

Lab 3

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1 Introduction

The following are results from testing 10 different differential evolution techniques against particle swarm optimization. Differential evolution is a technique to mimic genetic evolution on a population by treating solution vectors as a gene sequence. Particle swarm optimization mimic bird flocks. Each particle in the swarm is pulled to the global best solution and that particles best solution. the ten strategies used for differential evolution are as follow: DE/best/1/exp, DE/rand/1/exp, DE/rand-to-best/1/exp, DE/best/2/exp, DE/rand/2/bin, DE/best/1/bin, DE/rand/1/bin, DE/rand-to-best/1/bin, DE/best/2/bin, DE/rand/2/exp. Each strategy is in the form De/x/y/z where bin is binomial crossover, exp is exponential crossover, and x and y in the prior data is the vector to be perturbed and the number of difference vectors considered for perturbation.

The experimental values for differential evolution were 200, 0.6, 0.9, 0.8, and 100 for population size, crossover factor, scaling factor, second scaling factor, and generations respectively. The experimental values for particle swarm optimization were 200, 0.8, 1.2, and 100 for the number of particles, first scaling factor, second scaling factor, and iterations respectively.

Table 1: DE results for 10 dimension

Problem	DE/best/1/exp			DE/rand/1/exp		
	Avg	Std	Time	Avg	Std	Time
Schwefel's	388.5	85.93	23.25	525.56	66.16	24.01
1st De Jong's	73.4	25.45	12.86	220.55	62.03	13.55
Rosenbrock	157624.03	91389.52	23.36	1297350.77	894159.38	24.2
Rastrigin	-4218.84	987.8	24.78	-1018.09	1225.85	26.56
Griewangk	1.41	0.12	27.33	2.27	0.37	28.06
Sine Envelope Sine Wave	-11.95	0.17	41.25	-11.75	0.25	42.01
Stretched V Sine Wave	9.91	0.26	66.17	10.05	0.34	66.98
Ackley's One	-10.74	3.2	36.81	-1.51	2.8	37.58
Ackley's Two	35.73	3.88	52.75	54.25	4.79	52.89
Egg Holder	-5797.33	312.5	32.53	-5518.89	237.76	33.4

Table 2: DE results for 20 dimension

Problem	DE/best/1/exp			DE/rand/1/exp		
	Avg	Std	Time	Avg	Std	Time
Schwefel's	2163.26	213.03	36.88	2141.56	138.75	37.63
1st De Jong's	3230.81	533.72	16.03	5100.98	874.49	16.96
Rosenbrock	162589518.2	55823445.26	38.1	331098061.1	148456654.1	39.07
Rastrigin	60609.79	11045.14	40	93736.28	16676.51	41
Griewangk	21.8	4.08	45.41	34.54	5.13	46.36
Sine Envelope Sine Wave	-21.85	0.43	76	-21.4	0.42	76.91
Stretched V Sine Wave	26.4	1.31	128.74	26.93	1.55	129.35
Ackley's One	62.44	9.06	66.82	81.06	10.49	67.78
Ackley's Two	210.37	9.55	98.33	233.23	10.86	98.85
Egg Holder	-9125.62	472.89	57.47	-8857.06	446.11	58.18

Table 3: DE results for 30 dimension

Problem	DE/best/1/exp			DE/rand/1/exp		
	Avg	Std	Time	Avg	Std	Time
Schwefel's	4634.42	359.46	50.47	4518.22	272.38	51.17
1st De Jong's	14885.38	1915.31	19.57	17314.75	2293.11	20.57
Rosenbrock	2000542756	654694678.2	52.99	3028736910	664703813	53.93
Rastrigin	385648.85	54596.72	55.4	493137.47	51079.58	56.41
Griewangk	92.71	13.88	63.58	110.27	13.88	64.56
Sine Envelope Sine Wave	-30.51	0.46	110.71	-30.28	0.59	111.64
Stretched V Sine Wave	48.69	1.57	191.13	47.79	1.91	191.68
Ackley's One	192.68	14.86	96.97	216.82	14.29	97.9
Ackley's Two	408.81	12.01	144.25	419.91	15.32	144.88
Egg Holder	-11336.32	474.91	82.33	-11381.46	530.68	83.08

DE/rand-to-best/1/exp			DE/best/2/exp		
Avg	Std	Time	Avg	Std	Time
728.73	86.05	24.67	617.47	122.29	25.98
65.57	16.07	14.14	444.78	147.06	15.53
182691.17	97691.45	26.41	4081878.1	3114919.72	25.95
-4311.34	721.8	26.26	2156.78	1658.66	27.37
1.38	0.13	28.8	3.76	0.74	29.95
-12.04	0.19	42.72	-11.5	0.28	44.27
10.01	0.26	67.64	10.02	0.4	68.82
-9.55	2.7	38.31	5.37	4.43	39.65
35.04	3.92	54.15	72.22	7.81	54.47
-5654.39	213.57	34.01	-5542.57	235.56	35.79

