Assignment: Using Simulated Annealing and Genetic Evolution to to minimise travel distance for the F1 season 2023

Student name: Ali Benjouad

Student number: 3052766

For the documentation component regarding the programming assignment, I will be discussing the following points that corelate to the implementation made in my script:

- Overview of the simulation integration
- Simulated annealing implementation
- Genetic algorithm implementation
- Comparispn of results

The python script is heavily logged for debugging which turned out to be a massive help in the development process of the functionalities.

1) Overview:

The script provided alongside the documentation successfully implements the multiple components of the simulation of the F1 2023 calendar, the script adheres to the requirements demanded in the assignment's brief, following a step by step implementation of the functionalities present in the firstly provided f1-calendar-base.py, the implementation of these functions proved to be successful as each one passed their respective unit testing following an organised and structured implementation plan which was deduced from the brief as the following:

Priority List for Function Implementation:

➔ **CSV File Reading Functions**

- **readCSVFile**
- **readTrackLocations**
- **readRaceWeekends**
- **readSundays**

Logic behind it: These are foundational and crucial to the program as they load the necessary data from CSV files. Without this data, other functions cannot perform their tasks.

➔ **Data Conversion Functions**

- **convertColToFloat**

- **convertColToInt**

Logic behind it: These functions are necessary to convert string data from CSV files into the appropriate numerical formats for further processing.

- **Haversine Function**

Logic behind it : This is crucial for calculating distances, which is a core part of your simulation.

➔ **Core Simulation Functions**

- **calculateSeasonDistance**
- **checkTemperatureConstraint**
- **checkFourRaceInRow**
- **checkSummerShutdown**

2) Simulated annealing implementation:

I have used the provided Travelling salesman simulation annealing problem tat is provided in moodle in order to derive my work from, and I have sucesfully implemented the simulation providing an optimized race distance after utilizing the functions mentioned above to provide the necessary data for the simulation to work.

The 'F1CalendarOptimization' class derived fron 'Annealer' is setup to implement the Simulated annealing algorithm.

The 'move' function in this case will go ahead and swape race weekends thus generating new states, and the 'energy' function is used to calculated the total of the travel distabce which will translate as the objective function.

And then the 'SAcases' function is the one that executes the simulated annealing algorithm and returns the total travel distance.

Example output:

- The below screenshot depicts the end of the test run on the execution of simulated annealing algorithm, and prints out the corresponding race order to that total distance.

```
Ran 11 tests in 0.002s

OK
 Temperature        Energy    Accept   Improve     Elapsed   Remaining
     2.50000      62545.91     0.00%     0.00%     0:00:11     0:00:00
Optimized Race Order:
Bahrain International Circuit
Jeddah Corniche Circuit
Hungaroring
Red Bull Ring
Monza
Monaco
Catalunya
Spa Francorchamps
Zandvoort
Silverstone
Circuit Gilles Villeneuve
Las Vegas Strip Circuit
COTA
Autodromo Hermanos Rodriguez
Miami International Autodromo
Interlagos
Albert Park
Marina Bay Street Circuit
Suzuka
Baku City Circuit
Lusail
Yas Marina
Total Travel Distance: 62138.46 Km
```

3) Genetic algorithm implementation

Following the simulated annealing implementation was the genetic evolution algorithm featured in the script, it includes ‘F1CalendarGA’ class that implements the algorithm, the class defines ‘evallF1Calendar’ method that is usd to evaluate the fitness of the total travel distance.

The genetic algorithm is then configured with mating, mutation and selection using the ‘setupToolbox’

And in the GAcases,, this function is the one responsible for executing the genetic algorithm and then prints out the best found assumed race calendar and prints out the total distance travelled abnd the the respective race track names/locations

I will provide below a screenshot of an example output when running the genetic evolution:

I have used the example given on moodle regarding the travelling salesman as a derived version and adapted it to the script adhering to the assignment’s requirements.

gen	nevals	avg	min	max
0	300	157492	111375	193692
1	171	145374	110641	182797
2	195	137646	103820	187523
3	175	131676	99547	172899
4	172	126041	97409.5	162927
5	174	122571	98727	164898
6	188	118781	94995.1	160487
7	162	113921	90791.1	157127
8	177	112643	89222.7	165414
9	178	109855	88728.2	153312
10	175	107864	80195.3	147948
11	169	105906	79858	168020
12	175	102599	70976.3	156351
13	184	100855	70976.3	151497
14	174	97694.4	70976.3	160262
15	177	94814.8	70931.8	173764
16	189	93640.8	71152.3	153929
17	171	89765	65284.2	166403
18	178	87054.3	65284.2	170128
19	180	86051.9	65284.2	156912
20	173	82924	65284.2	147076
21	180	81846.2	68676.9	138863
22	178	80333.6	68676.9	118466
23	169	79363.3	66198.4	163313
24	177	78407	67924.5	139448
25	199	76641	64302.9	133308
26	174	78081.6	63278.7	143692
27	195	77958	63278.7	134558
28	167	76022.3	63278.7	143131
29	175	76618.8	63278.7	155720
30	169	77611.6	63278.7	162419
31	179	75520.4	63278.7	145634
32	172	74568.3	62479.1	144337
33	180	73832.8	59784.9	151292
34	181	71543.9	59784.9	140765
35	158	67954.2	59784.9	136231
36	180	67412.2	59784.9	127233
37	181	67667.8	59784.9	133386
38	172	67046.3	59784.9	139210
39	175	65867.1	59741.2	135097
40	185	64748.9	59707.2	144941

```
Optimized Race Order (GA):
Albert Park
Suzuka
Marina Bay Street Circuit
Yas Marina
Lusail
Baku City Circuit
Bahrain International Circuit
Jeddah Corniche Circuit
Interlagos
Miami International Autodromo
Autodromo Hermanos Rodriguez
COTA
Las Vegas Strip Circuit
Circuit Gilles Villeneuve
Silverstone
Catalunya
Monaco
Zandvoort
Spa Francorchamps
Red Bull Ring
Monza
Hungaroring
Total Travel Distance (GA): 59707.17 Km

Comparison of Optimizations:
Simulated Annealing Total Distance: 62138.46 Km
Genetic Algorithm Total Distance: 59707.17 Km
Genetic Algorithm produced a shorter total travel distance.
ali@Ali NO test % 33
```

4) Comparison of results:

I have made multiple test runs on both algorithns, in each of the test runs, I have noticed that the genetic algorithm always produces a shorter travel distance, showing that even though the simulated annealing showed versatibility in it's optimization performace but it was consistently outperformed by the genetic algorithm.

Few things I have noticed, as an F1 enthusiast myself I did notice that the races are generally grouped together geographically in genetic algorithnm, this would be because of trying to reduce the carbon print on the distance travelled over the season, however some races wouldn't make sense to have at the end of the year considering spa with it's constant rainy conditions even sometimes mid season, red bull ring might encounter snow at the end of the season….

However, overall, for the genetic algorithm and it's evolutionary approach is very well suited for solving complex problems that require optimisation.