DEEC
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Applied Computational Intelligence 2024/2025

Project 2 – EAs for Single and Multi-Objective Optimization

(Week 7)

This project aims at applying Evolutionary Computation methods to solve the **Traveling Salesman Problem** (TSP) problem. In section 1, the problem is presented. In section 2, the details on the single objective problem to be solved and the expected tests are described. In section 3, the multi-objective problem to be solved, as well as the desired output figures are described. Finally, in section 4, the details on the submission (code and report) are given.

1. Problem Description

The Traveling Salesman Problem (TSP) is a classical combinatoric problem where a traveling salesman should visit all the specified cities, **only once**, minimizing the traveling cost. The variant to this problem, that should be implemented in this project, is described in the following sections.

1.1. The Variant to the TSP

For this project the scenario will be Europe and the objective will be to travel around the Europe mainland with the lowest cost. The salesman is allowed to travel only by collective transports, i.e., plane, train or bus but not by boat, car, bike, etc.

1.2. Data Set

In this problem, **each project group** must collect and prepare **their one data set**. Details on the data to be collected are given next:

1. Select 50 major cities in Europe from at least 30 different countries. These cities must have, at least, one airport, train station or bus station. Make sure that, at least, 30 cities have airport, 30 cities have train station and 30 cities have bus station.
2. Collect the latitude and longitude for each of the 50 selected cities. This information should be stored in a **csv file** named **xy.csv**. The 1st column should be the name of the city, the 2nd column the name of the country, the 3rd column the latitude and the 4th column the longitude. For simplicity, just consider integers to represent the latitude and longitude, i.e., consider just the degrees and not the minutes and seconds. (see example in table 1)

Table 1: Example of **xy.csv** for 5 cities

City	Country	Latitude	Longitude
Lisbon	Portugal	+39	-9
London	United Kingdom	+52	0
Lyon	France	+46	+5
Ljubljana	Slovenia	+46	+15
Leipzig	Germany	+51	+12

3. For each type of transport, i.e., plane, train and bus, build a matrix of cost (€) and matrix of travel time (h) with data for each pair of cities. This information should be stored in **csv files** named **costplane.csv**, **timeplane.csv**, **costtrain.csv**, **timetrain.csv**, **costbus.csv**, **timebus.csv**.

Table 2: Example of **timebus.csv** for 5 cities

City	**Lisbon**	**London**	**Lyon**	**Ljubljana**	**Leipzig**
Lisbon	-	23h	16h	28h	25h
London	23h	-	9h	15h	10h
Lyon	16h	9h	-	9h	10h
Ljubljana	28h	15h	9h	-	7h
Leipzig	25h	10h	10h	7h	-

4. The most accurate the collected data is the better! Indicate the sources of data in your project report.
5. Your program should plot the selected cities in a planar map … be creative!

1.3. Single-Objective Optimization Problem

The **single objective optimization** problem applied to this TSP problem will consist of minimizing the total cost or time to travel using each kind of transport individually and, also, the three at the same time.

1.4. Multi-Objective Optimization Problem

The **multi-objective optimization** problem will repeat the case studies considered for the single-objective but now considering 2 objectives simultaneously, minimizing cost and minimizing time.

2. Implementing the Single-Objective Optimization Problem

2.1. Problem Formulation and EA Set Up

First, start by defining how to represent the candidate solutions and identify which would be the evolutionary operators to consider. Afterwards, select an evolutionary approach and use either functions from an existing library or implement the EA from scratch (both solutions have their pros and cons … multi-objective problem 😉)

2.2. Solving the Optimization Problem

Solve the problem for both minimizing cost and time. First, consider just one type of transport for 30 cities (the first from your data set in alphabetic order). Consider the 10, 30 and 50 cities when using the 3 types of transportation simultaneously. So, make tests for a total of 12 case studies.

Consider a map of 100x100 and maximum number of evaluations 10000, e.g., for a population of 40 elements and generating 40 offsprings limit the number of generations to 250. Remember that you are free to choose the EA approach. Explore and adjust the parameters of the chosen EA approach for considered case studies (10, 30 and 50 cities).

2.2.1. Results

Complete the following table based on the execution of 30 runs (with different random seed) for each case and make a plot of the best path from each case study.

#Cities	Plane mCost		Train mCost		Bus mCost	
	Mean	STD	Mean	STD	Mean	STD
30						

#Cities	Plane mTime		Train mTime		Bus mTime	
	Mean	STD	Mean	STD	Mean	STD
30						

#Cities	PlaneTarinBus mCost		PlaneTarinBus mTime	
	Mean	STD	Mean	STD
10				
30				
50				

Generate the convergence curves (horizontal axis - #Generations; vertical axis the total cost or total time) for the best run from each of the 12 case studies. Generate only 2 graphs, one for the mCost and 30 cities, one for mTime and 30 cities and superimposed the curves from the 4 case studies (individual transport and all together).

2.3. Using Heuristics

Define one heuristic to generate one solution to be included in the initial population. Describe and illustrate your heuristic in the report.

2.3.1. Results

Complete the following table based on the execution of 30 runs (with different random seed) for each case using heuristics.

#Cities	PlaneTarinBus mCost		PlaneTarinBus mTime	
	Mean	STD	Mean	STD
10				
30				
50				

Compare the results with the ones from 2.2.1

3. Implementing the Multi-Objective Optimization Problem

3.1. Problem Formulation and EA Set Up

First, start by defining how to represent the candidate solutions and identify which would be the evolutionary operators to consider. Moreover, **the candidate evaluation is now a pair of values**, one the time to complete the trip and other the overall cost.

3.2. Solving the Optimization Problem

Solve the problem for minimizing cost and time. Consider the 10, 30 and 50 cities when using the 3 types of transportation simultaneously. So, make tests for a total of 3 case studies.

Consider a map of 100x100 and maximum number of evaluations 10000, e.g., for a population of 40 elements and generating 40 offsprings limit the number of generations to 250. Remember that you are free to choose the EA approach. Explore and adjust the parameters of the chosen EA approach for considered case studies (10, 30 and 50 cities).

3.2.1. Results

Generate the Pareto curve (horizontal axis - Cost; vertical axis - time) for each of the 3 case studies. **Complete the following table for the Pareto front obtained** for each case and make a plot of the corresponding path.

#Cities	Min Cost		Min Time	
	Time	Cost	Time	Cost
10				
30				
50				

Generate the hypervolume evolution curve for each of the 3 case studies (with the use of heuristic for the initial population).

4. Work Submission

The work should be **submitted on the course website by October 27th, 23:59 (no deadline extensions!)**. The submission must include a zip package with: (1) the **code (commented)** and all data files to be tested in lab environment, also, include a **README file** describing the use and the sequence of results the user will see when testing your work; (2) the **report** should include (2.1) a **brief introduction**; (2.2) a **brief description of the chosen representation, algorithm, operators and hyperparameters for each problem** (single and multiple objective); (2.3) the **tables and graphs from sections 2.2.1, 2.3.1 and 3.2.1;** and (2.4) a final section with **concluding remarks**. The report **should not exceed 4 pages** (not considering the Title page).

5. Grading

The work grading is based on the work submitted and on the oral discussion. Oral discussions will take place on October 29th, 30th and 31st. The **data collection and report** (5 over 20). The **single-objective part** corresponds to 1/2 of the work classification (10 over 20). The **multiple-objective part** corresponds to 1/4 of the work classification (5 over 20).

6. Plagiarism Check

The projects will be submitted to a plagiarism check system, so, take this into account when developing your own project.