
Understanding Optimization Landscapes Using Bio- Inspired Algorithms

Giorgio Melchiorri





Datasets

- ObesityDataSet – **16 features**, *multi-class classification* task (7 classes), 2111 rows.
- Winequality-white – **11 features**, *multi-class classification* task (10 classes), 4899 rows.
- MAGIC Gamma Telescope – **10 features**, *binary classification*, 19021 rows.

Gender	Age	Height	Weight	family_history_with_overweight	FAVC	FCVC	NCP	CAEC	SMOKE	CH2O	SCC	FAF	TUE	CALC	MTRANS	NObeyesdad
Female	21.0	1.62	64.0	yes	no	2.0	3.0	Sometimes	no	2.0	no	0.0	1.0	no	Public_Transportation	Normal_Weight
Female	21.0	1.52	56.0	yes	no	3.0	3.0	Sometimes	yes	3.0	yes	3.0	0.0	Sometimes	Public_Transportation	Normal_Weight
Male	23.0	1.80	77.0	yes	no	2.0	3.0	Sometimes	no	2.0	no	2.0	1.0	Frequently	Public_Transportation	Normal_Weight
Male	27.0	1.80	87.0	no	no	3.0	3.0	Sometimes	no	2.0	no	2.0	0.0	Frequently	Walking	Overweight_Level_I
Male	22.0	1.78	89.8	no	no	2.0	1.0	Sometimes	no	2.0	no	0.0	0.0	Sometimes	Public_Transportation	Overweight_Level_II

fixed acidity	volatile acidity	citric acid	residual sugar	chlorides	free sulfur dioxide	total sulfur dioxide	density	pH	sulphates	alcohol	quality
7.0	0.27	0.36	20.7	0.045	45.0	170.0	1.0010	3.00	0.45	8.8	6
6.3	0.30	0.34	1.6	0.049	14.0	132.0	0.9940	3.30	0.49	9.5	6
8.1	0.28	0.40	6.9	0.050	30.0	97.0	0.9951	3.26	0.44	10.1	6
7.2	0.23	0.32	8.5	0.058	47.0	186.0	0.9956	3.19	0.40	9.9	6
7.2	0.23	0.32	8.5	0.058	47.0	186.0	0.9956	3.19	0.40	9.9	6

	fLength	fWidth	fSize	fConc	fConc1	fAsym	fM3Long	fM3Trans	fAlpha	fDist	class
0	28.7967	16.0021	2.6449	0.3918	0.1982	27.7004	22.0110	-8.2027	40.0920	81.8828	g
1	31.6036	11.7235	2.5185	0.5303	0.3773	26.2722	23.8238	-9.9574	6.3609	205.2610	g
2	162.0520	136.0310	4.0612	0.0374	0.0187	116.7410	-64.8580	-45.2160	76.9600	256.7880	g
3	23.8172	9.5728	2.3385	0.6147	0.3922	27.2107	-6.4633	-7.1513	10.4490	116.7370	g
4	75.1362	30.9205	3.1611	0.3168	0.1832	-5.5277	28.5525	21.8393	4.6480	356.4620	g

Machine Learning Model

Random Forest:

- n trees = 100
- max depth = 10
- min samples split = 10

Dataset Split

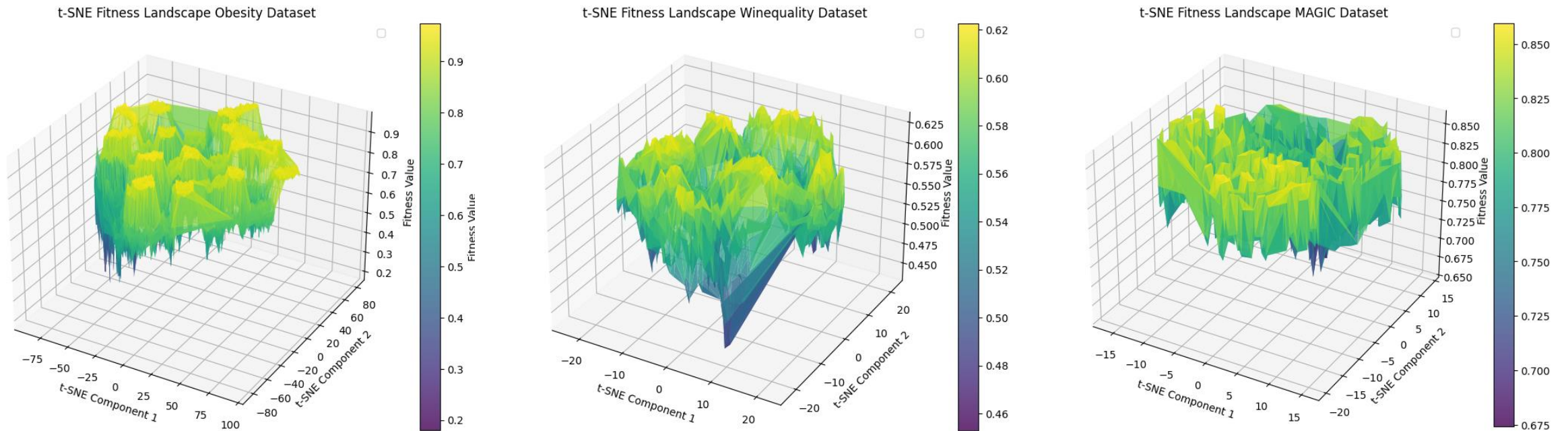
The dataset was split into a training set (80%) and a test set (20%) using a fixed random seed (42).

Penalty Weight and Local optima

Dataset	Number of Local Minima
ObesityDataSet	803
Winequality DataSet	26
MAGIC Gamma Telescope	15

Table 1: Number of local minima calculated for each dataset with *weight* = 0.001.

Fitness Landscape Visualization: t-SNE



Algorithms Implementation

(Random Initialization – Population = 20 – Number of Generations = 30)

SGA

- Selection: Tournament Selection, with tournament size = 3.
- Crossover: Two-Point Crossover.
- Mutation: Bit-Flip Mutation.
- Survivor Selection: The Offsprings replace the previous generation.

NSGA-II

- Parent Selection: Tournament Selection, with tournament size = 3.
- Crossover: Two-Point Crossover.
- Mutation: Bit-Flip Mutation.
- Survivor Selection: A crowding distance mechanism ensured diversity among solutions while minimizing two objectives:
 - The error produced by the random forest model based on the selected features.
 - The number of selected features.

PSO

- **Velocity Update:** Each particle adjusts its speed based on:
 - Its personal best (pBest)
 - The swarm's global best (gBest)
 - The best neighbor within Hamming distance < 2 (lBest)
- **Position Update:**
 - Converts velocity into a probability using the sigmoid function
 - Sets each dimension to **1** (if $\text{random}() < \text{prob}$) or **0** otherwise

