Student ID: 1804900

CE310 – Evolutionary Algorithm Assignment part 2

Problem 1:

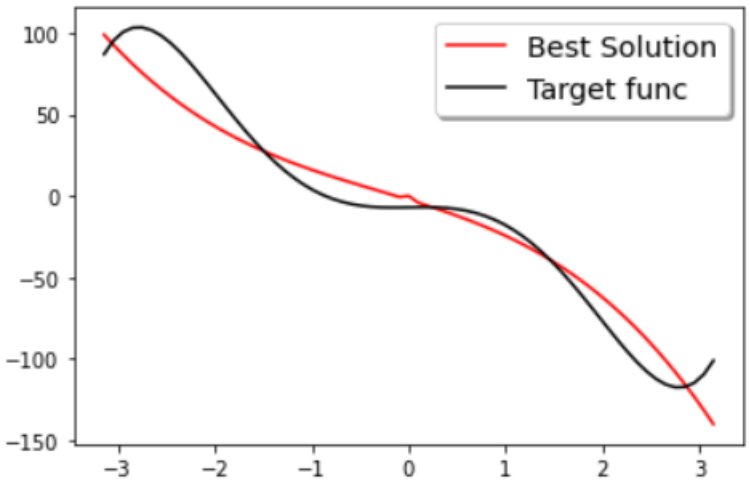
$$p_1(x) = x^5 - 13 \cdot x^3 + x - 7$$

Experiment 1:

Parameters:

Population size = 500, Tournament size = 2

(Usual result)



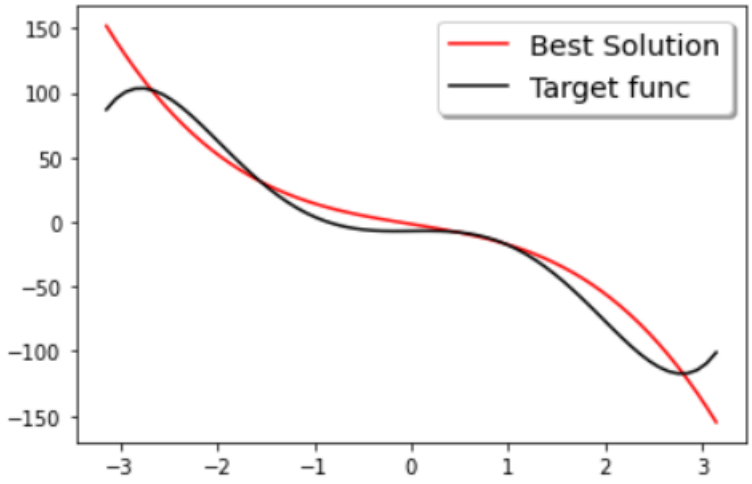
Experiment 2:

Parameters:

Population size = 2000, Tournament size = 2

(Usual result)

Student ID: 1804900

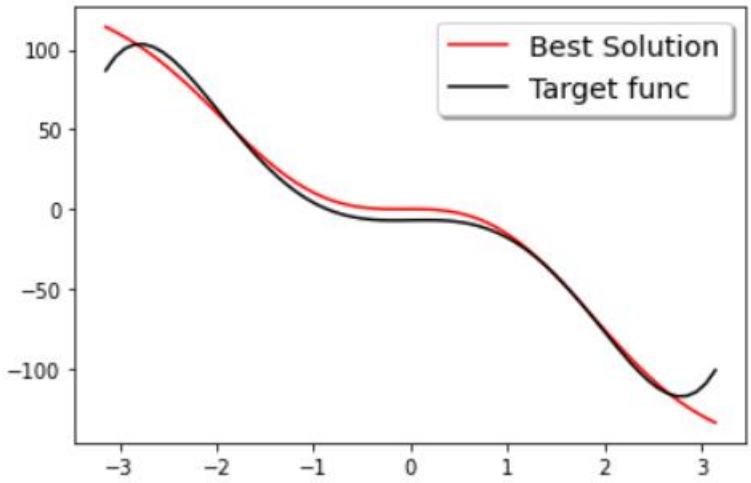


Experiment 3:

Parameters:

Population size = 500, Tournament size = 5

(Usual result)



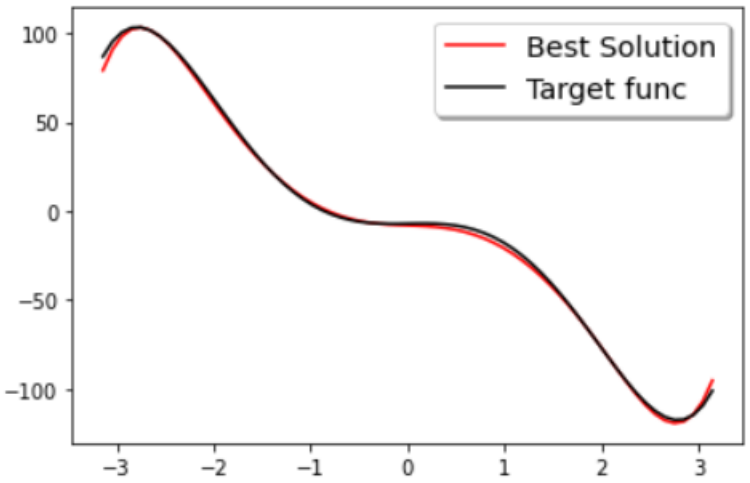
Experiment 4:

Parameters:

Population size = 2000, Tournament size = 5

(Usual result)

Student ID: 1804900



The GA seems to minimise fitness, hence indicating that the fitness function measures the area or distance (squared) between the curves, and a lower fitness value represents the result being closer to the original problem (equation) - difference between each value of x (for GP and actual equation).

The plot showing normalised fitness and size shows a general decrease in fitness and an increase in size, however different Hyper Parameters influence convergence (of fitness) and the growth of the program, such that the generated program will reflect the original problem much more accurately (optimal performance) through the generations.

(All chosen statistics for each run are the same: minimum and maximum from the mean and median fitness and size of the individual, as well as the average size in the first and last generation)

It is expected that the GP with a higher population size will produce a better solution (program) as this parameter has a significant impact on performance in GAs, and much like GAs, it will explore and sample more of the search space (more likely to find an optimal solution).

