

UNIVERSITÀ DEGLI STUDI DI SALERNO

**DIPARTIMENTO DI INGEGNERIA DELL'INFORMAZIONE ED
ELETTRICA E MATEMATICA APPLICATA**



**NATURAL COMPUTATION
PROJECT**

TORCS COMPETITION



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GROUP 17

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PROBLEM DESCRIPTION

- **GOAL:** evolve a controller for making it able to race for two laps on a set of unknown tracks against other controllers, trying to reach the finish line in the shortest possible time, causing as little damage as possible and arriving in the first positions.
- **EVOLUTION CONSTRAINTS**
 - At least two of four provided circuits
 - At least eight provided opponents
 - 2-laps race
- **BASELINE:** *SnakeOil* controller with default parameters.



DESIGN OF SOLUTION – TRACK ANALYSIS



Four pairs of circuits with complementary characteristics.



IDEA: Optimize the controller racing in parallel on two complementary circuits and then combining the obtained results.

FORZA



CG-TRACK-2



WHEEL-1



E-TRACK-3



Name	Length
Forza	5784.10 m
Wheel-1	4328.54 m
CG-Track-2	3185.83 m
E-Track-3	4208.37 m

DESIGN OF SOLUTION - ALGORITHM

Differential Evolution with adaptive strategy – variant rand/1/bin

- Ideal for optimizing functions of real variable
- Few hyper-parameters
- Fast convergence
- Stable solution



DESIGN OF SOLUTION – PARALLEL COMPUTATION

- ▶ Time needed to complete a generation is very large
- ▶ *Master-slave protocol* via computer network: master runs the whole DE algorithm, while slaves perform individuals evaluation



EXPERIMENTS: INTRODUCTION



► Two phases:

1. Without Opponents:

- Improve the average speed and the behaviour in tight curves for decreasing the lap time
 - *Two experiments* performed

2. With Opponents:

- Improve the overtaking skill
- Limit the damage of the car.
- Try to reach the first positions in the shorter possible time
 - *Four experiments* performed.



EXPERIMENTS: WITHOUT OPPONENTS

- ▶ Default controller has good performances in straight roads but many problems with sharp bends
- ▶ Fitness evaluation is performed racing in parallel on every possible pairs of complementary circuits
 - ▶ each pair is chosen randomly at each generation
 - ▶ each pair is used for the 25% of the total number of generations



FIRST EXPERIMENT – FITNESS FUNCTION

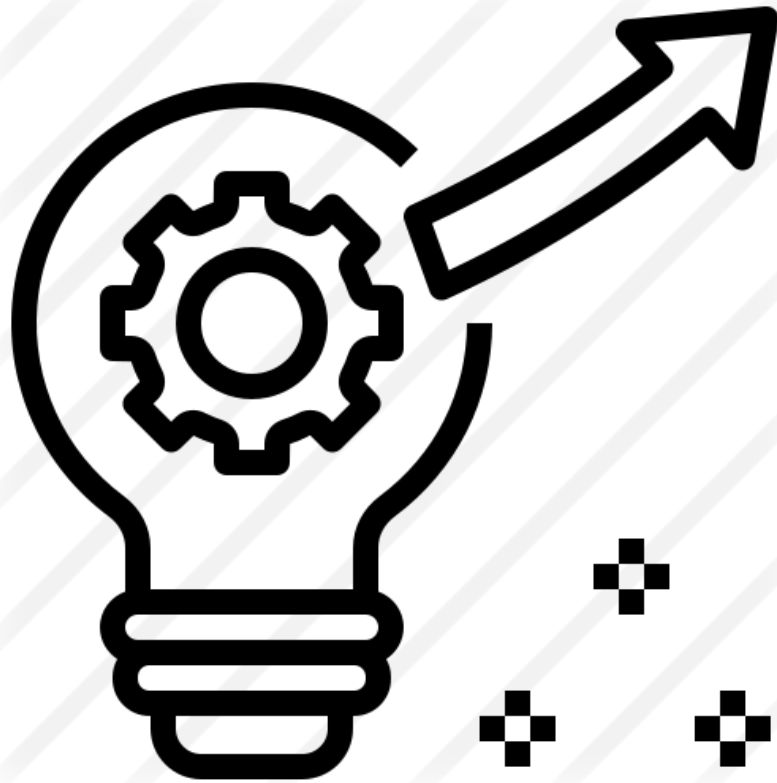
$$f = -\left(\frac{D_1}{T_1} * \frac{D_2}{T_2} - \frac{(D_1 - L_1) * (D_2 - L_2)}{100}\right)$$

where:

T: Time (s) to complete the two laps.

D: Distance (m) covered by the car from the beginning of the race.

L: Length (m) of the circuit. The training is based on two laps, so this value is twice the distance of the single lap of the circuit.



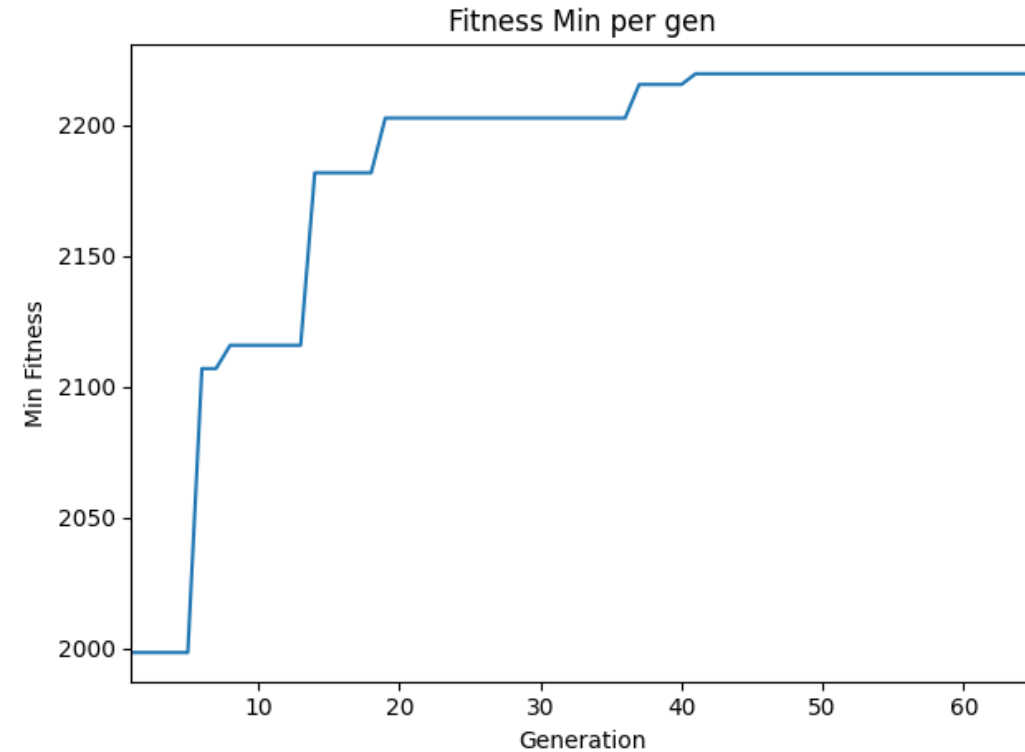
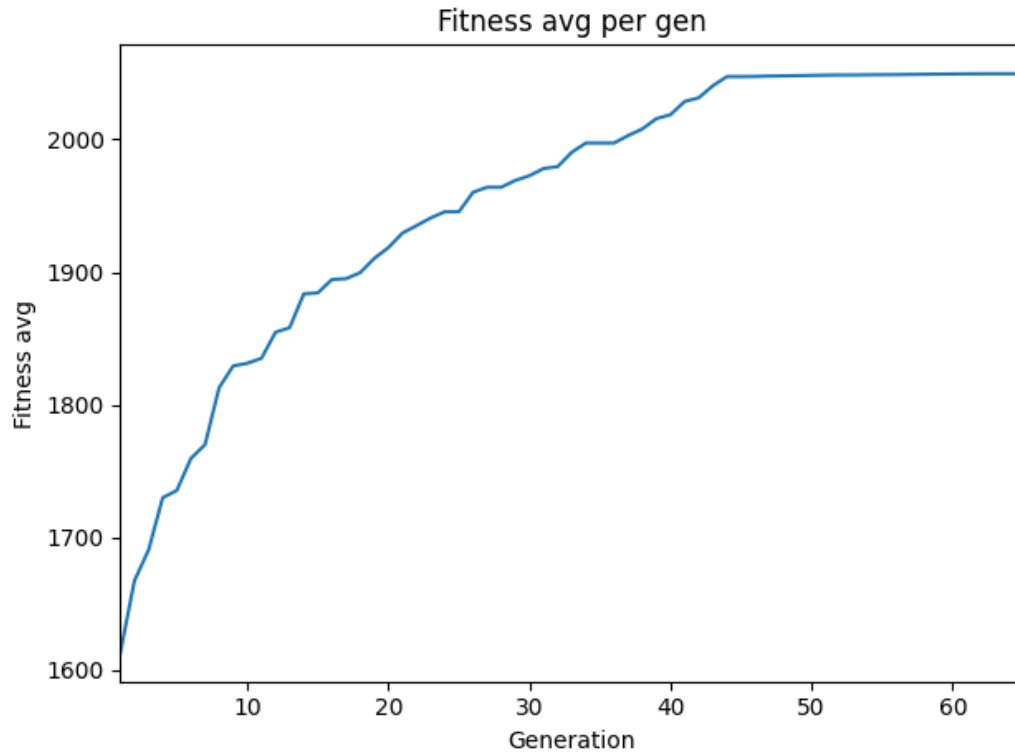
FIRST EXPERIMENT – SETUP



