - VRP

```
EXECUTING  10  INSTANCES
------------------------------------------------------------Executing FIRST PART: VRP ------------------------------------

Capacity of trucks =  50
Frontier =  ---------

Chromosome:  [(3, 10), (6, 10), (5, 10), (0, 10), (7, 10), ('truck', 50), (2, 10), (4, 10), (1, 10)]
Solution:  (['Granada', 'Malaga', 'Jaen', 'Almeria', 'Sevilla', '---------', 'Cordoba', 'Huelva', 'Cadiz'], 1017)
Chromosome:  [(3, 10), (7, 10), (5, 10), (6, 10), (1, 10), ('truck', 50), (2, 10), (4, 10), (0, 10)]
Solution:  (['Granada', 'Sevilla', 'Jaen', 'Malaga', 'Cadiz', '---------', 'Cordoba', 'Huelva', 'Almeria'], 979)
Chromosome:  [(3, 10), (7, 10), (5, 10), (0, 10), ('truck', 50), (2, 10), (1, 10), (4, 10), (6, 10)]
Solution:  (['Granada', 'Sevilla', 'Jaen', 'Almeria', '---------', 'Cordoba', 'Cadiz', 'Huelva', 'Malaga'], 1003)
Chromosome:  [(6, 10), (7, 10), (5, 10), (0, 10), ('truck', 50), (3, 10), (1, 10), (4, 10), (2, 10)]
Solution:  (['Malaga', 'Sevilla', 'Jaen', 'Almeria', '---------', 'Granada', 'Cadiz', 'Huelva', 'Cordoba'], 1038)
Chromosome:  [(6, 10), (7, 10), (5, 10), (2, 10), ('truck', 50), (3, 10), (0, 10), (4, 10), (1, 10)]
Solution:  (['Malaga', 'Sevilla', 'Jaen', 'Cordoba', '---------', 'Granada', 'Almeria', 'Huelva', 'Cadiz'], 1062)
Chromosome:  [(3, 10), (7, 10), (6, 10), (0, 10), ('truck', 50), (2, 10), (1, 10), (4, 10), (5, 10)]
Solution:  (['Granada', 'Sevilla', 'Malaga', 'Almeria', '---------', 'Cordoba', 'Cadiz', 'Huelva', 'Jaen'], 1053)
Chromosome:  [(3, 10), (7, 10), (4, 10), (0, 10), ('truck', 50), (2, 10), (5, 10), (1, 10), (6, 10)]
Solution:  (['Granada', 'Sevilla', 'Huelva', 'Almeria', '---------', 'Cordoba', 'Jaen', 'Cadiz', 'Malaga'], 1099)
Chromosome:  [(3, 10), (7, 10), (5, 10), (6, 10), ('truck', 50), (2, 10), (1, 10), (4, 10), (0, 10)]
Solution:  (['Granada', 'Sevilla', 'Jaen', 'Malaga', '---------', 'Cordoba', 'Cadiz', 'Huelva', 'Almeria'], 962)
Chromosome:  [(2, 10), (7, 10), (5, 10), (6, 10), (1, 10), ('truck', 50), (3, 10), (4, 10), (0, 10)]
Solution:  (['Cordoba', 'Sevilla', 'Jaen', 'Malaga', 'Cadiz', '---------', 'Granada', 'Huelva', 'Almeria'], 1098)
Chromosome:  [(5, 10), (7, 10), (3, 10), (0, 10), (1, 10), ('truck', 50), (2, 10), (4, 10), (6, 10)]
Solution:  (['Jaen', 'Sevilla', 'Granada', 'Almeria', 'Cadiz', '---------', 'Cordoba', 'Huelva', 'Malaga'], 1171)
Chromosome:  [(3, 10), (4, 10), (5, 10), (6, 10), (7, 10), ('truck', 50), (2, 10), (1, 10), (0, 10)]
Solution:  (['Granada', 'Huelva', 'Jaen', 'Malaga', 'Sevilla', '---------', 'Cordoba', 'Cadiz', 'Almeria'], 980)


Total time:  23.30999994277954  secs.
```