DE/rand-to-best/1/exp			DE/best/2/exp		
Avg	Std	Time	Avg	Std	Time
2470.26	203.99	39.57	2094.15	103.73	40.71
3239.78	594.3	18.69	7811.61	1389.02	20.53
160228524.3	61548689.85	41.23	874129630.5	249672860.6	42.01
52962.02	10883.45	42.77	142742.6	25742.8	43.98
20.78	3.1	48.11	49.65	10.78	49.41
-22.07	0.34	78.6	-20.7	0.44	79.99
26.62	1.4	131.32	28.14	1.23	132.22
59.1	8.41	69.49	106.51	14.42	70.81
206.77	9.31	101.4	263.29	10.35	101.38
-8824.99	311.61	60.11	-8896.1	308.9	61.2

DE/rand-to-best/1/exp			DE/best/2/exp		
Avg	Std	Time	Avg	Std	Time
5042.13	287.18	54.29	4315.95	211.9	55.38
14050.98	1710.27	23.99	24452.51	3146.24	24.65
1885179039	533579793.8	56.93	5301412288	1028401022	58.03
357269.93	48495.82	59.28	646446.33	90762.43	60.49
86.17	10.24	67.49	156.47	24.58	68.64
-30.88	0.66	114.72	-29.18	0.61	115.79
47.37	1.96	195	49.99	3.29	195.65
187.3	11.25	100.83	245.14	17.31	102.03
405.55	11.35	148.23	449.72	9.4	148.67
-11361.94	621.76	86.12	-11330.5	507.09	87.08

DE/rand/2/bin			DE/best/1/bin		
Avg	Std	Time	Avg	Std	Time
608.28	104.94	26.57	502.88	100.5	26.43
716.19	205.02	16	25.3	9.52	16.85
10497126.04	6397320.9	26.75	112832.25	55725.85	27.07
4338.19	2714.46	28.13	-5191.78	800.62	28.4
5.45	1.11	30.84	1.15	0.07	30.93
-11.4	0.28	45.02	-11.68	0.27	44.91
10.07	0.42	69.54	10.54	0.47	69.81
10.94	5.44	40.27	-12.93	2.58	40.31
85.28	7.59	55.08	25.91	3.82	56.91
-5352.6	236.85	35.93	-5891.1	360.55	35.99

DE/rand/2/bin			DE/best/1/bin		
Avg	Std	Time	Avg	Std	Time
2124.52	112.93	41.41	1852.83	187.14	45.31
9035.42	1610.96	20.82	3037.92	482.15	24.88
1038333291	337553712.5	42.87	291703953.7	145488256.3	47.04
163002.38	28794.95	44.8	57369.39	13311.64	48.88
57.72	10.64	50.22	21.34	3.57	54.28
-20.67	0.42	80.8	-20.81	0.58	84.89
27.77	1.58	132.91	31.71	1.82	137.43
116.32	14.57	72.07	62.69	11.62	75.57
268.77	9.97	102.06	183.24	15.54	108.05
-8899.28	472.59	61.9	-8850.37	667.43	66.16

DE/rand/2/bin			DE/best/1/bin		
Avg	Std	Time	Avg	Std	Time
4312.63	275.54	56.7	3714.96	576.39	64.27
27476.15	2910.55	25.8	16446.49	1652.76	33.78
5799454389	1937690207	58.94	3746750971	1079315468	67.33
729867.86	82222.59	61.38	456190.04	61151.54	69.64
170.85	16.65	69.55	106.3	13.81	77.84
-28.97	0.62	116.65	-29.05	0.74	125.06
50.63	2.04	196.45	57.92	2.94	205.04
258.28	20.33	102.99	201.23	14.08	111.09
454.44	8.46	149.3	384.19	12.62	159
-11399.42	441.13	87.8	-10305.19	743.7	96.41

DE/rand/1/bin			DE/rand-to-best/1/bin		
Avg	Std	Time	Avg	Std	Time
421.11	33.02	27.37	798.99	68.28	28.53
159.89	45.58	17	22.07	6.74	17.86
1065691.42	648198.74	27.81	81735.49	44672.04	28.56
-2488.39	1121.11	29.12	-4830.02	733.62	29.85
1.94	0.32	31.66	1.14	0.06	32.45
-11.48	0.25	45.6	-11.62	0.19	46.21
10.45	0.54	70.55	10.61	0.43	71.22
-3.35	3.15	41.09	-11.48	3.1	41.78
43.44	5.46	57.06	25.33	3.18	58.36
-5448.54	172.99	36.77	-5575.07	374.9	37.64