Parameters	Value
CR	0.9
F	0.8
Population Size	240
Number of Generations	64
Individuals Initialization	Latin Hypercube Sampling
Tracks	Forza, Wheel-1, E-Track-3, CG-Track-2
Seed	41



FIRST EXPERIMENT – RESULTS



- ▶ Important decrease in the average speed in favor of limitation of out of tracks
 - ▶ Not a great advantage on race time

SECOND EXPERIMENT – FITNESS FUNCTION

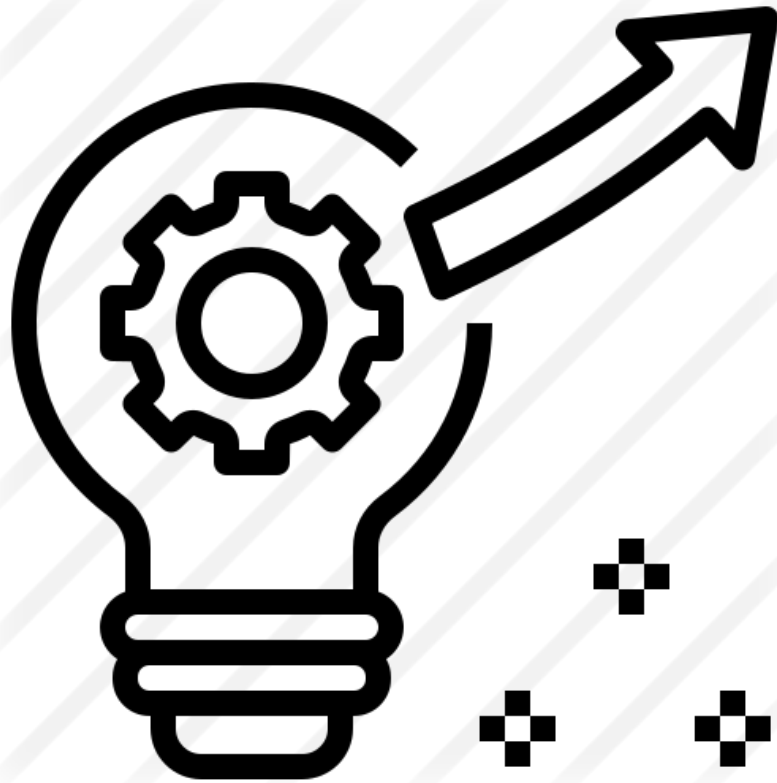
$$f = -\left(\frac{D_1}{T_1} * \frac{D_2}{T_2} - \frac{(D_1 - L_1) * (D_2 - L_2)}{1000}\right)$$

where:

T: Time (s) to complete the two laps.

D: Distance (m) covered by the car from the beginning of the race.

L: Length (m) of the circuit. The training is based on two laps, so this value is twice the distance of the single lap of the circuit.



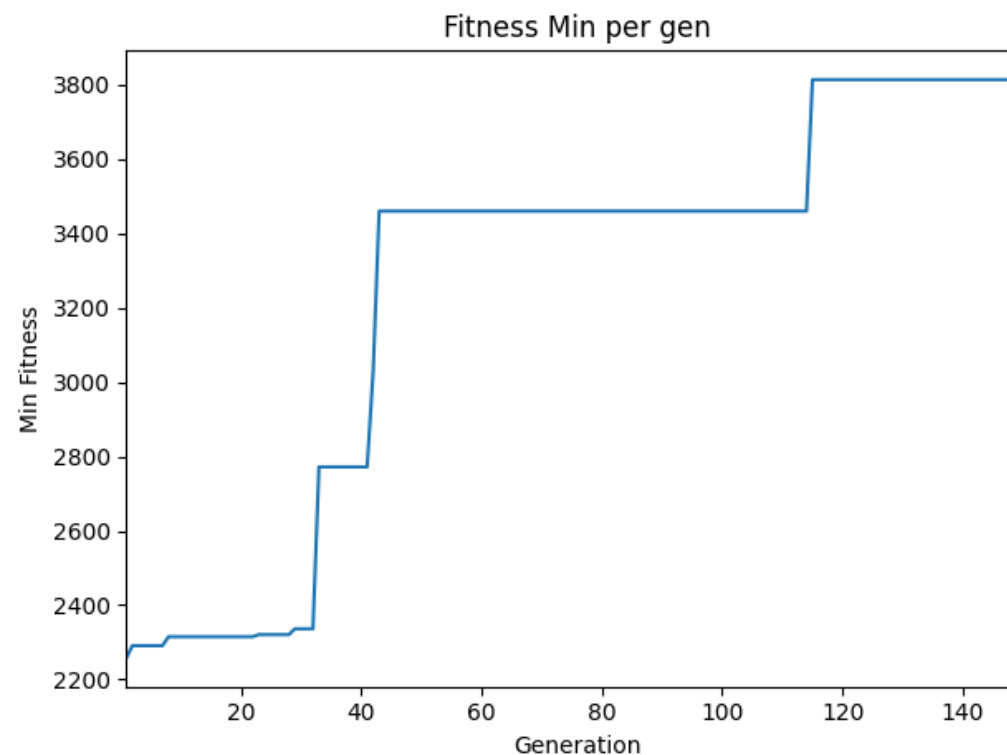
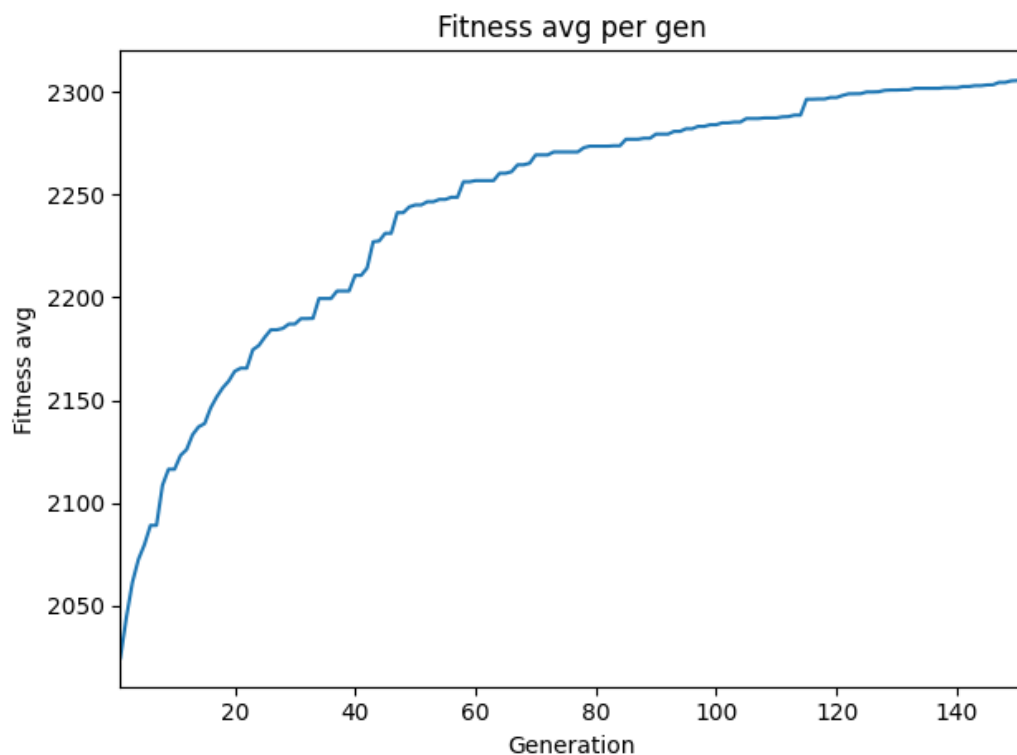
SECOND EXPERIMENT – SETUP