Run (N)	Experiment 1	Experiment 2	Experiment 3	Experiment 4
1	**Fitness: (min, max)** 3027.960744969552 , 4209.121486537739 **Mean Fitness:** **Gen 0:** 4.10322e+27 **Gen 15:** 4.79136e+27 **Gen 30:** 7.36063e+28 **Median Fitness:** **Gen 0:** 4209.12 **Gen 15:** 3979.02 **Gen 30:** 3027.96 **Evaluations:** 12339	**Fitness: (min, max)** 3067.431286301585 , 4209.121486537739 **Mean Fitness:** **Gen 0:** 3.47436e+28 **Gen 15:** 2.53776e+28 **Gen 30:** 1.91681e+29 **Median Fitness:** **Gen 0:** 4209.12 **Gen 15:** 3967.81 **Gen 30:** 3067.43 **Evaluations:** 49230	**Fitness: (min, max)** 116.31406002277905, 4203.066755640003 **Mean Fitness:** **Gen 0:** 1.58421e+29 **Gen 15:** 3.25717e+31 **Gen 30:** 3.97979e+31 **Median Fitness:** **Gen 0:** 4203.07 **Gen 15:** 333.408 **Gen 30:** 116.314 **Evaluations:** 12477	**Fitness: (min, max)** 115.8619714728973 , 4209.121486537739 **Mean Fitness:** **Gen 0:** 3.35841e+28 **Gen 15:** 5.6502e+31 **Gen 30:** 8.06935e+31 **Median Fitness:** **Gen 0:** 4209.12 **Gen 15:** 886.282 **Gen 30:** 115.862 **Evaluations:** 49491

Student ID: 1804900

2	**Fitness: (min, max)** 2733.653415848689, 4209.121486537739 **Mean Fitness:** **Gen 0:** 4213.98 **Gen 15:** 3900.27 **Gen 30:** 3286.93 **Median Fitness:** **Gen 0:** 4209.12 **Gen 15:** 3949.9 **Gen 30:** 2733.65 **Evaluations:** 12342	**Fitness: (min, max)** 1913.732416961233 4, 4201.988404596935 **Mean Fitness:** **Gen 0:** 1.23097e+28 **Gen 15:** 1.06589e+29 **Gen 30:** 1.11501e+28 **Median Fitness:** **Gen 0:** 4201.99 **Gen 15:** 3942.84 **Gen 30:** 1913.73 **Evaluations:** 49323	**Fitness: (min, max)** 220.3948119287469 2, 4209.121486537739 **Mean Fitness:** **Gen 0:** 1.05614e+29 **Gen 15:** 80581.5 **Gen 30:** 87151.8 **Median Fitness:** **Gen 0:** 4209.12 **Gen 15:** 941.616 **Gen 30:** 225.187 **Evaluations:** 12441	**Fitness: (min, max)** 122.0263021286373 5, 4209.121486537739 **Mean Fitness:** **Gen 0:** 3.33228e+28 **Gen 15:** 1.91232e+32 **Gen 30:** 1.57488e+32 **Median Fitness:** **Gen 0:** 4209.12 **Gen 15:** 807.618 **Gen 30:** 122.026 **Evaluations:** 49295
3	**Fitness: (min, max)** 3250.203134153122 , 4209.121486537739 **Mean Fitness:** **Gen 0:** 3.28258e+28 **Gen 15:** 3946.64 **Gen 30:** 3230.9 **Median Fitness:** **Gen 0:** 4209.12 **Gen 15:** 3960.9 **Gen 30:** 3250.2 **Evaluations:** 12390	**Fitness: (min, max)** 2777.021050776826 , 4208.73146377518 **Mean Fitness:** **Gen 0:** 4.16185e+28 **Gen 15:** 2.7563e+28 **Gen 30:** 6.56727e+29 **Median Fitness:** **Gen 0:** 4208.73 **Gen 15:** 3949.9 **Gen 30:** 2777.02 **Evaluations:** 49331	**Fitness: (min, max)** 184.1438697551839 , 4202.74913496607 **Mean Fitness:** **Gen 0:** 1.64129e+28 **Gen 15:** 4.37797e+29 **Gen 30:** 1848.68 **Median Fitness:** **Gen 0:** 4202.75 **Gen 15:** 1890.62 **Gen 30:** 184.144 **Evaluations:** 12351	**Fitness: (min, max)** 264.4946758304673 , 4201.988404596935 **Mean Fitness:** **Gen 0:** 1.17062e+29 **Gen 15:** 3.79241e+31 **Gen 30:** 9.99228e+28 **Median Fitness:** **Gen 0:** 4201.99 **Gen 15:** 981.616 **Gen 30:** 264.495 **Evaluations:** 49280
4	**Fitness: (min, max)** 3125.209598890105 , 4209.121486537739 **Mean Fitness:** **Gen 0:** 4223.66 **Gen 15:** 9.90772e+29 **Gen 30:** 1.48499e+30 **Median Fitness:**	**Fitness: (min, max)** 49332 **Mean Fitness:** **Gen 0:** 7.31892e+28 **Gen 15:** 4.30553e+28 **Gen 30:** 7.3279e+28 **Median Fitness:** **Gen 0:** 4209.12	**Fitness: (min, max)** 498.7967379176175 , 4201.557635366166 **Mean Fitness:** **Gen 0:** 4205.49 **Gen 15:** 3.46892e+30 **Gen 30:** 31827.9 **Median Fitness:** **Gen 0:** 4201.56	**Fitness: (min, max)** 388.9261335259753 , 4201.557635366166 **Mean Fitness:** **Gen 0:** 2.84168e+28 **Gen 15:** 4.02264e+28 **Gen 30:** 2.59882e+31 **Median Fitness:**