DE/rand/1/bin			DE/rand-to-best/1/bin		
Avg	Std	Time	Avg	Std	Time
2086.28	167.36	46.39	2651.74	308.48	48.4
6750.79	1113.98	25.86	2780.44	568.58	27.67
797569412	279297827.5	48.04	192065068.9	82858466.16	49.76
111300.33	16291.77	49.86	45798.38	8704.86	51.63
40.64	6.97	55.3	18.43	2.79	56.97
-20.36	0.5	85.87	-20.82	0.34	87.56
32.4	1.7	138.1	31.79	1.79	140.08
91.99	12.91	76.65	61.43	7.54	78.28
221.65	12.52	108.18	183.16	9.03	110.75
-8318.63	505.13	66.92	-8404.86	575.91	68.87

DE/rand/1/bin			DE/rand-to-best/1/bin		
Avg	Std	Time	Avg	Std	Time
4247.25	293.47	65.22	5170.61	475.83	68.43
24871.29	3016.76	34.82	14810.52	1822.46	37.69
6846094767	1845122117	68.31	2798519529	657468692.9	71.26
679712.11	78968.59	70.63	379980.37	47946.62	73.46
158.56	18.76	78.86	93.2	8.97	81.76
-28.33	0.72	125.96	-29.18	0.63	128.91
57.82	2.13	205.66	56.8	2.47	208.91
251.34	18.1	112.2	187.99	16.42	115
427.71	9.95	159.19	386.43	14.73	163.03
-10034.82	788.19	97.02	-9836.04	593.71	100.23

DE/best/2/bin			DE/rand/2/exp		
Avg	Std	Time	Avg	Std	Time
720.45	87.41	29.05	616.18	65.76	30.16
540.93	159.77	18.81	754.69	248.69	19.72
7490878.23	5615092.71	29.64	19340635.84	17962573.76	30.38
3172.78	1545	31.02	4996.19	2828.46	31.71
4.12	0.95	34.32	5.52	1.68	34.27
-11.16	0.28	47.6	-11.06	0.3	48.42
10.71	0.62	72.33	11.03	0.59	73.04
8.63	4.16	42.96	13.76	5.84	43.87
64.47	8.06	58.31	73.08	6.75	58.83
-5503.89	333.63	38.69	-5264.3	263.84	39.43

DE/best/2/bin			DE/rand/2/exp		
Avg	Std	Time	Avg	Std	Time
2116.51	182.93	49.17	2334.63	129.25	50.19
13208.64	1929.13	28.95	14606.89	2798.09	29.74
2798251210	767078825.9	51.08	3063861850	1013392354	51.9
221622.95	46505.48	52.94	262696.14	50912.82	53.72
86.12	11.99	58.31	93.21	15.4	59.22
-19.54	0.47	88.93	-19.3	0.43	89.72
33.23	2.1	140.95	33.22	2.46	141.53
141.52	13.57	79.72	148.19	11.37	80.58
264.91	9.37	110.32	275.22	10.66	110.92
-8179.27	550.21	69.9	-7897.79	448.61	70.64

DE/best/2/bin			DE/rand/2/exp		
Avg	Std	Time	Avg	Std	Time
3816.85	229.12	69.15	4529.1	256.34	70.22
37934	4316.5	38.97	40344.37	4801.3	39.96
12816719086	2629114805	72.68	13100257553	2960913691	73.33
1004467.47	106524.85	74.75	1100712.92	90904.71	75.67
249.32	26.18	83.05	254.37	23	83.85
-27.28	0.49	130.08	-27.07	0.54	130.96
60.65	2.76	209.44	60.99	2.6	210.19
320.49	26.01	116.45	330.36	21.17	117.35
468.32	9.73	162.5	475.8	10.66	163.12
-9983.91	663.65	101.15	-9943.36	695.15	101.91

Table 4: PSO results

Problem	PSO (10 Dim)			POS (20Dim)			PSO (30 Dim)		
	Avg	Std	Time	Avg	Std	Time	Avg	Std	Time
Schwefel's	1097.84	64.03	36.74	2241.52	57.25	67.99	3392.88	64.11	99.08
1st De Jong's	1236.75	502.02	26.67	13985.36	4191.87	48.86	44593.87	4656.76	70.06
Rosenbrock	3.13E+07	2.09E+07	37.04	1.31E+09	7.47E+08	69.99	1.21E+10	5.03E+09	102.88
∞ Rastrigin	12326.69	4721.96	38.59	277011.09	77526.65	72.09	1125354.5	188312.5	105.51
Griewangk	10.48	3.25	41.21	95.99	31.64	77.48	264.29	43.15	113.64
Sine Envelope	-10.11	0.41	54.56	-18.28	0.59	107.35	-26.01	0.75	159.98
Stretched V Sine Wave	12.23	0.88	79.29	38.22	1.87	159.08	67.23	2.73	239.49
Ackley's One	33.87	12.42	50.62	177.37	26.51	98.89	352.85	37.45	147.18
Ackley's Two	107.94	11.61	64.96	299.35	14.03	128.5	497.53	15.22	192.13
Egg Holder	-5362.6	335.58	45.48	-8410.69	437.36	87.14	-11602.23	568.75	128.72