Parameters	Value
CR	0.9
F	0.8
Population Size	240
Number of Generations	152
Individuals Initialization	<i>Individuals from first experiment</i>
Tracks	Forza, Wheel-1, E-Track-3, CG-Track-2
Seed	41



SECOND EXPERIMENT – RESULTS



- ▶ We stopped the training at 152th generation because the average fitness is quite stable in the last generations.
- ▶ Good brake management and optimal trajectory.

EXPERIMENTS: WITH OPPONENTS (1)

- ▶ So far evolved controller reaches quite good positions but causes lots of damage
- ▶ Study of the opponent's behaviour in order to create a homogeneous starting grid
 - ▶ the "damned" group has better performances than the "berniw hist" group
 - ▶ Opponents carry out a lot of randomness in the races
- ▶ Fitness evaluation is performed racing in parallel on only a pair of complementary circuits: **Forza and Wheel-1**



EXPERIMENTS: WITH OPPONENTS (2)



We gave great importance to *racePos* sensor



We wanted to give a sort of "weight" to each race position with the goal of collecting good positions in each circuits, so we thought about the actual points scoring system of Formula One (F1).



We adopt this mechanism for giving more difference to arrive in a certain position rather than in another one.



We denote as $F(P)$ the function that takes in input the final position of the car and gives as output the relative points. For example, if the car arrives in 6-th position: $F(6)$, the car collects 8 points.

Position	Points
1	25
2	18
3	15
4	12
5	10
6	8
7	6
8	4
9	2



THIRD EXPERIMENT – FITNESS FUNCTION

$$f = -((F(P_1) + F(P_2)) * 10 + \left(\frac{D_1}{T_1} + \frac{D_2}{T_2}\right) * 10 - (H_1 + H_2))$$

where:

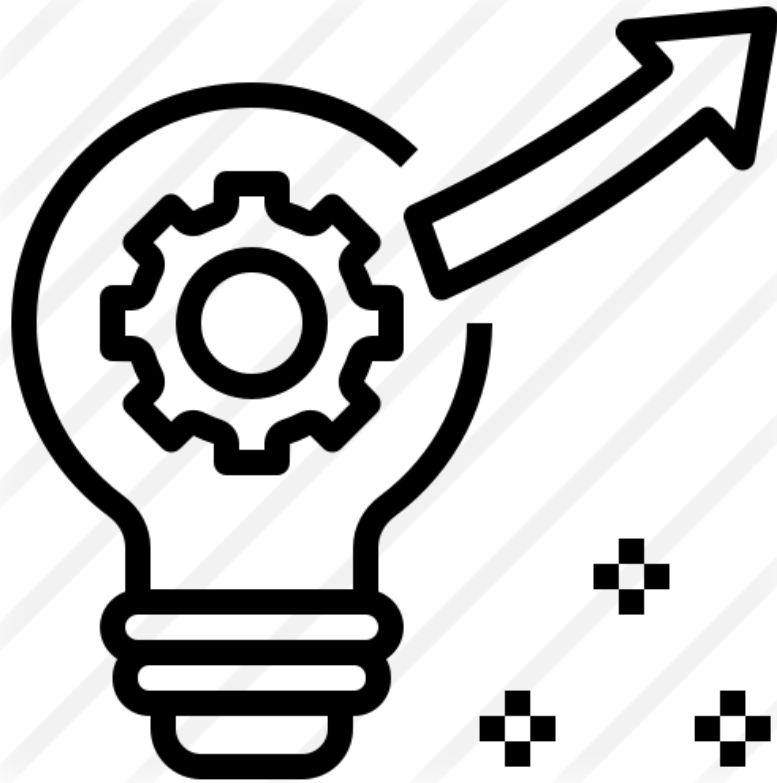
P: Position [1, 2, ..., 9] in the race with respect to other cars.

T: Time (s) to complete the two laps.

H: [0;+∞) Current damage of the car.

F(): Function of points scoring system.

D: Distance (m) covered by the car from the beginning of the race.



