471 Lab 4

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1 Introduction

In this Lab, the following algorithms have been coded.

1. Particle Swarm
2. Firely

The Particle Swarm algorithm treats each value in the 2d array as its own particle. Each particle is modified using a velocity value calculated by

$$v_{i,j}^{t+1} = v_{i,j}^{t} + c_1 * rand[0,1] * (pBest_{i,j}^{t} - p_{i,j}^{t}) + c_1 * rand[0,1] * (gBest_{i,j}^{t} - p_{i,j}^{t})$$

c_1 and c_2 are defined by the user. A higher c_1 value allows the particle to move towards its personal best while a higher c_2 value. After each particle is modified, the fitness of each row is then calculated, and then the value is checked against the global best. In this iteration, each row is handled by a thread and once all threads are completed the last thread to finish checks the best personal best against the global best.

Firefly Algorithm is modeled after the behaviors of fireflys. They are attracted towards the brightest firefly and are asexual, so they can breed with any other fireflys. The fireflys are seperated randomly and over time will converge towards the brightest one.

2 Experimentation

Particle Swarm and Firefly were used to minimize the standard benchmark functions listed in table 1. For Particle Swarm, the basic parameters were kept. For each however, c1 and c2 were set as three seperate value pairs (1.5, .5), (.8, 1.2), (.5, 1.5). The data was then collected and averaged to be put in tables 2, 3 and 4 based on dimension. Each Particle Swarm ran 100 times. Firefly was ran for 1000 iterations, however while taking a quick look at the 10 dimensional values for 100 iterations, the values are slightly worse, but still produce similar end results.

Table 1: Fitness Functions

Function	Name	Range
f_1	Schwefel's	[-512, 512]
f_2	1st De Jong's	[-100, 100]
f_3	Rosenbrock	[-100, 100]
f_4	Rastrigin	[-30, 30]
f_5	Griewangk	[-500, 500]
f_6	Sine Envelope Sine Wave	[-30, 30]
f_7	Stretched V Sine Wave	[-30, 30]
f_8	Ackley's One	[-32, 32]
f_9	Ackley's Two	[-32, 32]
f_{10}	Egg Holder	[-500, 500]
f_{11}	Rana	[-500, 500]
f_{12}	Pathological	[-100, 100]
f_{13}	Micalewicz	[-0, 3.14]
f_{14}	Masters' Cosine Wave	[-30, 30]
f_{15}	Shekel's Foxhole	[0, 10]

3 Analysis

For Particle Swarm, the data significantly improved. Looking at best/1/exp for differential evolution, the values obtained in most iterations of particle swarm were the same if not better. In the case of the rand/1/bin and best/2/bin, most solutions for particle swarm were exceptionally better. The particle swarm also took a fraction of the time to run. Excluding Sine

Envelope Sine Wave, every problem had a better average solution when given the c1, c2 parameters of 1.5 and .5. It would seem that if a particle is given permission to search on its own, the whole solution gets better. This did create a larger range of values in most cases. One iteration was ran to get the data to plot in the graphs. Because of this, many plots were ommitted for the sake of data integrity.

In the case of Firefly, we can see some significant improvement. Rosenbrocks Saddle is the most amazing result. It is close to the global best noted in the table in Lab 1 and the difference between 100 and 1000 iterations is numbers in the hundreds of thousands. The only firefly's that didn't see improvement were Schwefels and Pathological. This could be because of the nature of their algorithms or because of a bad seed for the fireflies. One conclusion that can be draw from this is that Firefly is a better algorithm. However, in the way it was coded, the Firefly took 40 minutes longer for all tests than the Particle Swarm. More work could be done to speed up the Firefly algorithm.

What can be taken away form this is that swarm algorithms are inherantly better than evolutionary algorithms. While a population needs more solutions to be effective, a moving swarm can accomplish the same results with many less resources. These results are also substantially better than the Local Search methods, in both time taken to run and the results they produce.