	Gen 0: 4209.12 **Gen 15:** 3973.9 **Gen 30:** 3125.21 **Evaluations:** 12395	**Gen 15:** 3971.75 **Gen 30:** 2853.34 **Evaluations:** 2853.3414754845544, 4209.121486537739	**Gen 15:** 2125.81 **Gen 30:** 518.793 **Evaluations:** 12430	**Gen 0:** 4201.56 **Gen 15:** 1460.76 **Gen 30:** 388.926 **Evaluations:** 49240
5	**Fitness: (min, max)** 2937.8809080751785, 4209.121486537739 **Mean Fitness:** **Gen 0:** 1.16215e+28 **Gen 15:** 3921.56 **Gen 30:** 4214.34 **Median Fitness:** **Gen 0:** 4209.12 **Gen 15:** 3955.3 **Gen 30:** 2937.88 **Evaluations:** 12294	**Fitness: (min, max)** 2989.8270739602244, 4208.73146377518 **Mean Fitness:** **Gen 0:** 1.22117e+29 **Gen 15:** 1.07108e+29 **Gen 30:** 1.23189e+30 **Median Fitness:** **Gen 0:** 4208.73 **Gen 15:** 3973.9 **Gen 30:** 2989.83 **Evaluations:** 49484	**Fitness: (min, max)** 218.2536008394273, 4208.73146377518 **Mean Fitness:** **Gen 0:** 1.64129e+28 **Gen 15:** 1.64129e+28 **Gen 30:** 4629.57 **Median Fitness:** **Gen 0:** 4208.73 **Gen 15:** 295.112 **Gen 30:** 218.254 **Evaluations:** 12407	**Fitness: (min, max)** 215.5741290869868, 4209.121486537739 **Mean Fitness:** **Gen 0:** 3.5075e+28 **Gen 15:** 8.70091e+29 **Gen 30:** 1.03019e+28 **Median Fitness:** **Gen 0:** 4209.12 **Gen 15:** 791.132 **Gen 30:** 215.574 **Evaluations:** 49340
6	**Fitness: (min, max)** 2959.914826220891, 4209.121486537739 **Mean Fitness:** **Gen 0:** 4.1695e+28 **Gen 15:** 6.12967e+28 **Gen 30:** 1.09541e+29 **Median Fitness:** **Gen 0:** 4209.12 **Gen 15:** 3974.31 **Gen 30:** 2959.91 **Evaluations:** 12404	**Fitness: (min, max)** 2989.8270739602244, 4208.73146377518 **Mean Fitness:** **Gen 0:** 2.2606e+28 **Gen 15:** 4.55581e+29 **Gen 30:** 2.79164e+28 **Median Fitness:** **Gen 0:** 4208.73 **Gen 15:** 3962.82 **Gen 30:** 2608.09 **Evaluations:** 49484	**Fitness: (min, max)** 96.10946424798601, 4202.874080105195 **Mean Fitness:** **Gen 0:** 1.64129e+28 **Gen 15:** 6.56515e+28 **Gen 30:** 1626.41 **Median Fitness:** **Gen 0:** 4202.87 **Gen 15:** 722.488 **Gen 30:** 97.8533 **Evaluations:** 12447	**Fitness: (min, max)** 201.3213063144171, 4208.73146377518 **Mean Fitness:** **Gen 0:** 2.58045e+28 **Gen 15:** 2.51549e+30 **Gen 30:** 7.95467e+30 **Median Fitness:** **Gen 0:** 4208.73 **Gen 15:** 808.281 **Gen 30:** 201.321 **Evaluations:** 49331
7	**Fitness: (min, max)** 2623.2971469283375, 4209.121486537739 **Mean Fitness:**	**Fitness: (min, max)** 2548.8146597057703, 4209.121486537739 **Mean Fitness:**	**Fitness: (min, max)** 98.95583670322767, 4201.557635366166 **Mean Fitness:**	**Fitness: (min, max)** 144.93090989056884, 4208.623395724519 **Mean Fitness:**

	Gen 0: 4.10322e+27 **Gen 15:** 6.10133e+28 **Gen 30:** 2.12206e+29 **Median Fitness:** **Gen 0:** 4209.12 **Gen 15:** 3973.9 **Gen 30:** 2623.3 **Evaluations:** 12447	**Gen 0:** 4.72573e+28 **Gen 15:** 1.96759e+28 **Gen 30:** 1.2812e+29 **Median Fitness:** **Gen 0:** 4209.12 **Gen 15:** 3905.59 **Gen 30:** 2548.81 **Evaluations:** 49264	**Gen 0:** 3.28258e+28 **Gen 15:** 3.12042e+30 **Gen 30:** 11495.5 **Median Fitness:** **Gen 0:** 4201.56 **Gen 15:** 1809.34 **Gen 30:** 98.9558 **Evaluations:** 12479	**Gen 0:** 6.83723e+28 **Gen 15:** 1.86709e+30 **Gen 30:** 6.69029e+29 **Median Fitness:** **Gen 0:** 4208.62 **Gen 15:** 1210.39 **Gen 30:** 144.931 **Evaluations:** 49426
8	**Fitness: (min, max)** 3368.848398043906 4, 4209.121486537739 **Mean Fitness:** **Gen 0:** 7.0086e+27 **Gen 15:** 4.10322e+27 **Gen 30:** 356959 **Median Fitness:** **Gen 0:** 4209.12 **Gen 15:** 3973.9 **Gen 30:** 3368.85 **Evaluations:** 12363	**Fitness: (min, max)** 2041.035863486703 2, 4208.623395724519 **Mean Fitness:** **Gen 0:** 2.73018e+28 **Gen 15:** 7.90765e+28 **Gen 30:** 4.3841e+29 **Median Fitness:** **Gen 0:** 4208.62 **Gen 15:** 3960.9 **Gen 30:** 2041.04 **Evaluations:** 49519	**Fitness: (min, max)** 266.91401471226436, 4201.557635366166 **Mean Fitness:** **Gen 0:** 5.81079e+28 **Gen 15:** 3096.91 **Gen 30:** 8.80471e+30 **Median Fitness:** **Gen 0:** 4201.56 **Gen 15:** 837.58 **Gen 30:** 291.884 **Evaluations:** 12339	**Fitness: (min, max)** 115.50067983047236, 4209.121486537739 **Mean Fitness:** **Gen 0:** 3.57631e+28 **Gen 15:** 8.28092e+29 **Gen 30:** 7.12734e+28 **Median Fitness:** **Gen 0:** 4209.12 **Gen 15:** 788.858 **Gen 30:** 115.501 **Evaluations:** 49414
9	**Fitness: (min, max)** 1344.591559830749 2, 4201.557635366166 **Mean Fitness:** **Gen 0:** 1.0151e+29 **Gen 15:** 1.37512e+28 **Gen 30:** 4.10322e+27 **Median Fitness:** **Gen 0:** 4201.56 **Gen 15:** 3884.38 **Gen 30:** 1344.59 **Evaluations:**	**Fitness: (min, max)** 2543.223590181326 5, 4209.121486537739 **Mean Fitness:** **Gen 0:** 4.58554e+28 **Gen 15:** 5.39873e+28 **Gen 30:** 5.89392e+29 **Median Fitness:** **Gen 0:** 4209.12 **Gen 15:** 3960.9 **Gen 30:** 2543.22	**Fitness: (min, max)** 158.0736534606831, 4209.121486537739 **Mean Fitness:** **Gen 0:** 4212.66 **Gen 15:** 1.0323e+30 **Gen 30:** 1.61989e+29 **Median Fitness:** **Gen 0:** 4209.12 **Gen 15:** 420.252 **Gen 30:** 158.074 **Evaluations:**	**Fitness: (min, max)** 141.44529426877267, 4209.121486537739 **Mean Fitness:** **Gen 0:** 5.07552e+28 **Gen 15:** 9.34734e+30 **Gen 30:** 1.52943e+29 **Median Fitness:** **Gen 0:** 4209.12 **Gen 15:** 648.188 **Gen 30:** 141.445