THIRD EXPERIMENT – SETUP

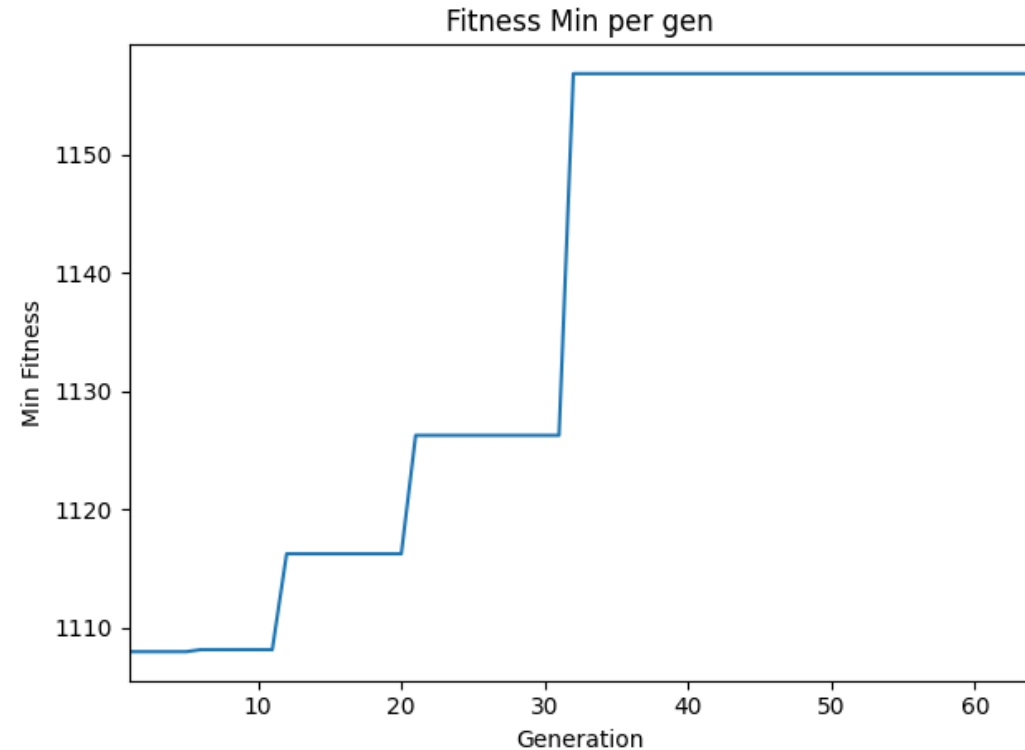
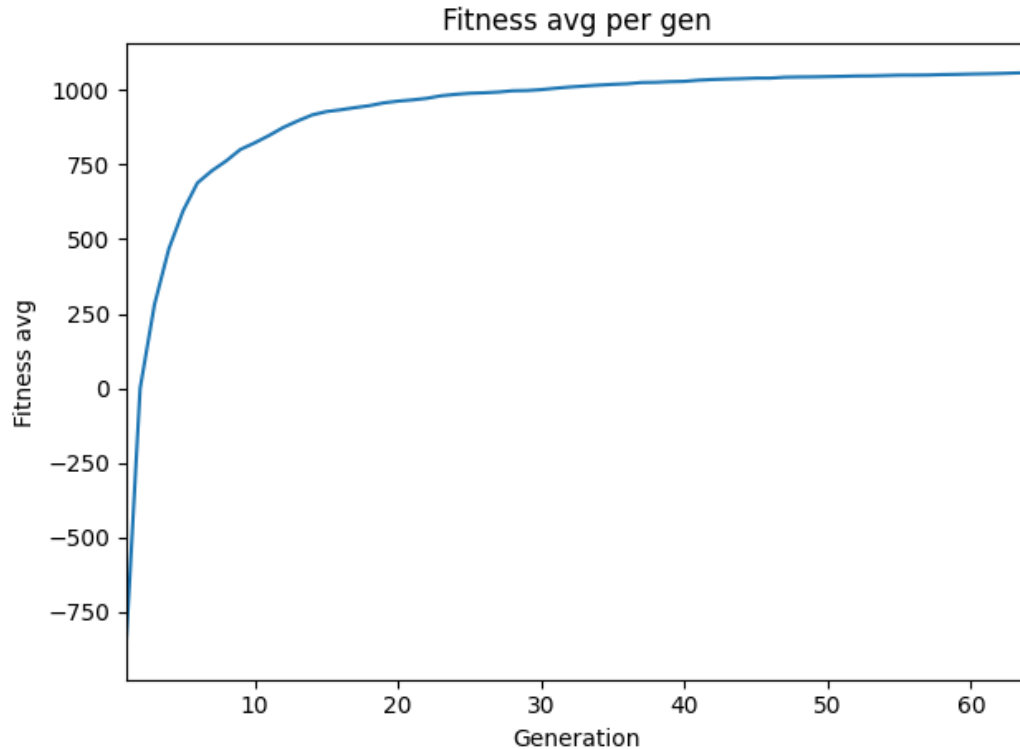


Parameters	Value
CR	0.9
F	0.8
Population Size	240
Number of Generations	64
Individuals Initialization	Individuals from <i>second experiment</i>
Tracks	Forza, Wheel-1
Number of Opponents	5
Starting Position	6
Seed	41



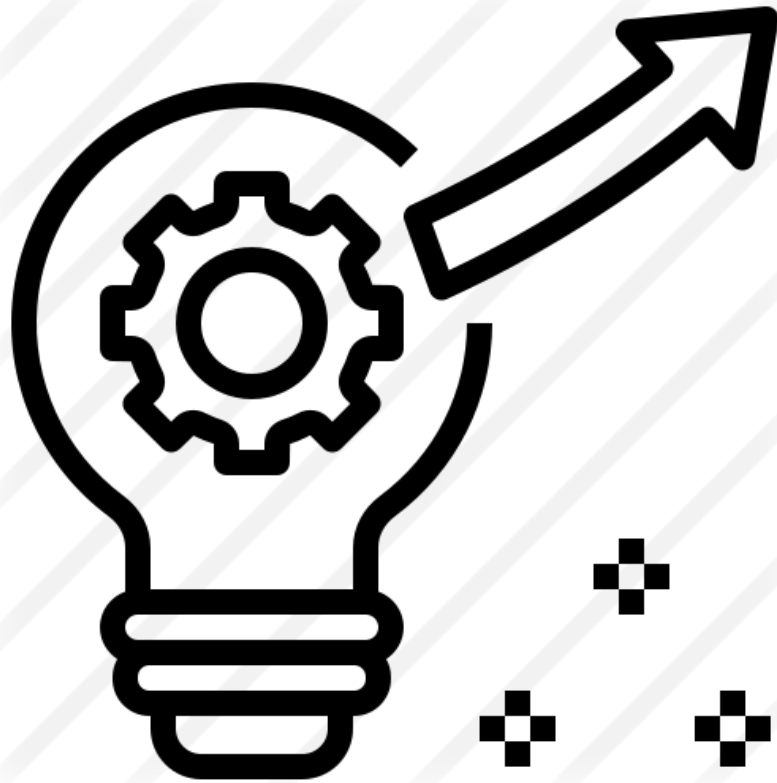


THIRD EXPERIMENT – RESULTS



- ▶ Controller tends to follow opponents staying at a certain distance
- ▶ Damage mostly due to the unpredictable behavior of the opponents

FOURTH EXPERIMENT – FITNESS FUNCTION



$$f = -((F(P_1) + F(P_2)) * 10 + \left(\frac{D_1}{T_1} + \frac{D_2}{T_2}\right) * 10 - (H_1 + H_2))$$

where:

P: Position [1, 2, ..., 9] in the race with respect to other cars.

T: Time (s) to complete the two laps.

H: $[0; +\infty)$ Current damage of the car.

F(): Function of points scoring system.

D: Distance (m) covered by the car from the beginning of the race.



