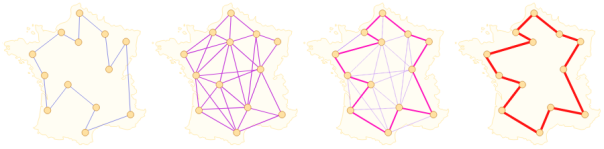
LAB 5:
Travelling Salesman Problem using Genetic Algorithms

COMPUTATION

Spring semester. Academic year 2023/2024



The aim of this final project is to achieve a good understanding of how genetic algorithms work, and at the same time, to develop the ability to analyse a problem from the point of view of Scientific Computing. More specifically, the aim is to study the effect that the variation of different parameters and/or techniques within a genetic algorithm has on the resolution of a specific problem.

1 Genetic Algorithms and definition of the problem

We begin with the set of 20 cities, the map of which is shown in Figure 1:
We have a cost matrix $\mathbf{M}$, with 20×20 dimensions and of positive real numbers, shown in Figure 2, where:

- $\mathbf{M}(A, B)$ is a measure of the cost of getting from city A to city B.
- As can be seen in Figure 2, symmetry is assumed: $\mathbf{M}(A, B) = \mathbf{M}(B, A)$, for all $A, B \in CITIES$, i.e., that the cost of travelling from city A to city B is the same as the cost of travelling from city B to city A.
- It is possible to go from any city to any other city.

PROBLEM: Starting from Pamplona, determine a route that allows you to pass through each of the cities exactly once and return to Pamplona at the lowest possible cost.

Figure 1: Map of Spanish cities to be travelled through

INDICATIONS:

1. The report to be submitted must describe the chosen chromosome representation and the cost function (or functions) used.
2. The objective of the practice is to study how the behaviour of the genetic algorithms used to solve this problem varies when the different parameters are varied. In particular, the following points must be studied:
   - If a solution is reached or not.
   - The temporal cost (and number of iterations) of the algorithm.
   - Any additional aspect that the student finds interesting.

More than the code itself, which must be correct, the quality of the resultant report will be valued, with an emphasis on the number of performed tests, the justification for the parameter changes made, the analysis on the behaviour of the algorithm caused by said changes and the conclusions extracted.
Some of the parameters to take into account are:

1. The method for assigning probabilities for choosing an individual as parent.
2. The parent selection method: at least the roulette and the tournament with k participant methods, with k one of the parameters to be studied, must be implemented.
3. The crossing method. At least two crossing methods must be considered.
4. The survivor selection method.
5. The effect of the presence or absence of mutations.