Table 2: Values for 30 tests of Particle Swarm and Firefly for 10 *dimensions*[1]

(C1,C2)	(1.5, .5)			(.8, 1.2)			(.5, 1.5)			Firefly		
Problem[2]	Min	Avg	Range	Min	Avg	Range	Min	Avg	Range			
f_1	-3307.42	-2868.077	747.84	-3038.14	-2697.767	642.45	-3059.74	-2562.000667	932.97	-2885.85	-2529.926	878.02
f_2	1153.53	4451.838	5550.18	3540.35	5486.347667	4369.03	4228.08	7201.429	7182.82	0.0180253	0.031136327	0.0325303
f_3	54992500	297278710	533648500	138544000	445438400	1296676000	62565200	401526440	1328434800	8.06052	91.87695167	666.17348
f_4	3098.36	6286.273333	8635.64	3441.44	8581.871333	9259.16	4919.02	12499.86433	16074.88	-1738.95	-1559.259667	288.18
f_5	12.9214	25.85717333	27.3301	25.3257	38.39408333	43.5096	19.5502	37.29920333	38.3198	0.074136	0.3914458	1.177044
f_6	-10.4235	-9.710598	1.40758	-10.8224	-9.689355667	1.56345	-10.1977	-9.532428333	1.46486	-12.6507	-12.23454	0.8071
f_7	-48.0066	-44.34324333	8.0708	-51.1593	-44.03325667	12.8993	-50.9627	-45.31627	14.0099	-47.0039	-38.48986667	12.9525
f_8	41.1426	58.80380333	39.3534	47.9058	66.66601	46.1178	43.03	72.49994667	50.5982	-24.5955	-19.49638733	15.34039
f_9	89.7218	116.7697633	57.8682	91.6523	130.4071433	53.7847	117.482	131.7923333	31.996	7.97867	19.33466567	48.78543
f_{10}	-6087.15	-4511.890667	2341.12	-5667.47	-4648.678	1864.21	-4740.15	-4298.915	1013.85	-4648.01	-3954.687667	2026.83
f_{11}	-3678.32	-2928.858667	1244.8	-3552.76	-2766.398667	1317.5	-3438.96	-2921.126667	1039.52	-2795.32	-2280.611	1084.61
f_{12}	0.864309	1.504478567	1.236401	1.30162	2.110692333	1.45528	1.69366	2.101828	0.80674	2.50671	2.892958	0.99359
f_{13}	-6.98873	-5.901567	12.69482	-7.52693	-6.529815	1.54332	-7.08126	-5.813566667	2.35726	-8.8488	-8.343356667	0.88867
f_{14}	-8.06024	-7.375619333	1.21616	-8.51589	-7.412709	1.96167	-8.26613	-7.266401	1.69357	-8.91591	-8.747302667	1.00835
f_{15}	-0.345772	-0.3444565	0.002631	-0.341809	-0.335312	0.012994	-0.482889	-0.4163655	0.133047	-1.45556	-1.427420667	0.04531

[1]Processor: Intel Core i7-6500U CPU 2.5GHz, Ram: 16GB

[2]Functions listed from table 1

Table 3: Values for 30 tests of Particle Swarm and Firefly for 20 *dimensions*[1]