FOURTH EXPERIMENT – SETUP

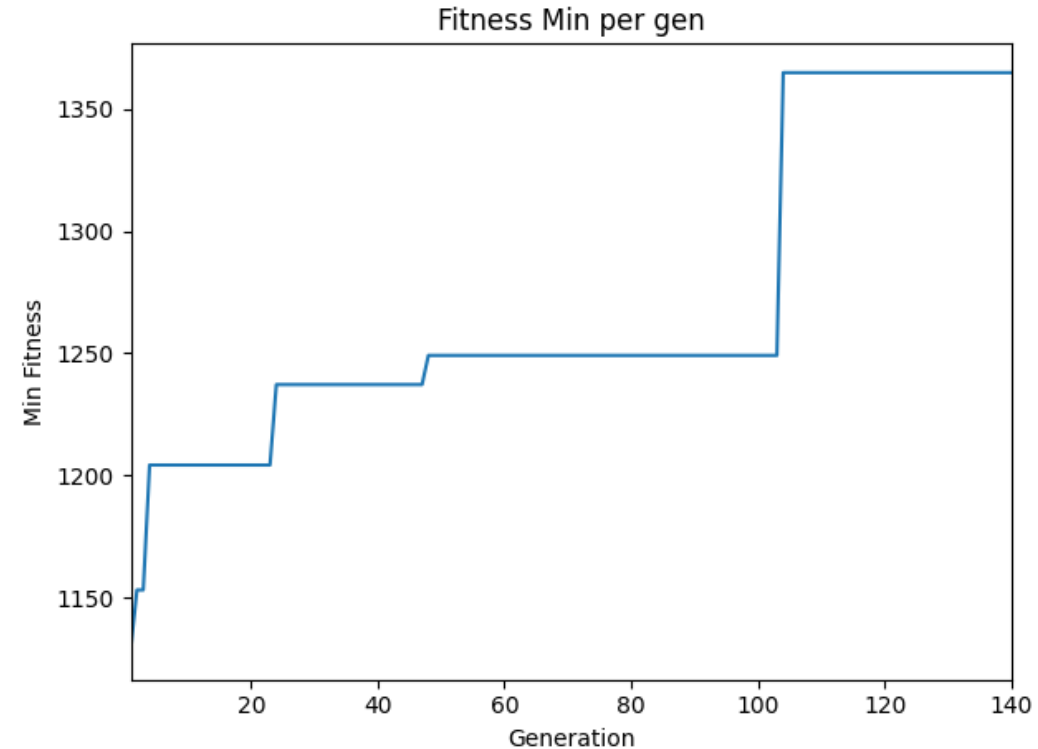
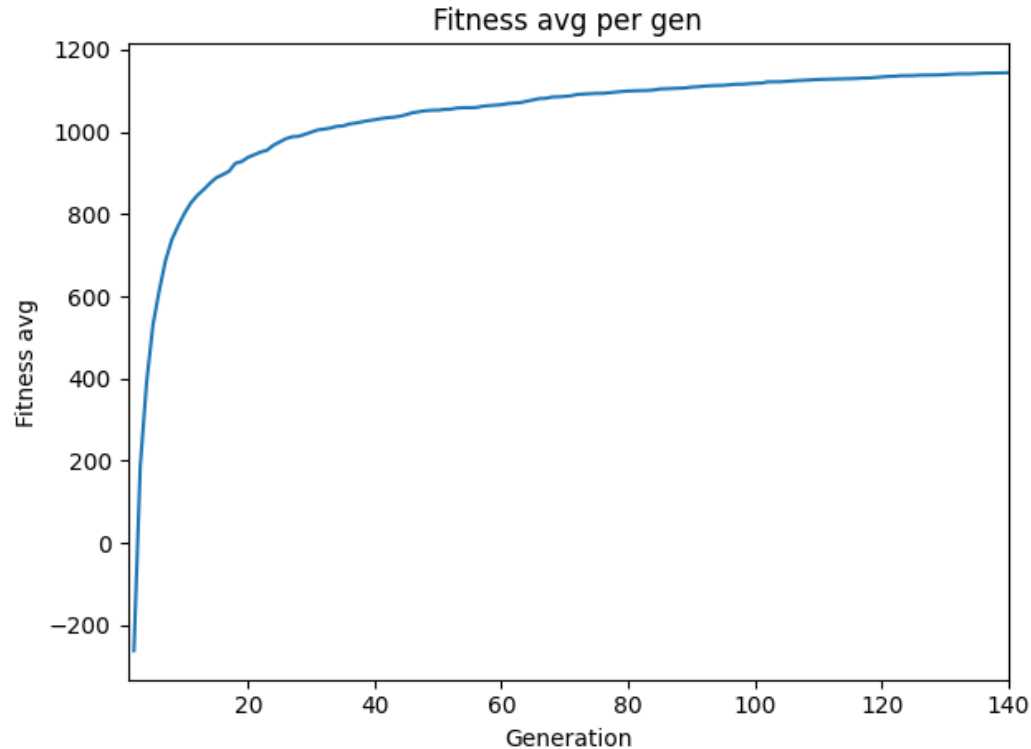


Parameters	Value
CR	0.9
F	0.8
Population Size	240
Number of Generations	140
Individuals Initialization	Individuals from <i>second experiment</i>
Tracks	Forza, Wheel-1
Number of Opponents	8
Starting Position	4
Seed	41



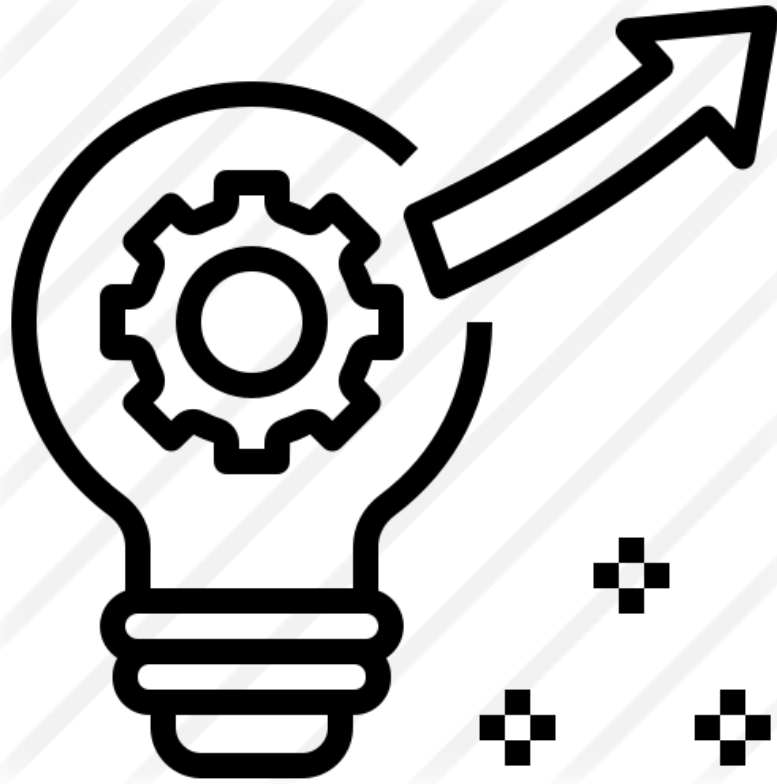


FOURTH EXPERIMENT – RESULTS



- ▶ Continuous evolution
- ▶ Best individual registers a big improvement around 100th generation
- ▶ Controller tends to follow opponents staying at a certain distance
- ▶ Damage mostly due to the unpredictable behavior of the opponents

FIFTH EXPERIMENT – FITNESS FUNCTION



$$f = -((F(P_1) + F(P_2)) * 10 + \left(\frac{D_1}{T_1} + \frac{D_2}{T_2}\right) * 10 - (H_1 + H_2))$$

where:

P: Position [1, 2, ... , 9] in the race with respect to other cars.

T: Time (s) to complete the two laps.

H: [0; +∞) Current damage of the car.

F(): Function of points scoring system.

D: Distance (m) covered by the car from the beginning of the race.