EXPERIMENTATION - VRP

```
------------------------------------------------------------Executing SECOND PART: VRP ----------------------------------------

Capacity of trucks =  50
Frontier =  ---------

Chromosome:  [(1, 10), (2, 10), (5, 10), (0, 10), ('truck', 50), (7, 10), (3, 10), (4, 10), (6, 10)]
Solution: (['Cadiz', 'Cordoba', 'Jaen', 'Almeria', '---------', 'Sevilla', 'Granada', 'Huelva', 'Malaga'], 1445) 5  GENERATIONS
Chromosome:  [(3, 10), (4, 10), (6, 10), ('truck', 50), (1, 10), (0, 10), (7, 10), (5, 10), (2, 10)]
Solution: (['Granada', 'Huelva', 'Malaga', '---------', 'Cadiz', 'Almeria', 'Sevilla', 'Jaen', 'Cordoba'], 1413) 1  GENERATIONS
Chromosome:  [(3, 10), (6, 10), (7, 10), (0, 10), (1, 10), ('truck', 50), (2, 10), (5, 10), (4, 10)]
Solution: (['Granada', 'Malaga', 'Sevilla', 'Almeria', 'Cadiz', '---------', 'Cordoba', 'Jaen', 'Huelva'], 1314) 1  GENERATIONS
Chromosome:  [(5, 10), (7, 10), (1, 10), (0, 10), (6, 10), ('truck', 50), (2, 10), (4, 10), (3, 10)]
Solution: (['Jaen', 'Sevilla', 'Cadiz', 'Almeria', 'Malaga', '---------', 'Cordoba', 'Huelva', 'Granada'], 1314) 2  GENERATIONS
Chromosome:  [(3, 10), (6, 10), (5, 10), ('truck', 50), (1, 10), (2, 10), (0, 10), (4, 10), (7, 10)]
Solution: (['Granada', 'Malaga', 'Jaen', '---------', 'Cadiz', 'Cordoba', 'Almeria', 'Huelva', 'Sevilla'], 1149) 1  GENERATIONS
Chromosome:  [(5, 10), (7, 10), (0, 10), (6, 10), ('truck', 50), (2, 10), (3, 10), (4, 10), (1, 10)]
Solution: (['Jaen', 'Sevilla', 'Almeria', 'Malaga', '---------', 'Cordoba', 'Granada', 'Huelva', 'Cadiz'], 1118) 3  GENERATIONS
Chromosome:  [(3, 10), (5, 10), (6, 10), (0, 10), (7, 10), ('truck', 50), (2, 10), (4, 10), (1, 10)]
Solution: (['Granada', 'Jaen', 'Malaga', 'Almeria', 'Sevilla', '---------', 'Cordoba', 'Huelva', 'Cadiz'], 1158) 1  GENERATIONS
Chromosome:  [(3, 10), (4, 10), (7, 10), (0, 10), ('truck', 50), (6, 10), (2, 10), (5, 10), (1, 10)]
Solution: (['Granada', 'Huelva', 'Sevilla', 'Almeria', '---------', 'Malaga', 'Cordoba', 'Jaen', 'Cadiz'], 1262) 1  GENERATIONS
Chromosome:  [(2, 10), (7, 10), (5, 10), ('truck', 50), (1, 10), (0, 10), (3, 10), (6, 10), (4, 10)]
Solution: (['Cordoba', 'Sevilla', 'Jaen', '---------', 'Cadiz', 'Almeria', 'Granada', 'Malaga', 'Huelva'], 1302) 1  GENERATIONS
Chromosome:  [(3, 10), (4, 10), (5, 10), (6, 10), ('truck', 50), (1, 10), (0, 10), (2, 10), (7, 10)]
Solution: (['Granada', 'Huelva', 'Jaen', 'Malaga', '---------', 'Cadiz', 'Almeria', 'Cordoba', 'Sevilla'], 1296) 1  GENERATIONS
Chromosome:  [(6, 10), (4, 10), (0, 10), ('truck', 50), (7, 10), (3, 10), (2, 10), (5, 10), (1, 10)]
Solution: (['Malaga', 'Huelva', 'Almeria', '---------', 'Sevilla', 'Granada', 'Cordoba', 'Jaen', 'Cadiz'], 1337) 1  GENERATIONS
|n
Total time:  62.651999950408936  secs.
```

EXPERIMENTATION - RESULTS

Schedule Time			
TSP - PART I	**TSP - PART II**	**VRP – PART I**	**VRP – PART II**
T = 16.25 s	T = 31.37 s	T = 23.30 s	T = 62.65s

NUMBER OF INSTANCES = 10

BIBLIOGRAPHY

- NP- Problems: https://en.wikipedia.org/wiki/BQP
- TSP Problem: https://en.wikipedia.org/wiki/Travelling_salesman_problem
- GAVaPS - a Genetic Algorithm with Varying Population Size: http://dlia.ir/Scientific/IEEE/iel2/1125/8059/00350039.pdf
- https://pdfs.semanticscholar.org/9db9/2c22e6e34ac3616dc28b89725869c3d780a0.pdf
- Cellular Genetic Algorithms : http://tracer.lcc.uma.es/tws/cEA/documents/AGTR02.pdf7
- VRP PROBLEM : https://thesai.org/Downloads/Volume2No7/Paper%2019-Solving%20the%20Vehicle%20Routing%20Problem%20using%20Genetic%20Algorithm.pdf
- Slides Unit 4: https://www.cs.us.es/docencia/aulavirtual/pluginfile.php/5152/mod_page/content/4/unit-04-2014-15.pdf

Thank You!