Student ID: 1804900

	12261	**Evaluations:** 49623	12324	**Evaluations:** 49344
10	**Fitness: (min, max)** 2954.480081247207 6, 4209.121486537739 **Mean Fitness:** **Gen 0:** 2.90538e+27 **Gen 15:** 4.10322e+27 **Gen 30:** 3539.58 **Median Fitness:** **Gen 0:** 4209.12 **Gen 15:** 3960.9 **Gen 30:** 2954.48 **Evaluations:** 12246	**Fitness: (min, max)** 1972.912877948857 2, 4208.73146377518 **Mean Fitness:** **Gen 0:** 3.04684e+28 **Gen 15:** 8.04689e+28 **Gen 30:** 1.25604e+29 **Median Fitness:** **Gen 0:** 4208.73 **Gen 15:** 3755.66 **Gen 30:** 1972.91 **Evaluations:** 49307	**Fitness: (min, max)** 197.7015595379879 2, 4209.121486537739 **Mean Fitness:** **Gen 0:** 1.64129e+28 **Gen 15:** 43472.1 **Gen 30:** 10265.2 **Median Fitness:** **Gen 0:** 4209.12 **Gen 15:** 1126.96 **Gen 30:** 197.702 **Evaluations:** 12413	**Fitness: (min, max)** 211.1363418786587 8, 4209.121486537739 **Mean Fitness:** **Gen 0:** 2.55114e+28 **Gen 15:** 1.82485e+30 **Gen 30:** 1.23055e+29 **Median Fitness:** **Gen 0:** 4209.12 **Gen 15:** 792.227 **Gen 30:** 211.136 **Evaluations:** 49310

Problem 2:

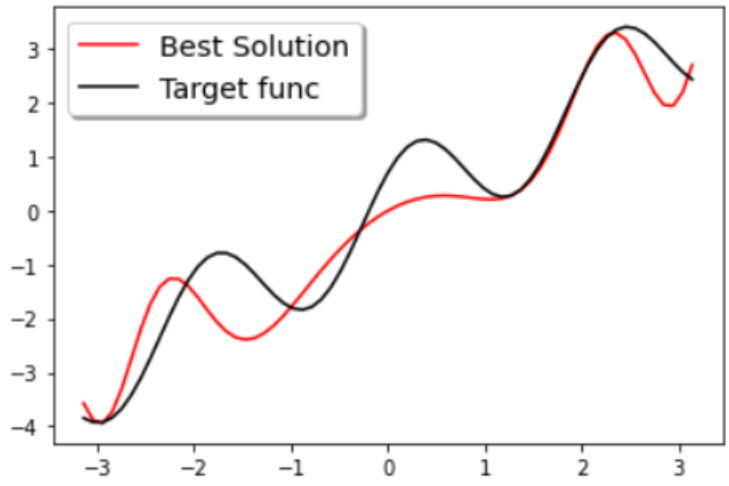
$$p_2(x) = \sin\left(\frac{\pi}{4} + 3 \cdot x\right) + x$$

Experiment 1:

Parameters:

Population size = 500, Tournament size = 2

(Usual result)



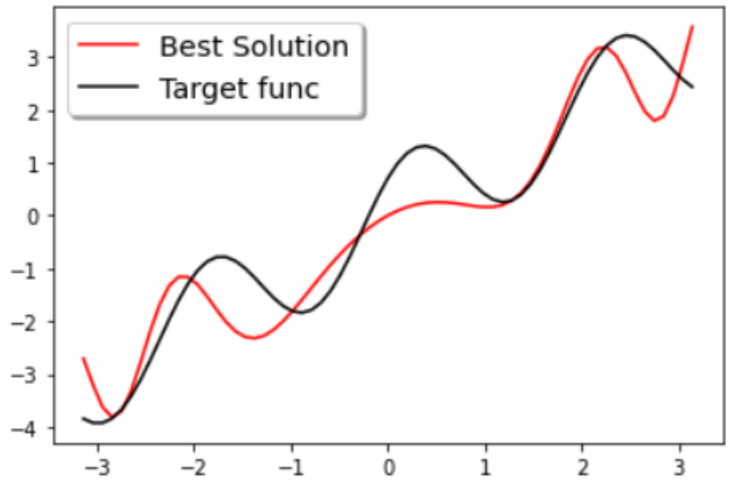
Experiment 2:

Student ID: 1804900

Parameters:

Population size = 2000, Tournament size = 2

(Usual result)

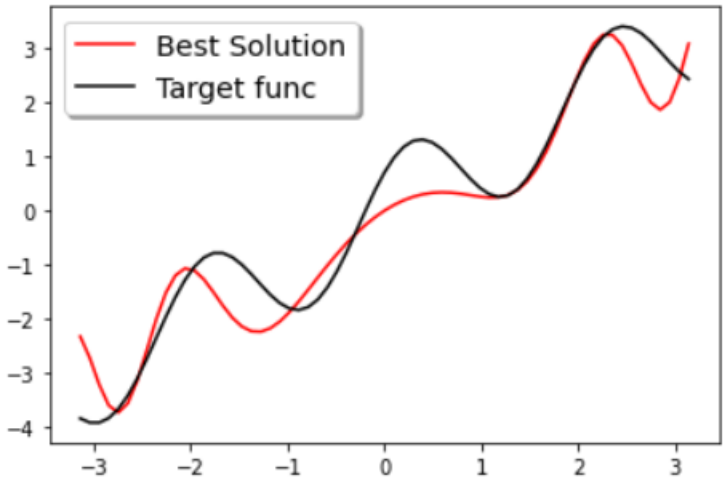


Experiment 3:

Parameters:

Population size = 500, Tournament size = 5

(Usual result)



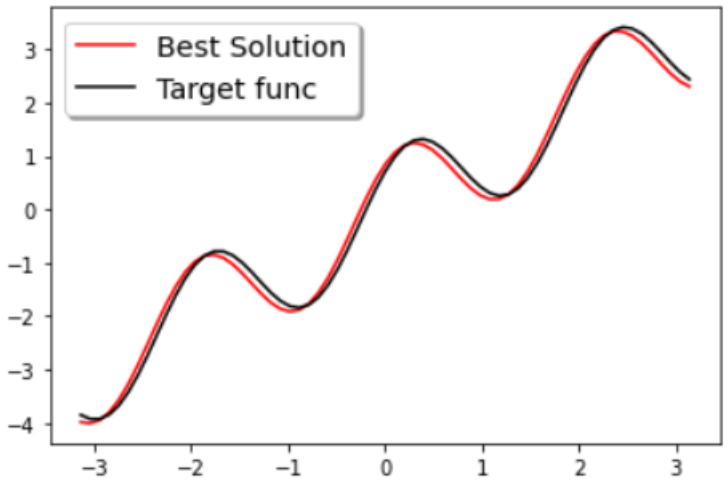
Experiment 4:

Parameters:

Population size = 2000, Tournament size = 5

(Usual result)

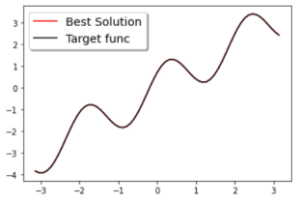
Student ID: 1804900



Run (N)	Experiment 1	Experiment 2	Experiment 3	Experiment 4
1	**Fitness: (min, max)** 0.5000000000000001, 5.043233995630595 **Mean Fitness:** **Gen 0:** 1.64129e+28 **Gen 15:** 4.10322e+27 **Gen 30:** 1.06149e+29 **Median Fitness:** **Gen 0:** 5.21666 **Gen 15:** 0.5 **Gen 30:** 0.5 **Evaluations:** 12457	**Fitness: (min, max)** 0.5000000000000001, 5.07984998575548 **Mean Fitness:** **Gen 0:** 1.20993e+29 **Gen 15:** 5.12903e+27 **Gen 30:** 4.97454e+27 **Median Fitness:** **Gen 0:** 5.07985 **Gen 15:** 0.5 **Gen 30:** 0.5 **Evaluations:** 49420	**Fitness: (min, max)** 0.5000000000000001, 5.07984998575548 **Mean Fitness:** **Gen 0:** 5.12523e+28 **Gen 15:** 4.87036e+28 **Gen 30:** 7.44961 **Median Fitness:** **Gen 0:** 5.07985 **Gen 15:** 0.5 **Gen 30:** 0.860604 **Evaluations:** 12371	**Fitness: (min, max)** 0.5000000000000001, 5.07984998575548 **Mean Fitness:** **Gen 0:** 3.51642e+28 **Gen 15:** 2.47708 **Gen 30:** 1.11799e+29 **Median Fitness:** **Gen 0:** 5.07985 **Gen 15:** 0.816615 **Gen 30:** 0.670642 **Evaluations:** 49566
2	**Fitness: (min, max)** 0.4786323685114684, 5.07984998575548 **Mean Fitness:** **Gen 0:** 5.21187e+28 **Gen 15:** 4.04972e+28 **Gen 30:** 5.69101e+28 **Median Fitness:**	**Fitness: (min, max)** 0.5000000000000001, 5.07984998575548 **Mean Fitness:** **Gen 0:** 4.70533e+28 **Gen 15:** 7.0086e+27 **Gen 30:** 7.90765e+28 **Median Fitness:**	**Fitness: (min, max)** 0.4440850567715003434, 5.043233995630595 **Mean Fitness:** **Gen 0:** 4.79136e+27 **Gen 15:** 26.262 **Gen 30:** 0.890222 **Median Fitness:** **Gen 0:** 5.04323	**Fitness: (min, max)** 0.4936274836557986767, 5.07984998575548 **Mean Fitness:** **Gen 0:** 1.69609e+28 **Gen 15:** 1.37507e+30 **Gen 30:** 8.05807e+60 **Median Fitness:**

	Gen 0: 5.07985 **Gen 15:** 0.5 **Gen 30:** 0.5 **Evaluations:** 12358	**Gen 0:** 5.07985 **Gen 15:** 0.5 **Gen 30:** 0.5 **Evaluations:** 49292	**Gen 15:** 0.992308 **Gen 30:** 0.444085 **Evaluations:** 12369	**Gen 0:** 5.07985 **Gen 15:** 0.493627 **Gen 30:** 0.493627 **Evaluations:** 49352
3	**Fitness: (min, max)** 0.5000000000000001, 5.07984998575548 **Mean Fitness:** **Gen 0:** 4.04972e+28 **Gen 15:** 1.39872e+27 **Gen 30:** 5.62219e+28 **Median Fitness:** **Gen 0:** 5.07985 **Gen 15:** 0.484901 **Gen 30:** 0.492585 **Evaluations:** 12340	**Fitness: (min, max)** 0.5000000000000001, 5.07984998575548 **Mean Fitness:** **Gen 0:** 3.33675e+28 **Gen 15:** 2.55353 **Gen 30:** 5.18193e+28 **Median Fitness:** **Gen 0:** 5.07985 **Gen 15:** 0.5 **Gen 30:** 0.5 **Evaluations:** 49464	**Fitness: (min, max)** 0.456372728063965, 5.07984998575548 **Mean Fitness:** **Gen 0:** 4.28928e+28 **Gen 15:** 2.29125 **Gen 30:** 0.922137 **Median Fitness:** **Gen 0:** 5.07985 **Gen 15:** 0.946356 **Gen 30:** 0.456373 **Evaluations:** 12295	**Fitness: (min, max)** 0.4074105769599533, 5.07984998575548 **Mean Fitness:** **Gen 0:** 3.47819e+28 **Gen 15:** 1.51753e+29 **Gen 30:** 2.35626e+30 **Median Fitness:** **Gen 0:** 5.07985 **Gen 15:** 1.42877 **Gen 30:** 0.407411 **Evaluations:** 49496
4	**Fitness: (min, max)** 0.5000000000000001, 5.07984998575548 **Mean Fitness:** **Gen 0:** 4.46004e+28 **Gen 15:** 4.1695e+28 **Gen 30:** 1.9865 **Median Fitness:** **Gen 0:** 5.07985 **Gen 15:** 0.5 **Gen 30:** 0.5 **Evaluations:** 12312	**Fitness: (min, max)** 0.5000000000000001, 5.07984998575548 **Mean Fitness:** **Gen 0:** 6.73019e+28 **Gen 15:** 6.27974e+28 **Gen 30:** 1.94983e+28 **Median Fitness:** **Gen 0:** 5.07985 **Gen 15:** 0.5 **Gen 30:** 0.5 **Evaluations:** 49465	**Fitness: (min, max)** 0.5000000000000001, 5.07984998575548 **Mean Fitness:** **Gen 0:** 3.28258e+28 **Gen 15:** 1.93379 **Gen 30:** 1.35782 **Median Fitness:** **Gen 0:** 5.07985 **Gen 15:** 0.5 **Gen 30:** 0.609894 **Evaluations:** 12381	**Fitness: (min, max)** 0.2039092060648398, 5.07984998575548 **Mean Fitness:** **Gen 0:** 3.44378e+28 **Gen 15:** 3.53462e+29 **Gen 30:** 0.720065 **Median Fitness:** **Gen 0:** 5.07985 **Gen 15:** 0.566918 **Gen 30:** 0.203909 **Evaluations:** 49418