FIFTH EXPERIMENT – SETUP

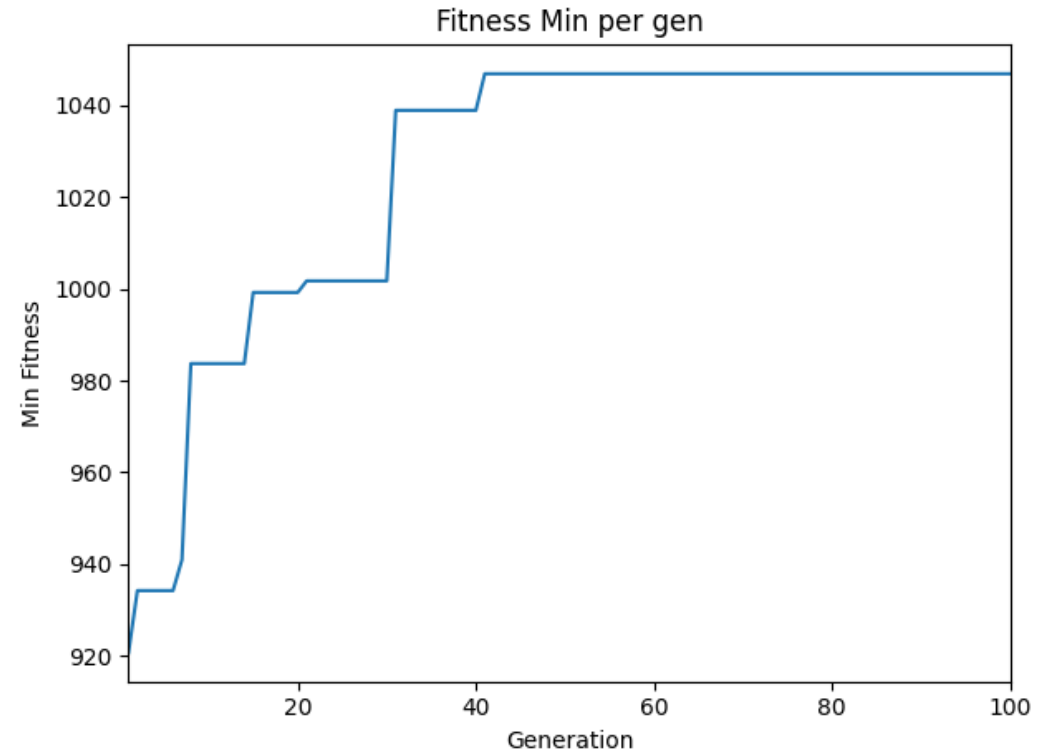
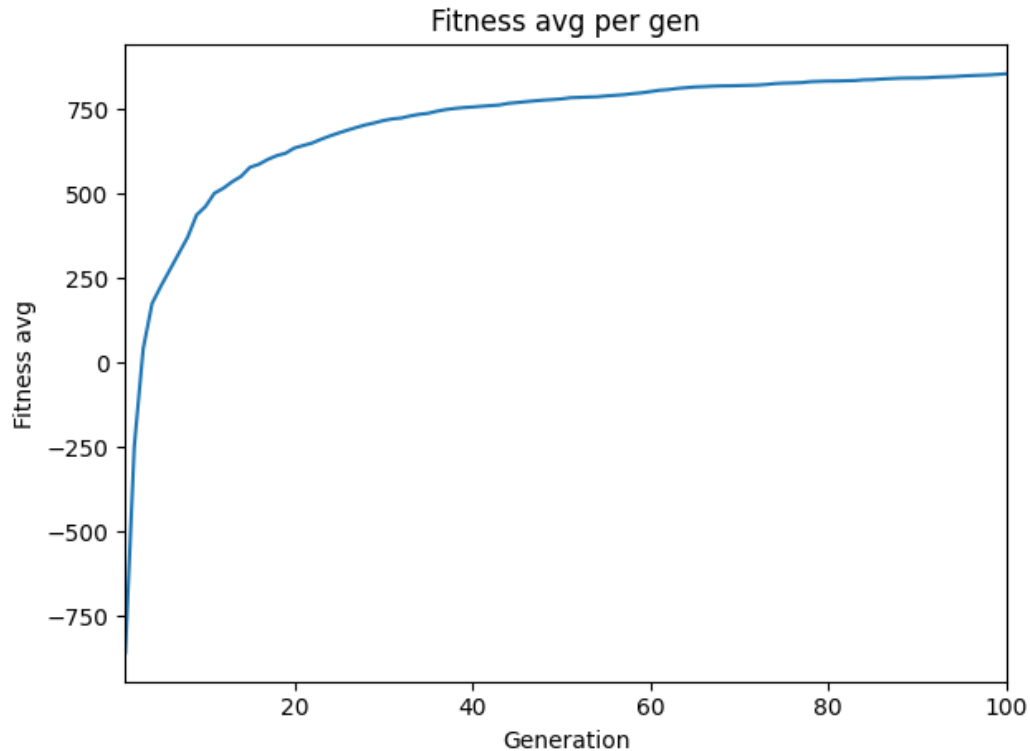


Parameters	Value
CR	0.9
F	0.8
Population Size	240
Number of Generations	100
Individuals Initialization	Individuals from <i>fourth experiment</i>
Tracks	Forza, Wheel-1
Number of Opponents	8
Starting Position	9
Seed	41



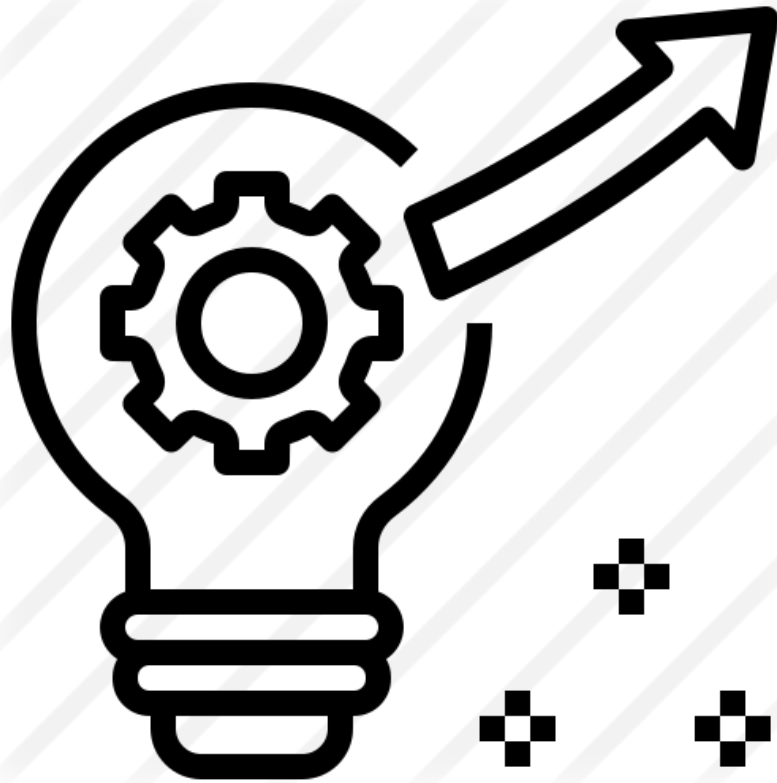


FIFTH EXPERIMENT – RESULTS



- ▶ Best fitness is increased a lot in the first 40 generations, where there has been a continuous improving in the plot of the average fitness; we decided to stop the training and to pass to the next experiment.
- ▶ Improved collisions management, but loss of positions in the race.

SIXTH EXPERIMENT – FITNESS FUNCTION



$$f = -((F(P_1) + F(P_2)) * 10 + (T_1 + T_2) * 10 - (H_1 + H_2))$$

where:

P: Position [1, 2, ..., 9] in the race with respect to other cars.

T: Time (s) to complete the two laps.

H: $[0; +\infty)$ Current damage of the car.

F(): Function of points scoring system.