(C1,C2)	(1.5, .5)			(.8, 1.2)			(.5, 1.5)			Firefly		
Problem[2]	Min	Avg	Range	Min	Avg	Range	Min	Avg	Range			
f_1	-5262.47	-4250.365667	1580.65	-4594.29	-3922.645333	1200.11	-4248.24	-3758.671333	1080.15	-4326.69	-3597.222333	1710.17
f_2	15459.1	23736.59333	21558.4	9320.57	26579.44233	26814.63	22325.2	29560.26667	13574.9	0.270145	0.317996233	0.151774
f_3	2.9 E+09	6.58 E+09	8.63 E+09	3.86 E+09	6.92 E+09	7.67 E+09	5.76 E+09	1.11 E+10	9.98 E+09	43.9018	175.7000233	2412.7782
f_4	52022.5	89426.91333	67904.5	83601.3	105691.5567	49078.7	64157.3	102552.5733	77521.7	-4802.15	-3398.095	2765.18
f_5	100.84	143.6976667	99.303	102.549	176.2841	125.712	163.622	208.9564	93.318	0.0404467	0.793202367	2.0122733
f_6	-18.5818	-17.55042667	2.1844	-19.0286	-17.81632333	2.2215	-18.5867	-17.37792	2.0573	-25.1581	-24.12332333	2.0247
f_7	-88.586	-72.81860333	25.9161	-79.9229	-68.75118	22.7018	-86.4054	-69.18948	27.6379	-98.9396	-80.1739	34.9098
f_8	172.625	207.1600667	83.561	185.142	222.8675	77.281	171.018	235.1541333	95.225	-38.7	-24.35174667	25.7599
f_9	279.27	309.6444333	50.837	281.467	315.0902667	58.85	305.35	325.7179	38.348	44.9094	69.13354333	81.8686
f_{10}	-8066.15	-7030.683333	2253.02	-7329.08	-6153.487333	2182.57	-7495.92	-6421.499667	2364.81	-7263.84	-5766.472	2446.23
f_{11}	-5354.32	-4471.234	1533.37	-4574.28	-3884.188667	1358.76	-5337.61	-4176.723667	1959.9	-5556.38	-4469.873667	2239.86
f_{12}	2.70344	3.915558667	2.3988	4.61083	5.584084333	2.10808	5.03145	6.035843	1.7264	6.69953	7.038698	0.90394
f_{13}	-10.7341	-8.671754333	3.48562	-9.446	-8.376957	1.88817	-10.4391	-8.564559333	2.69112	-14.2644	-12.36623667	3.045
f_{14}	-14.0956	-11.631577	4.63679	-13.9881	-11.39067867	4.25117	-12.6892	-11.62225667	2.2415	-17.7059	-16.50583667	2.2829

[1]Processor: Intel Core i7-6500U CPU 2.5GHz, Ram: 16GB

[2]Functions listed from table 1

[3]Graphed values are not part of the 30 tests.

Table 4: Values for 30 tests of Particle Swarm and Firefly for 30 *dimensions*[1]

(C1,C2)	(1.5, .5)			(.8, 1.2)			(.5, 1.5)			Firefly		
Problem[2]	Min	Avg	Range	Min	Avg	Range	Min	Avg	Range			
f_1	-6722.09	-5359.868667	2213.97	-5527.14	-4821.762667	1535.35	-5339.48	-4660.217	1323.92	-6256.52	-4926.136667	2083.92
f_2	35540	50211.43667	23756.4	38712.8	57823.53333	27300.6	48637.7	61469.86667	21854.2	1.05141	1.178440667	0.53193
f_3	2.9 E+09	6.58 E+09	8.63 E+09	3.86 E+09	6.92 E+09	7.67 E+09	5.76 E+09	1.11 E+10	9.98 E+09	112.991	323.0147333	1221.539
f_4	207775	276163.4333	106207	265355	312907.1667	101897	282390	339628.6	102719	-5723.77	-3657.652	4562.93
f_5	255.088	321.7818333	168.282	234.045	357.8138667	185.768	354.573	398.1241667	91.504	1.53443	3.445160333	3.53841
f_6	-26.6812	-25.29226333	2.3614	-26.8678	-25.34963	2.9625	-26.1199	-24.83895667	2.1264	-36.3556	-35.16174667	3.5421
f_7	-109.105	-92.20514667	28.4513	-108.559	-93.26265	26.8657	-104.345	-89.99067333	29.8762	-135.618	-122.7133033	42.9593
f_8	332.522	394.3161	99.692	339.467	404.0947667	101.577	372.569	434.4003667	90.787	-42.714	-30.60958	30.71
f_9	465.702	494.2757333	52.56	478.05	508.2753667	47.064	496.221	520.5076333	41.971	70.8106	131.88306	156.7674
f_{10}	-11331.1	-9495.312	3749.85	-10293.1	-7821.004	3989.66	-8559.14	-7320.700667	2389.73	-9836.7	-7324.88	4355.16
f_{11}	-7874.16	-6137.533	3152.96	-6256.03	-5153.661333	2020.78	-6278.82	-4999.751333	2052.77	-6605.35	-5262.411667	1865.17
f_{12}	5.17904	6.905728	3.24644	7.3033	9.720120667	3.6181	8.07116	9.384332667	2.80554	10.1639	11.16533667	2.0279
f_{13}	-12.1411	-10.27934467	2.97708	-13.1153	-10.24204833	4.64429	-11.2194	-9.694836667	3.05732	-16.156 -14.99832667 2.1696		
f_{14}	-17.7912	-14.81444	4.6969	-19.2365	-15.05550333	5.8616	-18.1155	-15.36264333	4.9131	-24.3984 -21.84409333 4.276		