Student ID: 1804900

				 **Perfect Solution!**
5	**Fitness: (min, max)** 0.5000000000000001, 5.309954308961832 **Mean Fitness:** **Gen 0:** 3.28258e+28 **Gen 15:** 9.57061e+28 **Gen 30:** 4.62048e+29 **Median Fitness:** **Gen 0:** 5.30995 **Gen 15:** 0.5 **Gen 30:** 0.5 **Evaluations:** 12336	**Fitness: (min, max)** 0.5000000000000001, 5.07984998575548 **Mean Fitness:** **Gen 0:** 2.55114e+28 **Gen 15:** 2.05161e+27 **Gen 30:** 1.01604e+28 **Median Fitness:** **Gen 0:** 5.07985 **Gen 15:** 0.5 **Gen 30:** 0.5 **Evaluations:** 49243	**Fitness: (min, max)** 0.4923305167239735 4, 5.043233995630595 **Mean Fitness:** **Gen 0:** 6.30882 **Gen 15:** 1.07836e+28 **Gen 30:** 6.23028 **Median Fitness:** **Gen 0:** 5.04323 **Gen 15:** 0.5 **Gen 30:** 0.493627 **Evaluations:** 12362	**Fitness: (min, max)** 0.2554460467257755 87, 5.07984998575548 **Mean Fitness:** **Gen 0:** 2.55114e+28 **Gen 15:** 6.42789 **Gen 30:** 1.01243e+28 **Median Fitness:** **Gen 0:** 5.07985 **Gen 15:** 0.5 **Gen 30:** 0.255446 **Evaluations:** 49463
6	**Fitness: (min, max)** 0.5000000000000001, 5.07984998575548 **Mean Fitness:** **Gen 0:** 1.93183e+28 **Gen 15:** 1.64129e+28 **Gen 30:** 1.18446e+28 **Median Fitness:** **Gen 0:** 5.07985 **Gen 15:** 0.5 **Gen 30:** 0.5 **Evaluations:** 12387	**Fitness: (min, max)** 0.5000000000000001, 5.07984998575548 **Mean Fitness:** **Gen 0:** 4.48999e+28 **Gen 15:** 1.83307e+28 **Gen 30:** 3.35405e+28 **Median Fitness:** **Gen 0:** 5.07985 **Gen 15:** 0.5 **Gen 30:** 0.5 **Evaluations:** 49328	**Fitness: (min, max)** 0.3016779798878486, 5.07984998575548 **Mean Fitness:** **Gen 0:** 7.74262e+28 **Gen 15:** 2.96992 **Gen 30:** 0.591947 **Median Fitness:** **Gen 0:** 5.07985 **Gen 15:** 0.655457 **Gen 30:** 0.301678 **Evaluations:** 12346	**Fitness: (min, max)** 0.4511709237517238, 5.07984998575548 **Mean Fitness:** **Gen 0:** 5.99492e+28 **Gen 15:** 1.41057e+60 **Gen 30:** 2.52673e+91 **Median Fitness:** **Gen 0:** 5.07985 **Gen 15:** 0.5 **Gen 30:** 0.451171 **Evaluations:** 49412
7	**Fitness: (min, max)** 0.5000000000000001, 5.07984998575548	**Fitness: (min, max)** 0.5000000000000001, 5.07984998575548	**Fitness: (min, max)** 0.5000000000000001, 5.288197177233015	**Fitness: (min, max)** 0.4041625837777484 4, 5.07984998575548

Student ID: 1804900

	Mean Fitness: **Gen 0:** 7.09492 **Gen 15:** 2.36559 **Gen 30:** 1.28327e+28 **Median Fitness:** **Gen 0:** 0.5 **Gen 15:** 0.5 **Gen 30:** 0.5 **Evaluations:** 12362	**Mean Fitness:** **Gen 0:** 3.26302e+28 **Gen 15:** 2.09749e+28 **Gen 30:** 4.74529e+28 **Median Fitness:** **Gen 0:** 5.07985 **Gen 15:** 0.5 **Gen 30:** 0.5 **Evaluations:** 49456	**Mean Fitness:** **Gen 0:** 6.38604 **Gen 15:** 4.04972e+28 **Gen 30:** 8.04212e+29 **Median Fitness:** **Gen 0:** 5.07985 **Gen 15:** 0.5 **Gen 30:** 5.2882 **Evaluations:** 12442	**Mean Fitness:** **Gen 0:** 2.56834e+28 **Gen 15:** 5.72289e+28 **Gen 30:** 9.58817e+27 **Median Fitness:** **Gen 0:** 5.07985 **Gen 15:** 0.5 **Gen 30:** 0.404163 **Evaluations:** 49391
8	**Fitness: (min, max)** 0.493627483655798 67, 5.07984998575548 **Mean Fitness:** **Gen 0:** 1.16215e+28 **Gen 15:** 2.21578 **Gen 30:** 4.04972e+28 **Median Fitness:** **Gen 0:** 5.07985 **Gen 15:** 0.5 **Gen 30:** 0.5 **Evaluations:** 12286	**Fitness: (min, max)** 0.493627483655798 67, 5.07984998575548 **Mean Fitness:** **Gen 0:** 4.04972e+28 **Gen 15:** 1.74387e+28 **Gen 30:** 4.63226e+28 **Median Fitness:** **Gen 0:** 5.07985 **Gen 15:** 0.5 **Gen 30:** 0.493627 **Evaluations:** 49249	**Fitness: (min, max)** 0.496292721070883 2, 5.07984998575548 **Mean Fitness:** **Gen 0:** 6.10133e+28 **Gen 15:** 7.4084e+27 **Gen 30:** 1.24624 **Median Fitness:** **Gen 0:** 5.07985 **Gen 15:** 0.992308 **Gen 30:** 0.496293 **Evaluations:** 12286	**Fitness: (min, max)** 0.455364100843707 1, 5.043233995630595 **Mean Fitness:** **Gen 0:** 1.55293e+28 **Gen 15:** 11.2825 **Gen 30:** 1.18222e+28 **Median Fitness:** **Gen 0:** 5.04323 **Gen 15:** 1.52034 **Gen 30:** 0.455364 **Evaluations:** 49401
9	**Fitness: (min, max)** 0.500000000000000 1, 5.107523988709597 **Mean Fitness:** **Gen 0:** 6.10133e+28 **Gen 15:** 5.37531 **Gen 30:** 2.57192 **Median Fitness:** **Gen 0:** 5.10752 **Gen 15:** 0.5 **Gen 30:** 0.5 **Evaluations:**	**Fitness: (min, max)** 0.500000000000000 1, 5.051989430488548 **Mean Fitness:** **Gen 0:** 2.20899e+28 **Gen 15:** 1.42275e+28 **Gen 30:** 2.01597e+28 **Median Fitness:** **Gen 0:** 5.05199 **Gen 15:** 0.5 **Gen 30:** 0.5	**Fitness: (min, max)** 0.487254967311597 23, 5.07984998575548 **Mean Fitness:** **Gen 0:** 4.57982e+28 **Gen 15:** 4.04972e+29 **Gen 30:** 1.89793e+29 **Median Fitness:** **Gen 0:** 5.07985 **Gen 15:** 0.510574 **Gen 30:** 0.426697	**Fitness: (min, max)** 0.441005153340447 43, 5.07984998575548 **Mean Fitness:** **Gen 0:** 4.38804e+28 **Gen 15:** 1.41054e+29 **Gen 30:** 3.13815 **Median Fitness:** **Gen 0:** 5.07985 **Gen 15:** 1.52176 **Gen 30:** 0.441005