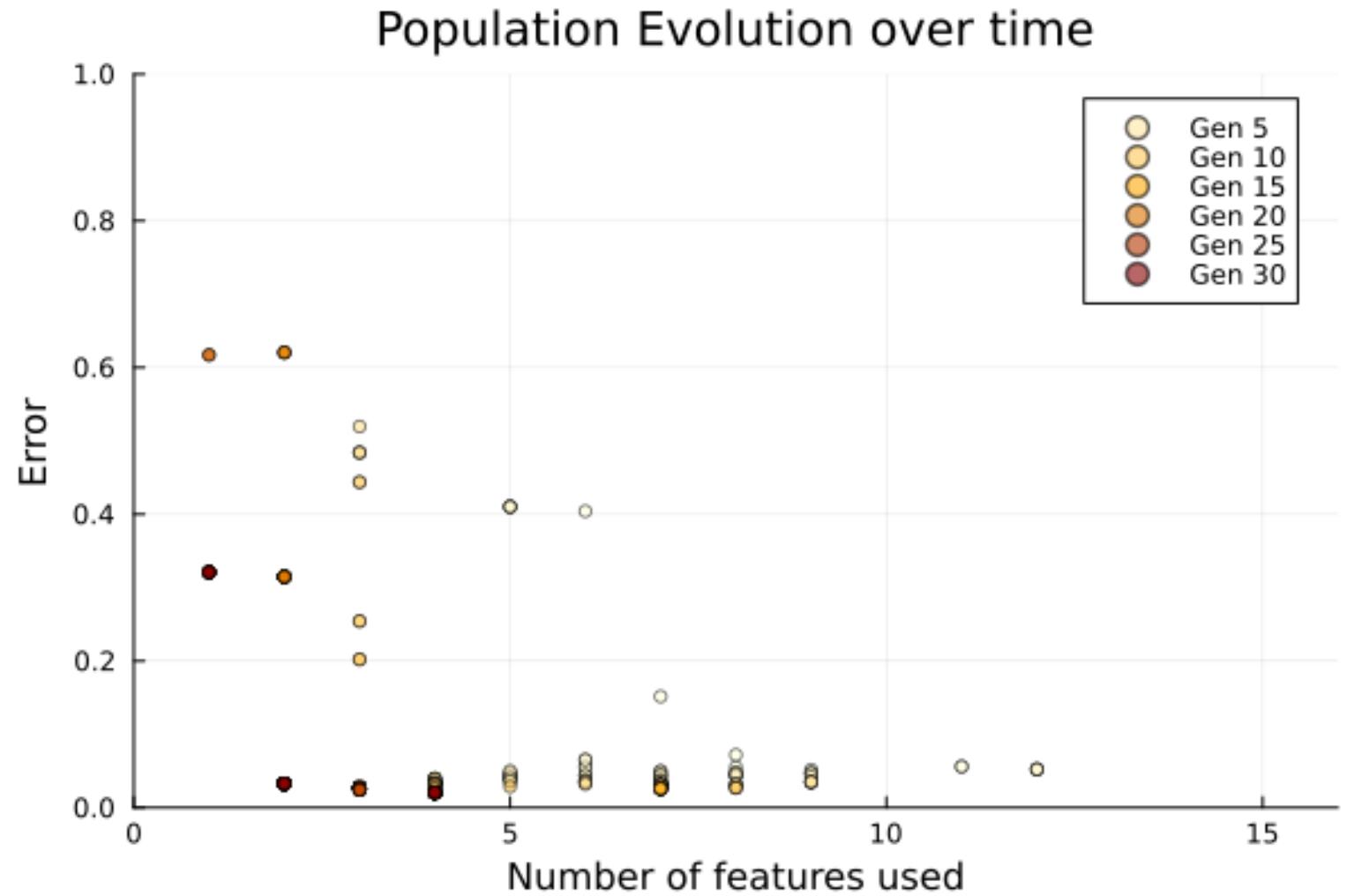
Results

Table 2: Performance Comparison of Optimization Algorithms over 100 runs, each with 30 iterations.

Algorithm	ObesityDataSet	Winequality DataSet	MAGIC Gamma Telescope
Best Fitness Target			
-	0.020	0.367	0.137
Mean Fitness ± Standard Deviation			
SGA	0.021 ± 0.001	0.367 ± 0.0007	0.137 ± 0.00
NSGA-II	0.021 ± 0.001	0.369 ± 0.0019	0.138 ± 0.00001
PSO	0.022 ± 0.0015	0.368 ± 0.0015	0.138 ± 0.0002
Success Rate (% of Runs Reaching Target Fitness)			
SGA	48%	95%	100%
NSGA-II	52%	50%	84%
PSO	43%	70%	82%
Convergence Speed (Iterations to Reach Best Fitness)			
SGA	17.6	10.2	6.7
NSGA-II	14.9	7	7.4
PSO	18.5	9.7	6.3

About NSGA-II

Wine Dataset:
Global optima has 8 features out
of 11



Results On the Lookup Table Provided

Algorithm	Heart Disease (Cleveland)	Zoo
Best Fitness Target		
-	0.398	0.544
Mean Fitness \pm Standard Deviation		
SGA	0.404 ± 0.005	0.555 ± 0.0046
NSGA-II	0.409 ± 0.004	0.557 ± 0.0036
PSO	0.405 ± 0.005	0.555 ± 0.0043
Success Rate (% of Runs Reaching Target Fitness)		
SGA	50%	7%
NSGA-II	13%	1%
PSO	36%	4%
Convergence Speed (Iterations to Reach Best Fitness)		
SGA	13.0	14.5
NSGA-II	6.0	26
PSO	12.4	15.5