SIXTH EXPERIMENT – SETUP

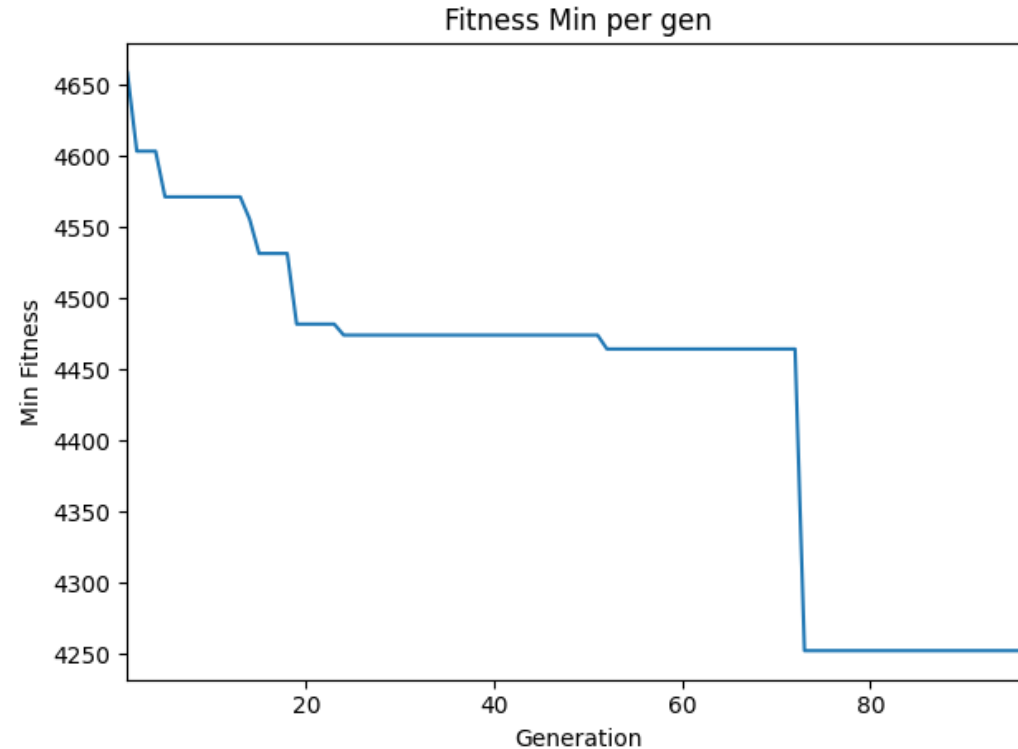
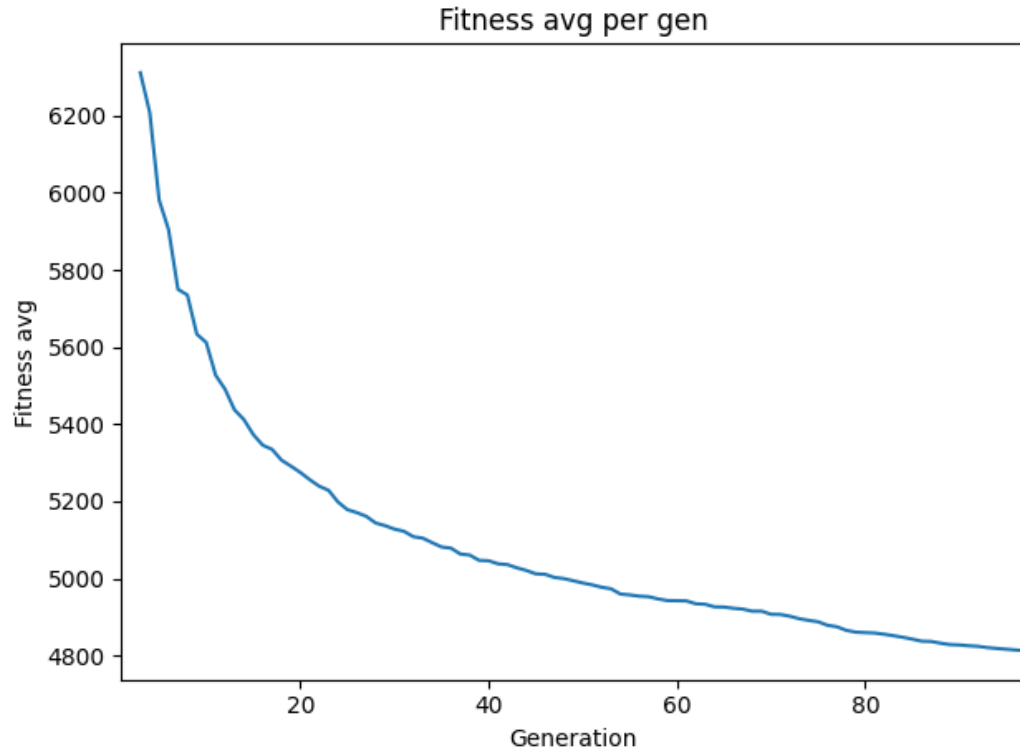


Parameters	Value
CR	0.9
F	0.8
Population Size	240
Number of Generations	154
Individuals Initialization	Individuals from <i>second experiment</i>
Tracks	Forza, Wheel-1
Number of Opponents	8
Starting Position	9
Seed	41





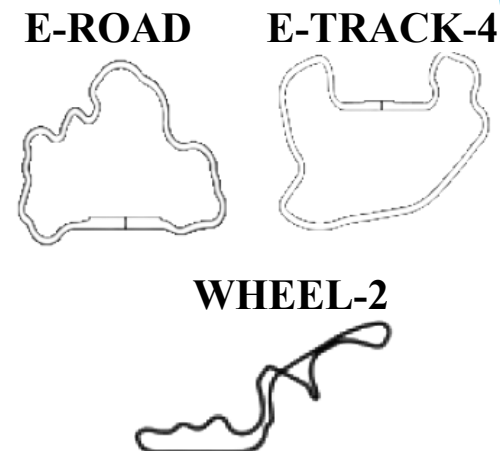
SIXTH EXPERIMENT – RESULTS



- ▶ The average decreased continuously, in fact the best doesn't present the same value for a lot of generations as in previous experiments; moreover, at the end, we registered a big improvement in the best fitness, this because population is still evolving as you can see by the average fitness.
- ▶ The car follows the most of ideal trajectory.

COMPARISON - INTRODUCTION

- ▶ Evolved controllers wrt default controller
- ▶ **Test Specifications:**
 - ❑ 2-laps races
 - ❑ Starting position: 9/9
 - ❑ Common starting grid at each race
 - ❑ 7 circuits: 4 of specifications and 3 never used during the evolution



Name	Length
E-Road	3260.43 m
E-Track-4	7041.68 m
Wheel-2	6205.46 m





COMPARISON – SNAKEOIL vs 5TH EXPERIMENT

The next table shows the percentage of improvement of the total time, best time and damage of the controller obtained with parameters of the fifth experiment wrt the default controller.

Track	Tot. Time	Best Time	Damage
Forza	-5.24 %	-6.15 %	-100 %
Wheel-1	-15.30 %	-7.84 %	-91.0 %
E-Track-3	-18.28 %	-21.42 %	-62.07 %
CG-Track-2	+0.05 %	-0.42 %	0 %
E-Track-4	-0.44 %	-1.75 %	+28.0 %
Wheel-2	+5.72 %	+11.04 %	-39.20 %
E-Road	+1.07 %	+1.44 %	-34.88 %

SnakeOil	5 th Exp.
9 th	8 th
9 th	6 th
9 th	7 th
6 th	6 th
7 th	7 th
7 th	9 th
6 th	7 th