	12447	**Evaluations:** 49323	**Evaluations:** 12376	**Evaluations:** 49318
10	**Fitness: (min, max)** 0.49362748365579867, 5.07984998575548 **Mean Fitness:** **Gen 0:** 1.64129e+28 **Gen 15:** 4.46004e+28 **Gen 30:** 8.32755e+28 **Median Fitness:** **Gen 0:** 5.07985 **Gen 15:** 0.5 **Gen 30:** 0.493627 **Evaluations:** 12311	**Fitness: (min, max)** 0.5000000000000001, 5.07984998575548 **Mean Fitness:** **Gen 0:** 2.7563e+28 **Gen 15:** 2.27717e+28 **Gen 30:** 5.64439e+28 **Median Fitness:** **Gen 0:** 5.07985 **Gen 15:** 0.5 **Gen 30:** 0.5 **Evaluations:** 49407	**Fitness: (min, max)** 0.49362748365579867, 5.07984998575548 **Mean Fitness:** **Gen 0:** 6.49314 **Gen 15:** 1.64129e+28 **Gen 30:** 4.85662 **Median Fitness:** **Gen 0:** 5.07985 **Gen 15:** 0.493627 **Gen 30:** 1.27929 **Evaluations:** 12311	**Fitness: (min, max)** 0.4211721498665185, 5.07984998575548 **Mean Fitness:** **Gen 0:** 2.02549e+28 **Gen 15:** 1.02581e+27 **Gen 30:** 1.47361 **Median Fitness:** **Gen 0:** 5.07985 **Gen 15:** 0.794008 **Gen 30:** 0.421172 **Evaluations:** 49421

The general correlation between all experiments shows that the most effective hyper parameter for the fitness of a program is **population size**. This is due to the search space being explored more deeply with a higher population, therefore an optimal solution is more likely to be explored, as opposed to a smaller population, which would likely result in a less optimal solution (less than ideal fitness).

In terms of **tournament** size, it is also a very prominent parameter that goes hand in hand with the population size. With a higher population, and a bigger tournament size of 5, there is more of a chance of picking fitter individuals as they are compared to a higher number of other individuals within the tournament. 2 individuals could both have a low fitness, in which case the individual with only a slightly better fitness is chosen - the average fitness increases slightly. A size of 5 individuals increases the probability of an individual with a significantly higher fitness being chosen – the optimal tournament size depends on the population size, but the average fitness will be much better.

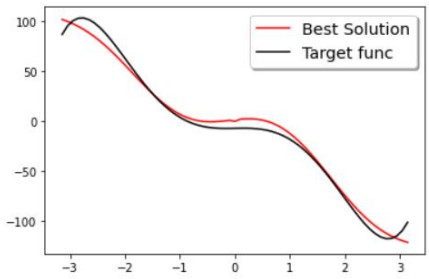
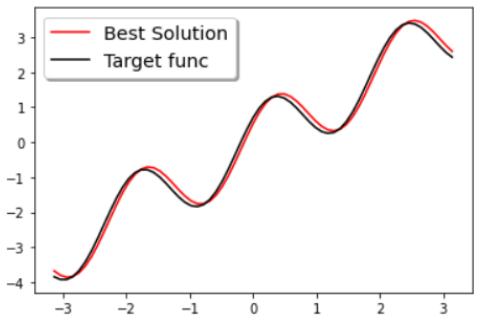
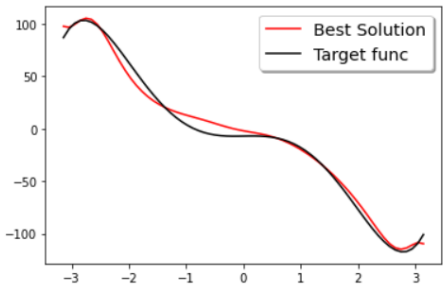
In this case, the larger population size proves to be more effective than a lower one, as there is more likely to be individuals with a higher fitness (a higher probability) selected to be in the tournament.

As every program in the population is randomly generated, there were inevitable variations based around the typical result shown for each experiment, and in some tests the variations between the fittest programs were ample – the fittest individuals for each run would vary but usually have a similarly shaped function, however there would be the exception where the shape of the solution is very different to the perfect solution – this was especially seen in experiments 1, 2 and 3. Experiment 4, which used the best combination of parameters for generating the (most accurate) fittest individual, had more variations based on the function produced (visual representation), but not enough to say they were ample – only on a rare occasion would the GP produce a clearly unfit program. This is likely because more randomly generated programs are produced (higher

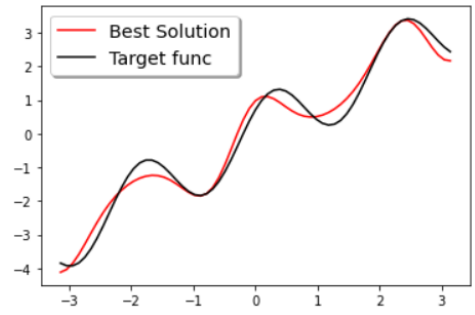
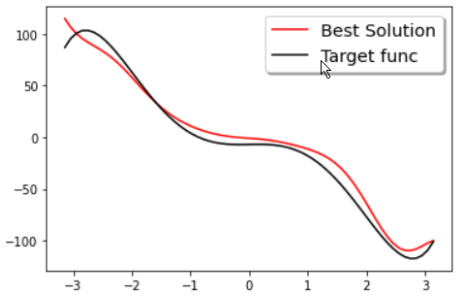
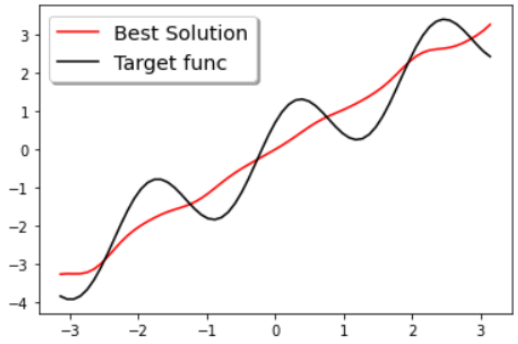
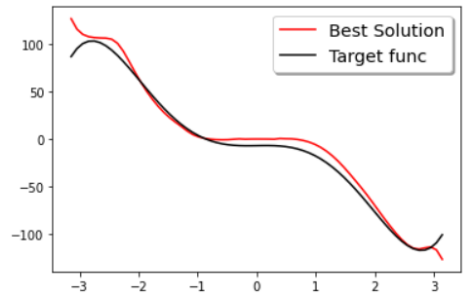
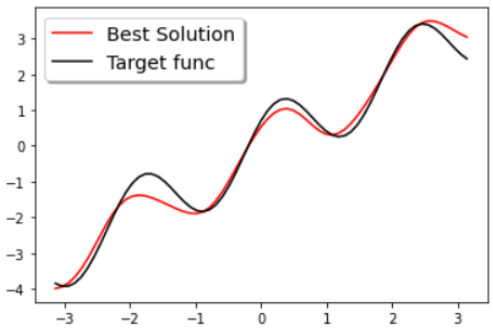
population) – as each new individual is generated via reproduction, crossover, mutation, or architecture altering operation (all mutually exclusive), a higher population is likely to have more mutated individuals, which can cause more of these varied results (fluctuation of fitness).