Results on Test n. 1: Heart Disease

Best Individual Found:

[0, 1, 1, 0, 1, 1, 0, 0, 1, 0, 1, 1, 1]

Fitness: 0.307

Accuracy: 0.692



Results on Test n. 2: Zoo

Best Individuals Found:

[0, 0, 0, 1, 0, 1, 0, 0, 1, 0, 0, 0, 1, 0, 0, 0],

[0, 0, 0, 1, 0, 1, 0, 1, 0, 0, 0, 0, 1, 0, 0, 0]

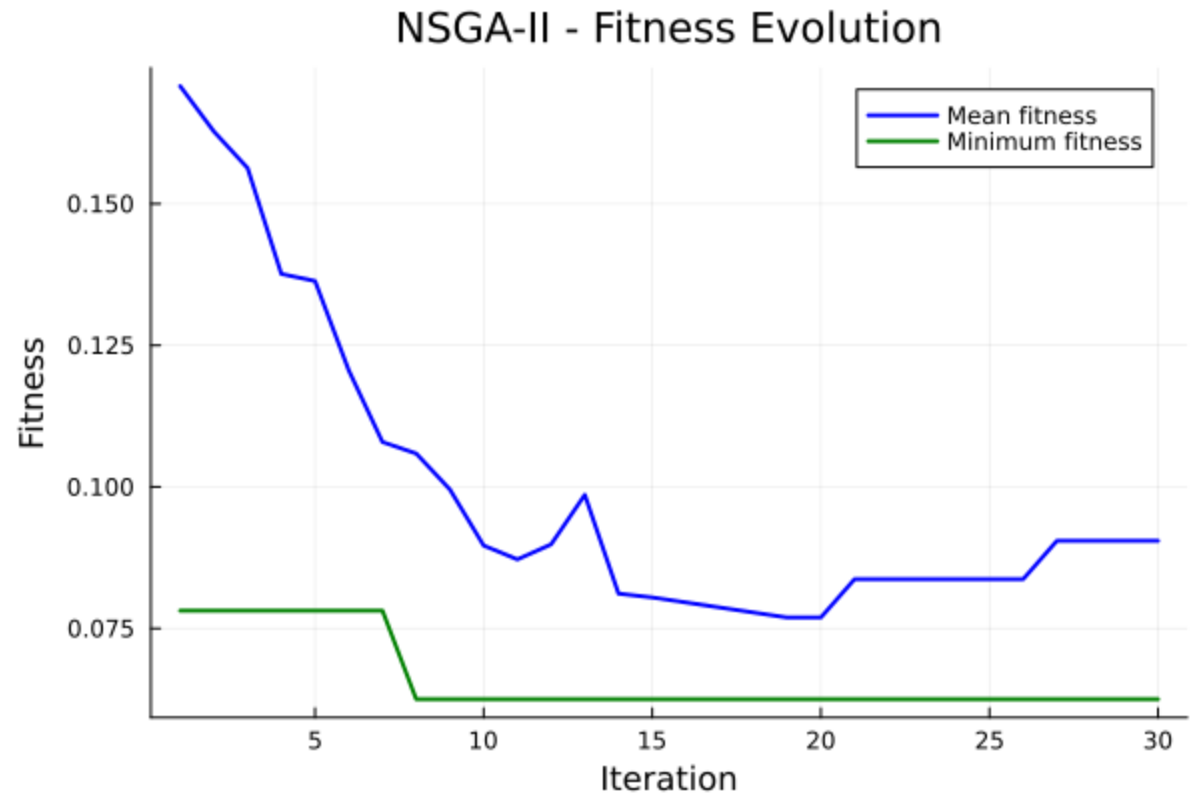
[0, 0, 0, 1, 0, 0, 0, 1, 0, 1, 0, 0, 1, 0, 0, 0]

[1, 0, 0, 0, 0, 0, 0, 0, 1, 1, 0, 0, 1, 0, 0, 0]

and **many more..**

Fitness: 0.0625

Accuracy: 1.0



Results on Test n. 3: Letter recognition

Best Individual Found:

[0, 0, 0, 0, 0, 0, 0, 1, 1, 0, 0, 0, 1, 0, 1, 0]

Fitness: 0.784

Accuracy: 0.716

