Impact of meta-genetic algorithm in optimising benchmark genetic algorithm performance

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December 8, 2024

Abstract

This report contains the functionality of a meta-evolutionary genetic algorithm. The Meta-GA optimizes the parameters of a primary genetic algorithm by employing a secondary genetic algorithm. The methodology, experimental setup, and results are discussed in detail.

1 Introduction

The meta-algorithm is an optimization process that determines the optimal parameters for a primary genetic algorithm. The Meta-GA operates by evolving a population of candidates, where each candidate encodes a specific parameter configuration for the primary GA. This approach ensures a systematic and automated way of parameter tuning, improving the performance and adaptability of the primary GA.

2 Methods

2.1 Encoding Parameters

Parameters of the primary genetic algorithm, such as population size, number of generations, selection method, mutation probability, sigma, and crossover probability, are encoded in binary format. Each candidate in the meta-evolutionary population (`metaPopulation`) represents a specific set of parameters as binary strings.

2.2 Candidate Evaluation

The `Meta_Evaluation` function evaluates each candidate in the meta-population by running the primary GA multiple times with the parameters decoded from the candidate. The fitness of a candidate is determined as the average performance of the primary GA over these runs.

2.3 Selection, Mutation, and Crossover

The Meta-GA evolves the population using the following steps:

- **Selection**: The best-performing candidates are preserved through elitism. The remaining population is selected probabilistically, with a fortune wheel algorithm.
- **Mutation**: Each bit in the population can flip with a probability `META_P_mut`$=\frac{2}{79}$ (79 is the total length of a candidate of the GA-META).
- **Crossover**: Two candidates are selected for crossover, and their binary segments are exchanged at a randomly chosen cut point.

3 Results

3.1 Parameters

General Meta-algorithm parameters:

- Population Size for GA-META: 10
- Number of Generations for GA-META: 100
- Mutation Probability for GA-META: 0.02531
- Crossover Probability (P_Crossover) for GA-META: 0.4

3.2 Functions

Rastrigin function parameters:

- Domain: [-5.12, 5.12]
- Population Size: 30
- Number of Generations: 20000
- Mutation Probability (P_Mutation): 0.05000
- Sigma: 0.30000
- Crossover Probability (P_Crossover): 0.01000

Function parameters found with GA-META:

- Population Size: 195
- Number of Generations: 1405
- Mutation Probability (P_Mutation): 0.02720
- Sigma: 0.30128
- Crossover Probability (P_Crossover): 0.53137
- Selection Method:2
- Tournament Size or Number of Elites (only for Selection Method elitism or tournament): 2

	HC - Best	SA	GA-E	GA-META
$n = 5$				
Min. value	0.00000	0.00000	0.00000	0.00000
Max. value	1.23582	8.14915	1.23582	6.17911
Mean	0.40413	2.67206	0.03090	1.17403
Standard Deviation	0.50265	1.68146	0.19540	1.34070
Average time(sec)	1.39	7.15	0.91	0.64
$n = 10$				
Min. value	0.99496	1.98992	0.00000	0.00000
Max. value	5.45652	12.37491	3.70747	11.10253
Mean	3.61979	5.03176	0.67970	3.27245
Standard Deviation	0.97000	2.55480	1.04526	2.78693
Average time(sec)	7.62	12.21	1.66	1.21
$n = 30$				
Min. val.	18.85637	11.20057	1.23582	7.69741
Max. val	32.95540	28.22147	17.26176	21.02567
Mean	27.70595	18.15091	6.29723	13.65235
St. Dev.	2.99251	4.01798	3.70064	3.30298
Avg. time	168.66	33.58	21.77	13.50

Table 1: Rastrigin: exact global minima: n=5/10/30 $->$ 0

Michalewicz function parameters:

- Domain: [0.00, 3.14]
- Population Size: 100
- Number of Generations: 2500
- Mutation Probability (P_Mutation): 0.05263
- Sigma: 0.23000
- Crossover Probability (P_Crossover): 0.01000

Function parameters found with GA-META:

- Population Size: 131
- Number of Generations: 1369
- Sigma: 0.35701
- Mutation Probability (P_Mutation): 0.00131
- Crossover Probability (P_Crossover): 0.05326
- Selection Method:3
- Tournament Size or Number of Elites (only for Selection Method elitism or tournament): 2