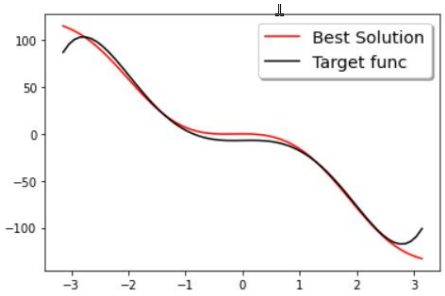
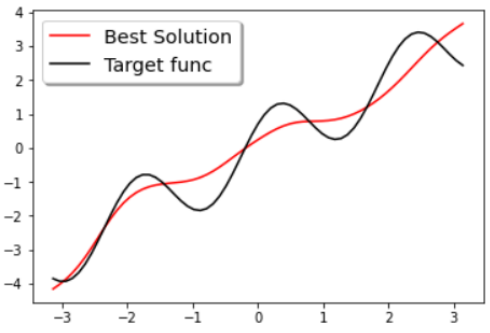
As shown by the table below, the next 10 runs (5 runs for each problem) show consistent results with the first batch.

Chosen optimal configuration (tournament size: 5, population size: 2000)

Run (N)	Experiment 4 - Batch 2 (Problem 1)	Experiment 4 – Batch 2 (Problem 2)
1	**Fitness: (min, max)** 77.70481229401409, 4208.926475156459 **Mean Fitness:** **Gen 0:** 5.92229e+28 **Gen 15:** 6.43256e+28 **Gen 30:** 4.34448e+30 **Median Fitness:** **Gen 0:** 4208.93 **Gen 15:** 974.716 **Gen 30:** 77.7048 **Evaluations:** 49300 	**Fitness: (min, max)** 0.331951084272608, 5.07984998575548 **Mean Fitness:** **Gen 0:** 3.2692e+28 **Gen 15:** 5544.7 **Gen 30:** 2.50416e+27 **Median Fitness:** **Gen 0:** 5.07985 **Gen 15:** 0.493627 **Gen 30:** 0.331951 **Evaluations:** 49531 
2	**Fitness: (min, max)** 122.3946813017185, 4209.121486537739 **Mean Fitness:** **Gen 0:** 2.03823e+28 **Gen 15:** 4.93917e+28 **Gen 30:** 3058.48 **Median Fitness:** **Gen 0:** 4209.12 **Gen 15:** 373.811 **Gen 30:** 122.395 **Evaluations:** 49546 	**Fitness: (min, max)** 0.4386016516407071, 5.07984998575548 **Mean Fitness:** **Gen 0:** 2.7563e+28 **Gen 15:** 1.02581e+27 **Gen 30:** 1.02581e+27 **Median Fitness:** **Gen 0:** 5.07985 **Gen 15:** 0.5 **Gen 30:** 0.438602 **Evaluations:** 49501

Student ID: 1804900

		
3	**Fitness: (min, max)** 277.4425697063118, 4209.121486537739 **Mean Fitness:** **Gen 0:** 1.74387e+28 **Gen 15:** 2.48569e+28 **Gen 30:** 5.21661e+30 **Median Fitness:** **Gen 0:** 4209.12 **Gen 15:** 846.895 **Gen 30:** 277.443 **Evaluations:** 49360 	**Fitness: (min, max)** 0.4398736331590296, 5.07984998575548 **Mean Fitness:** **Gen 0:** 8.43393e+28 **Gen 15:** 1.91876e+29 **Gen 30:** 9.40742e+28 **Median Fitness:** **Gen 0:** 5.07985 **Gen 15:** 1.24145 **Gen 30:** 0.439874 **Evaluations:** 49466 
4	**Fitness: (min, max)** 113.51705923459308, 4209.121486537739 **Mean Fitness:** **Gen 0:** 4.55879e+28 **Gen 15:** 5.86994e+31 **Gen 30:** 4.44499e+30 **Median Fitness:** **Gen 0:** 4209.12 **Gen 15:** 788.163 **Gen 30:** 113.517 **Evaluations:** 49319 	**Fitness: (min, max)** 0.18202754167865454, 5.07984998575548 **Mean Fitness:** **Gen 0:** 2.81556e+28 **Gen 15:** 2.9447e+29 **Gen 30:** 1.05316e+28 **Median Fitness:** **Gen 0:** 5.07985 **Gen 15:** 0.487793 **Gen 30:** 0.182028 **Evaluations:** 49428 

5	**Fitness: (min, max)** 142.89707367971545, 4208.73146377518 **Mean Fitness:** **Gen 0:** 1.11372e+29 **Gen 15:** 2.09812e+31 **Gen 30:** 9.97889e+29 **Median Fitness:** **Gen 0:** 4208.73 **Gen 15:** 1040.7 **Gen 30:** 232.326 **Evaluations:** 49552 	**Fitness: (min, max)** 0.4030478300419816, 5.07984998575548 **Mean Fitness:** **Gen 0:** 6.75768 **Gen 15:** 4.83956e+29 **Gen 30:** 7.12622e+28 **Median Fitness:** **Gen 0:** 5.07985 **Gen 15:** 0.5 **Gen 30:** 0.403048 **Evaluations:** 49072 

To conclude, by using the correct parameters, such as the optimal combination concluded in this experiment, GP is a very good method of finding an accurate solution (at least an **almost perfect** solution).