Table 5: Analysis for 10 dimensions

Problem	DE Strat	DE	PSO	t - value	p - value	p < 0.05
Schwefel's	DE/best/1/exp	388.5	1097.84	-35.65	3.87E-41	yes
1st De Jong's	DE/rand-to-best/1/bin	22.07	1236.75	-13.03	7.13E-19	yes
Rosenbrock	DE/rand-to-best/1/bin	81735.49	3.13E+07	-8.05	4.98E-11	yes
Rastrigin	DE/best/1/bin	-5191.78	12326.69	-19.41	8.57E-27	yes
Griewangk	DE/rand-to-best/1/bin	1.14	10.48	-15.49	2.88E-22	yes
Sine Envelope Sine Wave	DE/rand-to-best/1/exp	-12.04	-10.11	-22.99	7.85E-31	yes
Stretched V Sine Wave	DE/best/1/exp	9.91	12.23	-13.65	9.06E-20	yes
Ackley's One	DE/rand-to-best/1/bin	-12.93	33.87	-19.08	1.13E-26	yes
Ackley's Two	DE/rand-to-best/1/bin	25.33	107.94	-36.97	5.14E-42	yes
Egg Holder	DE/best/1/bin	-5891.1	-5362.6	-5.78	3.15E-07	yes

Table 6: Analysis for 20 dimensions

Problem	DE Strat	DE	PSO	t - value	p - value	p < 0.05
Schwefel's	DE/best/1/bin	1852.83	2241.52	-10.7	2.42E-15	yes
1st De Jong's	DE/rand-to-best/1/bin	2780.44	13985.36	-14.26	1.27E-20	yes
Rosenbrock	DE/rand-to-best/1/exp	1.60E+08	1.31E+09	-8.29	1.97E-11	yes
Rastrigin	DE/rand-to-best/1/bin	45798.38	277011.09	-15.96	6.93E-23	yes
Griewangk	DE/rand-to-best/1/bin	18.43	95.99	-13.15	4.74E-19	yes
Sine Envelope Sine Wave	DE/rand-to-best/1/exp	-22.07	-18.28	-29.94	5.76E-37	yes
Stretched V Sine Wave	DE/best/1/exp	26.4	38.22	-27.9	2.67E-35	yes
Ackley's One	DE/rand-to-best/1/exp	59.1	177.37	-22.9	9.73E-31	yes
Ackley's Two	DE/rand-to-best/1/bin	183.16	299.35	-37.51	2.28E-42	yes
Egg Holder	DE/best/1/exp	-9125.62	-8410.69	-5.98	1.49E-07	yes

Table 7: Analysis for 30 dimensions

Problem	DE Strat	DE	PSO	t - value	p - value	p < 0.05
Schwefel's	DE/best/1/bin	3714.96	3392.88	2.99	0.004079818	yes
1st De Jong's	DE/rand-to-best/1/exp	14050.98	44593.87	-33.16	2.13E-39	yes
Rosenbrock	DE/rand-to-best/1/exp	1.89E+09	1.21E+10	-10.83	1.50E-15	yes
Rastrigin	DE/rand-to-best/1/exp	357269.93	1125354.5	-21.27	4.49E-29	yes
Griewangk	DE/rand-to-best/1/exp	86.17	264.29	-21.63	1.89E-29	yes
Sine Envelope Sine Wave	DE/rand-to-best/1/exp	-30.88	-26.01	-26.28	6.59E-34	yes
Stretched V Sine Wave	DE/rand-to-best/1/exp	47.37	67.23	-31.82	2.05E-38	yes
Ackley's One	DE/rand-to-best/1/exp	187.3	352.85	-22.8	1.23E-30	yes
Ackley's Two	DE/best/1/bin	384.19	497.53	-30.88	1.06E-37	yes
Egg Holder	DE/rand/2/bin	-11399.42	-11602.23	9.95	3.79E-14	yes

2 Conclusion

There were statistically significant differences between the two algorithms for every equation and every dimension. Interestingly, differential evolution produced a more fit vector than particle swarm optimization for every equation and every dimension other than Schwefel's in 30 dimensions and Egg Holder in 30 dimensions. Particle Swarm optimization also performed noticeably slower than differential evolution for solution vectors with 30 dimensions.