COMPARISON – SNAKEOIL vs 6TH EXPERIMENT

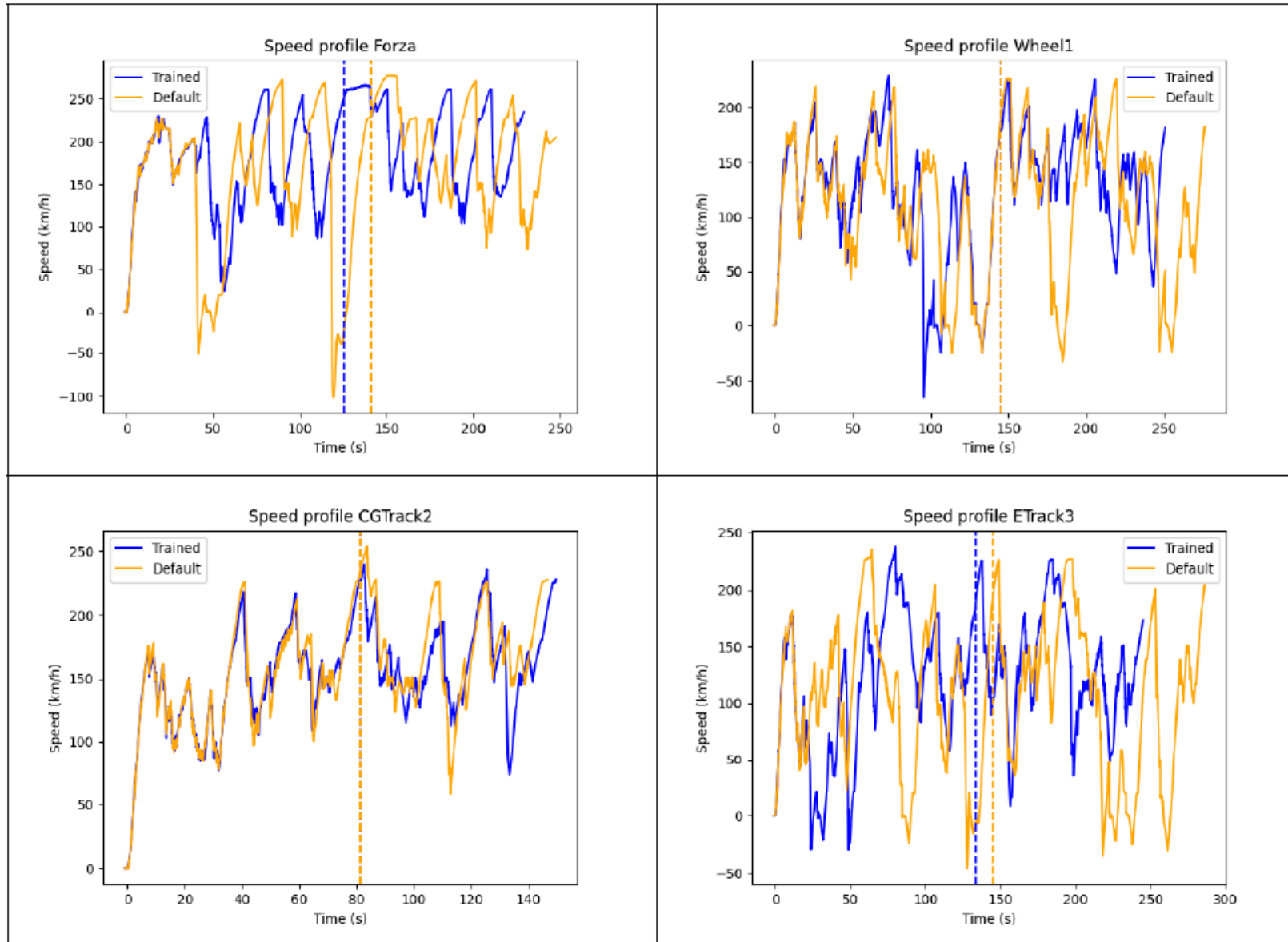
The next table shows the percentage of improvement of the total time, best time and damage of the controller obtained with parameters of the sixth experiment wrt the default controller

Track	Tot. Time	Best Time	Damage
Forza	-8.0 %	-12.27 %	-99.64 %
Wheel-1	-10.19 %	-3.28 %	-83.51 %
E-Track-3	-13.23 %	-9.51 %	+50.31 %
CG-Track-2	+0.78 %	+0.80 %	0 %
E-Track-4	-4.08 %	-9.94 %	-52.07 %
Wheel-2	+3.22 %	+1.02 %	+66.57 %
E-Road	-0.02 %	-1.80 %	+6.97 %

SnakeOil	6 th Exp.
9 th	7 th
9 th	9 th
9 th	9 th
6 th	6 th
7 th	6 th
7 th	8 th
6 th	7 th

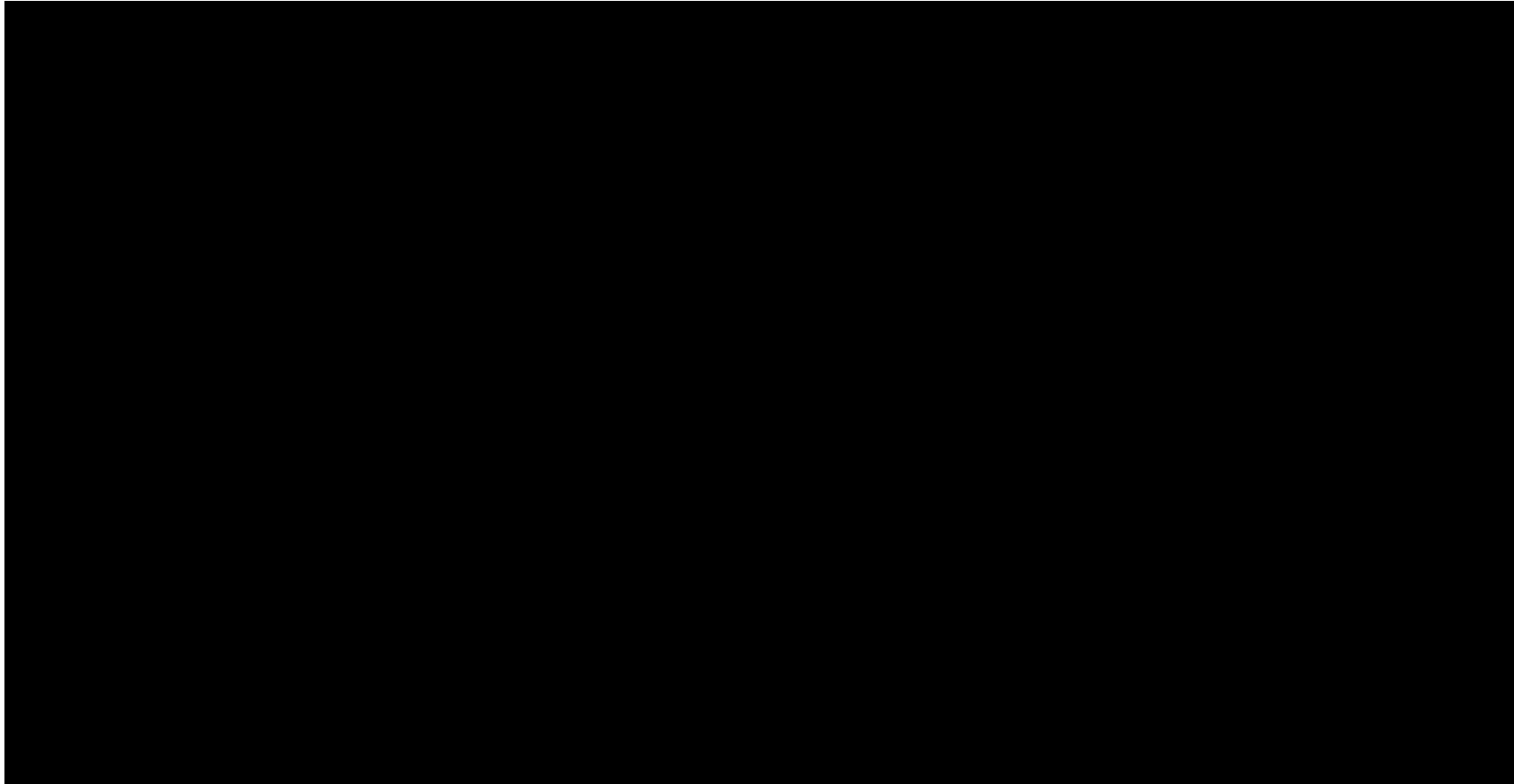


COMPARISON – SNAKEOIL VS 6TH EXPERIMENT – SPEED PROFILES



- ▶ Shorter race time, except on CG-Track-2
- ▶ Reduction of the important crashes, especially on E-Track-3
- ▶ Small reduction of maximum speed

VIDEO DEMO



CONCLUSIONS AND FUTURE ENHANCEMENTS

- ▶ In *conclusion*, we have obtained:
 - ❑ *driving skills* on various circuits, racing alone
 - ❑ *overtaking skills* and **reduction of damage and race time** with opponents
 - ❑ good trade-off between lap time, damage and final position.
- ▶ For *future*, it is possible to:
 - ❑ Solve the controller problems.
 - ❑ Add a more powerful overtaking feature to the baseline.
 - ❑ Try different optimization algorithms.



NATURAL COMPUTATION PROJECT

**THANKS
FOR
THE
ATTENTION**

GROUP 17