	HC - Best	Simulated Annealing	GA-E	GA-META
$n = 5$				
Min. value	-4.68766	-4.68593	-4.68766	-4.68266
Max. value	-4.68153	-3.54586	-4.22151	-3.30584
Mean	-4.68681	-4.23580	-4.62307	-4.06332
Standard Deviation	0.00140	0.31140	0.09472	0.38773
Average time(sec)	1.71	0.01	0.44	0.42
$n = 10$				
Min. value	-9.57161	-9.24567	-9.61837	-9.04861
Max. value	-9.25546	-7.37724	-9.07125	-6.93495
Mean	-9.40824	-8.36363	-9.41060	-8.27826
Standard Deviation	0.07306	0.49831	0.11494	0.45330
Average time(sec)	10.24	0.02	0.88	0.66
$n = 30$				
Min. value	-27.54316	-27.14902	-28.86678	-26.69784
Max. value	-26.58271	-23.28145	-26.57300	-24.02609
Mean	-27.00167	-25.11001	-27.59616	-25.57546
Standard Deviation	0.21404	0.99451	0.51837	0.75976
Average time(sec)	216.71	0.25	2.47	2.44

Table 2: Michalewicz: exact global minima: n=5 $->$ -4.68765 ; n=10 $->$ -9.66015 ; n=30 $->$ -29.9

Schwefel function parameters:

- Domain: [-500.00, 500.00]
- Population Size: 110
- Number of Generations: 25000
- Mutation Probability (P_Mutation): 0.03704
- Sigma: 0.23000
- Crossover Probability (P_Crossover): 0.02000

Function parameters found with GA-META:

- Population Size: 200
- Number of Generations: 2000

- Sigma: 0.35355
- Mutation Probability (P_Mutation): 0.08654
- Crossover Probability (P_Crossover): 0.57051
- Tournament Size or Number of Elites (only for Selection Method elitism or tournament): 10
- Selection Method:2

	HC - Best	Simulated Annealing	GA-E	GA-META
$n = 5$				
Min. value	0.00011	0.00069	0.00069	0.00006
Max. value	0.20865	34.44355	0.41474	0.41536
Mean	0.09165	1.01453	0.25183	0.12529
Standard Deviation	0.06684	5.42187	0.09910	0.00001
Average time(sec)	3.31	58.45	5.02	1.21
$n = 10$				
Min. value	0.62312	0.00201	0.00202	0.10443
Max. value	248.34030	34.96195	0.72642	0.72706
Mean	107.34842	5.45540	0.33565	0.39298
Standard Deviation	53.76364	12.41442	0.16312	0.18362
Average time(sec)	21.04	107.05	9.80	2.30
$n = 30$				
Min. value	888.09205	0.72923	0.73108	1.35494
Max. value	1411.22948	119.89815	1.66345	458.93638
Mean	1226.33757	30.82801	1.19695	198.09167
Standard Deviation	144.79832	38.17938	0.23221	116.85953
Average time(sec)	483.60	299.78	29.09	5.10

Table 3: Schwefel: exact global minima: n=5/10/30 $->$ 0

DeJong function parameters:

- Domain: [-5.12, 5.12]
- Population Size: 20
- Number of Generations: 1000
- Mutation Probability (P_Mutation): 0.00167
- Sigma: 0.30000
- Crossover Probability (P_Crossover): 0.01000

Function parameters found with GA-META:

- Population Size: 196
- Number of Generations: 1454
- Sigma: 0.25335
- Mutation Probability (P_Mutation): 0.35702
- Crossover Probability (P_Crossover): 0.48619
- Selection Method:2
- Tournament Size or Number of Elites (only for Selection Method elitism or tournament): 2

	HC - Best	Simulated Annealing	GA-E	GA-META
$n = 5$				
Min. value	0.00000	0.00000	0.00000	0.00000
Max. value	0.00000	0.00000	0.00000	0.00000
Mean	0.00000	0.00000	0.00000	0.00000
Standard Deviation	0.00000	0.00000	0.00000	0.00000
Average time(sec)	1.42	0.54	0.04	0.7
$n = 10$				
Min. value	0.00000	0.00000	0.00000	0.00000
Max. value	0.00000	0.00000	0.00000	0.00000
Mean	0.00000	0.00000	0.00000	0.00000
Standard Deviation	0.00000	0.00000	0.00000	0.00000
Average time(sec)	8.15	1.00	0.08	1.15
$n = 30$				
Min. value	0.00000	0.00000	0.00000	0.00000
Max. value	0.00000	0.00040	0.00010	0.00000
Mean	0.00000	0.00002	0.00000	0.00000
Standard Deviation	0.00000	0.00007	0.00002	0.00000
Average time(sec)	182.61	2.61	0.23	2.92

Table 4: De Jong: exact global minima: n=5/10/30 $->$ 0

4 Comparative Analysis

The meta-algorithm found in average worst results, compared to the primary GA, due to the fact that the primary GA used more computational power to obtain better results. The limits imposed on the meta-algorithm for finding solutions contributed to the poorer outcomes.

5 Conclusions

The meta-evolutionary genetic algorithm can provide a robust and automated method for tuning genetic algorithm parameters. By evolving a meta-population, it identifies optimal configurations that enhance the primary GA's efficiency.

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