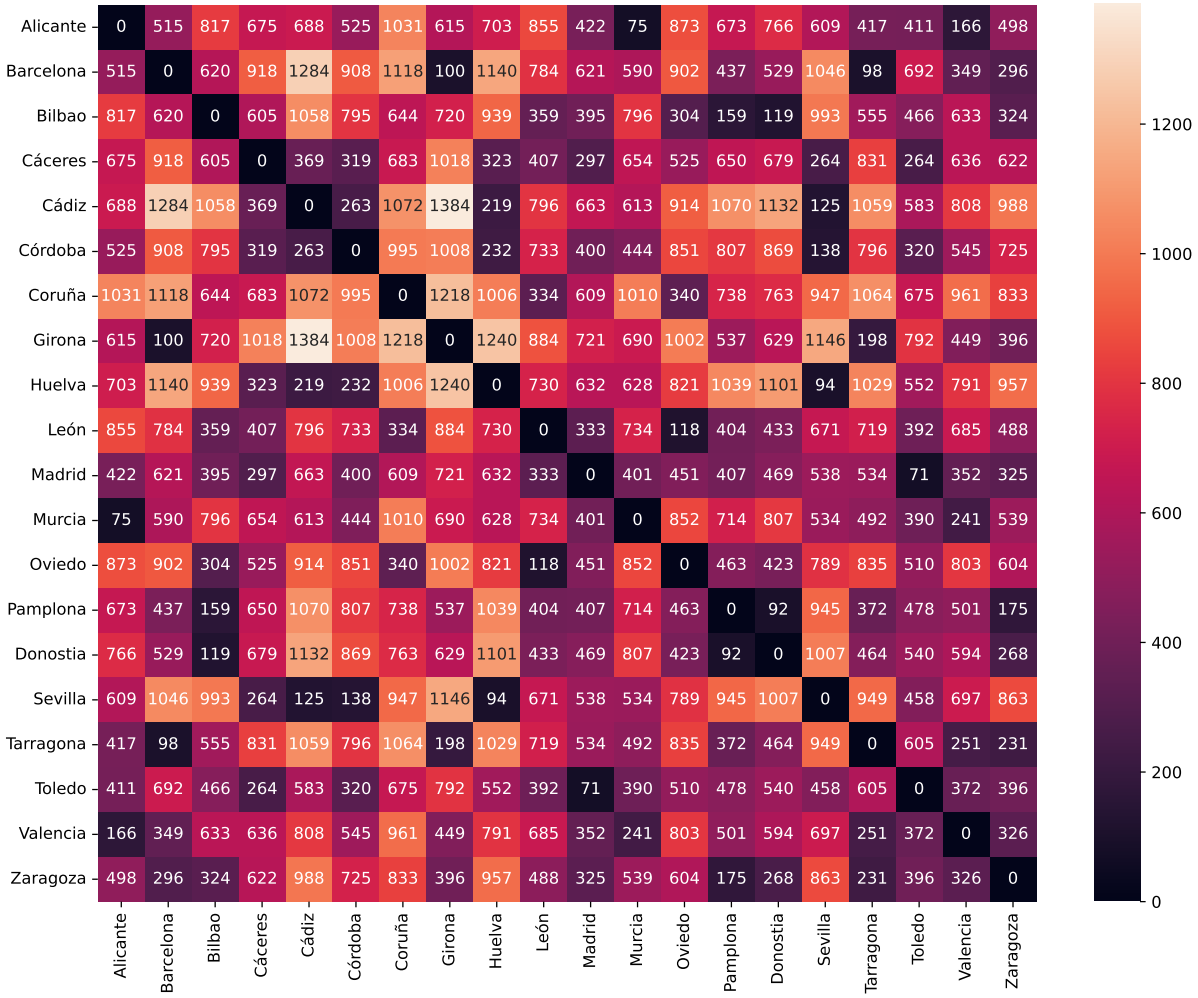


Figure 2: Cost matrix of the Spanish cities to be visited

6. Change the starting city.

7. The number of cities: can be removed (choose a subset of the 20 cities) or cities can be added (can be done randomly as long as it is consistent with the problem data).

Additionally, for each of these items, possible changes in their values must be considered (e. g. different probabilities for mutations)

2 Documentation to be submitted

The following two files will be submitted via the *MiAulario* assignments:

1 C5_Surname1Surname2.zip: A compressed .zip file containing all the necessary Python code files. The files must be commented so that the code is understandable.

In the case of programming in a Notebook (.ipynb), the main program must be named `main.ipynb` and the complete program must be clearly indicated and executed in the last cell of the Notebook.

If the program is not programmed in a Notebook, one of these files must be named `main.py`. When this file is executed, the complete program must be executed automatically until a solution is reached.

2 I5_Surname1Surname2.pdf: A PDF report including:

(I) Description of how the problem has been approached and solved. In particular, **the coding of the chromosomes and the used cost function** (or cost functions, if different cost functions have been tested) and its **justification** for use should be explained.

(II) Experiments:

- Description of the experiments carried out: different values of the parameters used and their results for each problem.
- A study of how the behaviour of the algorithm has been affected by the different parameter variations carried out, i.e. **interpretation and conclusion of the results** for each problem.

(III) **Conclusions** that can be reached after the realisation of a wide variety and combinations of parameters.

(IV) In general, on the presentation of the work:

- Identification: name, subject, title of the work, etc.
- Elements of the report: table of contents, page numbering, introduction and objectives section, organisation into sections indicating the specific objective of each section.
- Presentation of results: tables and graphs with the same format (including table or graph footer), interpretable and clear (graphs with labels and legends if necessary).
- Grammatically correct and understandable wording.

Example: if the student has the surname Pérez García, he/she must submit the following two files:

- `C5_PerezGarcia.zip`
- `I5_PerezGarcia.pdf`

The lab task will be weighted as the **80**% of the mark of the lab tasks of the subject (50%).

The remaining 20% will be obtained through the average of the submitted lab tasks.

The deadline for the submission of the lab task will be **May 21, 2024**.

Appendix

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# Vector of cities

CITIES = ["Alicante","Barcelona","Bilbao","Cáceres","Cádiz","Córdoba",
            "Coruña","Girona","Huelva","León","Madrid","Murcia","Oviedo",
            "Pamplona","Donostia","Sevilla","Tarragona","Toledo","Valencia",
            "Zaragoza"]


# Matrix of distances

M = [
[0,515,817,675,688,525,1031,615,703,855,422,75,873,673,766,609,417,411,166,498],
[515,0,620,918,1284,908,1118,100,1140,784,621,590,902,437,529,1046,98,692,349,296],
[817,620,0,605,1058,795,644,720,939,359,395,796,304,159,119,993,555,466,633,324],
[675,918,605,0,369,319,683,1018,323,407,297,654,525,650,679,264,831,264,636,622],
[688,1284,1058,369,0,263,1072,1384,219,796,663,613,914,1070,1132,125,1059,583,808,988],
[525,908,795,319,263,0,995,1008,232,733,400,444,851,807,869,138,796,320,545,725],
[1031,1118,644,683,1072,995,0,1218,1006,334,609,1010,340,738,763,947,1064,675,961,833],
[615,100,720,1018,1384,1008,1218,0,1240,884,721,690,1002,537,629,1146,198,792,449,396],
[703,1140,939,323,219,232,1006,1240,0,730,632,628,821,1039,1101,94,1029,552,791,957],
[855,784,359,407,796,733,334,884,730,0,333,734,118,404,433,671,719,392,685,488],
[422,621,395,297,663,400,609,721,632,333,0,401,451,407,469,538,534,71,352,325],
[75,590,796,654,613,444,1010,690,628,734,401,0,852,714,807,534,492,390,241,539],
[873,902,304,525,914,851,340,1002,821,118,451,852,0,463,423,789,835,510,803,604],
[673,437,159,650,1070,807,738,537,1039,404,407,714,463,0,92,945,372,478,501,175],
[766,529,119,679,1132,869,763,629,1101,433,469,807,423,92,0,1007,464,540,594,268],
[609,1046,993,264,125,138,947,1146,94,671,538,534,789,945,1007,0,949,458,697,863],
[417,98,555,831,1059,796,1064,198,1029,719,534,492,835,372,464,949,0,605,251,231],
[411,692,466,264,583,320,675,792,552,392,71,390,510,478,540,458,605,0,372,396],
[166,349,633,636,808,545,961,449,791,685,352,241,803,501,594,697,251,372,0,326],
[498,296,324,622,988,725,833,396,957,488,325,539,604,175,268,863,231,396,326,0]
]
```