[1]Processor: Intel Core i7-6500U CPU 2.5GHz, Ram: 16GB

[2]Functions listed from table 1

Table 5: Graphed Data

Function	Graphed Number	*Average*[1] Graphed Number	*Average*[1] Graphed Number	*Average*[1]		
f_4	64190.1	89426.91	98332.1	105691.56	97265.1	102552.57
f_6	-17.9177	-17.55	-16.9439	-17.82	-17.0524	-17.38
f_{10}	-8016.82	-7030.68	-6601.13	-6153.49	-5780.37	-6421.5

[1] Taken from Table 3

Figure 1:

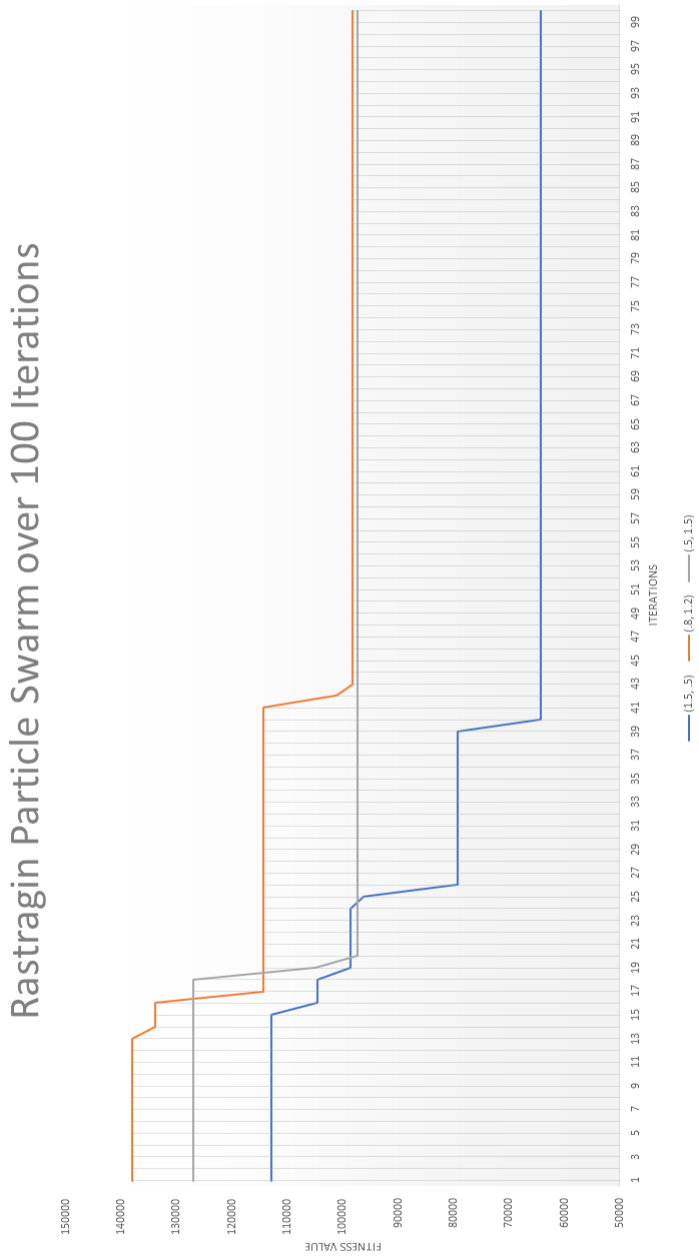

Rastragin Particle Swarm over 100 Iterations
FITNESS VALUE
150000
140000
130000
120000
110000
100000
90000
80000
70000
60000
50000
ITERATIONS
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39 41 43 45 47 49 51 53 55 57 59 61 63 65 67 69 71 73 75 77 79 81 83 85 87 89 91 93 95 97 99
(1.5, 5)
(.8, 1.2)
(.5, 1.5)

Figure 2:

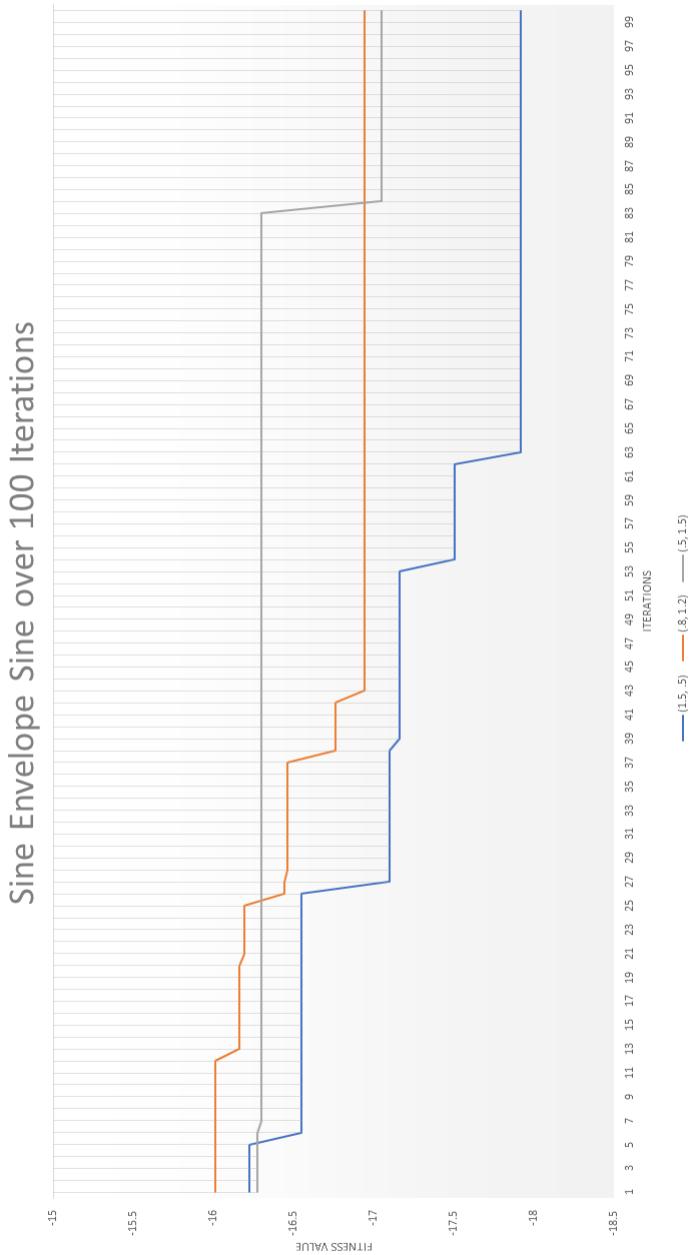
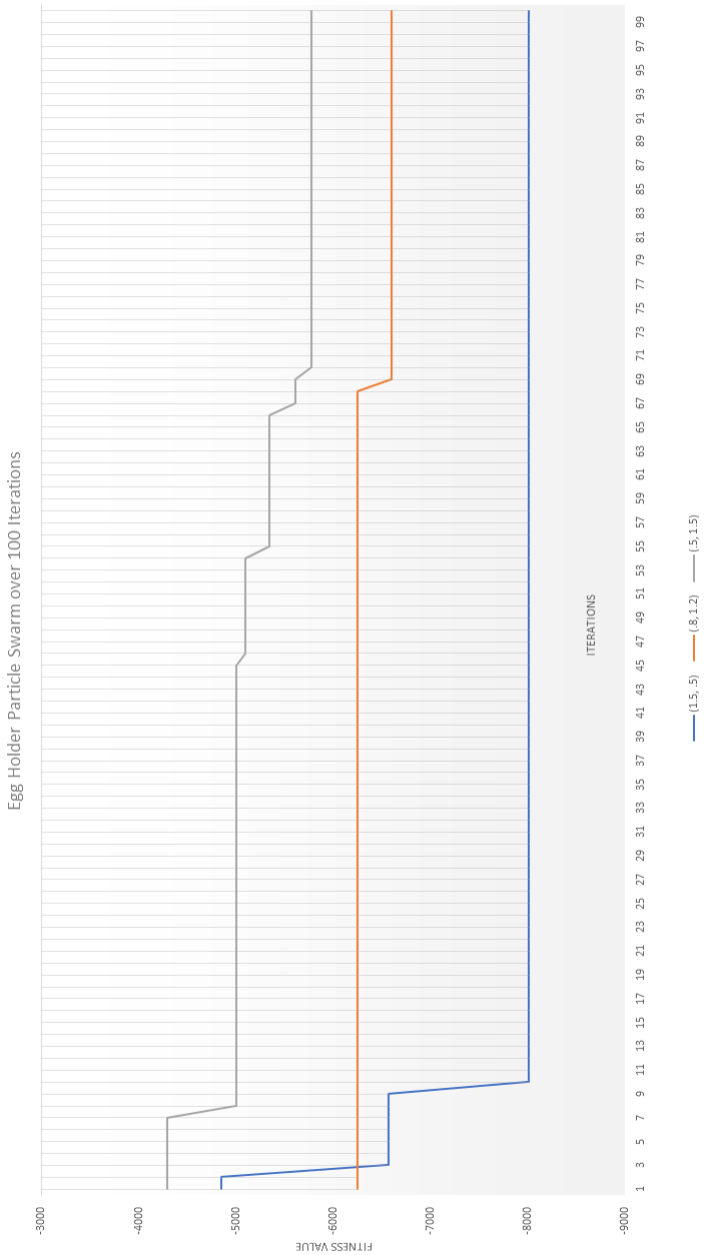

Sine Envelope Sine over 100 Iterations
FITNESS VALUE
-15
-15.5
-16
-16.5
-17
-17.5
-18
-18.5
ITERATIONS
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39 41 43 45 47 49 51 53 55 57 59 61 63 65 67 69 71 73 75 77 79 81 83 85 87 89 91 93 95 97 99
(1.5, 5)
(.8, 1.2)
(.5, 1.5)

Figure 3:


Egg Holder Particle Swarm over 100 Iterations
FITNESS VALUE
-3000
-4000
-5000
-6000
-7000
-8000
-9000
ITERATIONS
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39 41 43 45 47 49 51 53 55 57 59 61 63 65 67 69 71 73 75 77 79 81 83 85 87 89 91 93 95 97 99
(1.5, 5)
(8.1.2)
(5,1.5)