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CS 471 OPTIMIZATION

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Project 2 Report

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1 Introduction

For project 2, we were asked to optimize 18 standard benchmark functions namely Schwefel, De Jong 1, Rosenbrock's Saddle, Rastrigin, Griewangk, Sine Envelope Sine Wave, Stretch V Sine Wave, Ackley One, Ackley Two, Egg Holder, Rana, Pathological, Michalewicz, Master's Cosine Wave, Quartic, Levy, Step and Alpine. For this purpose, we've been given 3 optimization algorithms to be implemented then applied to those functions. Those algorithms are: Blind Search (Also Known as Random Walk), Local Search and Iterative Local Search. After implementing them, we ran them on each of the 18 functions using randomly generated data. Statistics for each algorithm were computed and stored in a tabular form and they will be discussed then analyzed later on in this report. However, for run time purposes, we considered making some adjustments to the local search algorithm and those adjustments will be discussed in the next section of this report.

2 Adjustments to the Local Search Algorithm

2.1 Problem Encountered and experimentation

After implementing the Local Search Algorithm as described in class, we experimented with it on the set of functions that were to be optimized and observed that elements of the X_new vector for some functions such as Rosenbrock's Saddle were almost always out of range which caused the program to run forever because trying to find an X vector that would produce X_new with all elements satisfying the constraints. Following this, we ran another experiment trying to observe how long it would take to generate a vector X that would produce X_new with its first k (k = 1, 2, 3, 4, 5,...) elements being within the range. We observed that finding X for k = 4 is the best we could do in a reasonable amount of time (about 5 minutes).

2.2 Adjustment

following the small experimentation mentioned in the previous sub-section, we implemented the Local Search algorithm following the process:

- step 1: generate a matrix of 30 rows (each row representing a solution for the function being optimized),

- step 2:find the best solution out of those 30 using Blind Search,
- step 3: try to generate X_new with the first 4 elements satisfying the constraints

  if successful, the remaining elements of X_new that do not satisfy the constraints are replaced with the lowest bound if they are smaller than the lowest bound or the highest bound if they are higher than the highest bound.

  if not successful go back to step 1
- step 4: compute the fitness of X_new and compare with the fitness of X.

  If smaller replace X with X_new then try step 3 again

  If successful, repeat step 4

  Else stop the search

  Else stop the search

3 Results

3.1 Blind Search - Random Walk

Table 1: Dimension 10 Statistics

functions	**Average**	**Std_Dev**	**Range**	**Median**	**Time**
Schwefel	2791.980667	291.0776924	962.2	2756.72	3.995
De Jong 1	16525.905	3617.690385	13096.2	16929.85	2.678
Rosenbrock's Saddle	4624192567	2200245473	9393093000	4288820000	3.04
Rastrigin	148664.7167	25816.99628	117756.8	145918.5	3.624
Griewangk	201.40451	54.26135096	208.219	201.822	3.206
Sine Envelope Sine Wave	-6.922858667	0.615849057	2.77131	-6.848245	1.48
Stretch V Sine Wave	3.14885	0	0	3.14885	1.519
Ackley One	117.9502767	12.70077553	61.5507	119.178	1.424
Ackley Two	155.9257667	10.47668637	36.86	160.025	1.518
Egg Holder	-1925.865933	493.5229002	2454.252	-1872.6	1.323
Rana	-1225.0452	271.6587289	1159.908	-1189.075	1.784
Pathological	2.832005333	0.385649688	1.41638	2.89944	1.353
Michalewicz	-3.042443667	0.44436953	1.659	-2.974425	1.964
Masters Cosine Wave	-4.86272	0	0	-4.86272	1.259
Quartic	262190090	97677136.01	448506000	237735500	1.403
Levy	3656.484	1295.195831	4943.7	3334.03	1.868
Step	13138.277	3374.336256	13117.89	13282.75	0.881
Alpine	131.9117867	26.00687297	121.9316	136.1985	1.019

3.2 Local Search

Table 2: Dimension 20 Statistics

functions	**Average**	**Std_Dev**	**Range**	**Median**	**Time**
Schwefel	6527.171	497.5107961	2439.71	6525.445	2.252
De Jong 1	41533.22	4928.844575	17352.1	40880.45	1.444
Rosenbrock's Saddle	16472465333	4250017316	17796330000	16453050000	1.715
Rastrigin	740840.4333	82896.64718	345145	741591.5	1.944
Griewangk	429.6261	80.48347128	321.087	436.6345	2.179
Sine Envelope Sine Wave	-12.62089	0.806189877	3.9751	-12.50965	3.103
Stretch V Sine Wave	6.64758	0	0	6.64758	2.841
Ackley One	284.143	19.37699629	111.196	286.921	2.915
Ackley Two	347.7151	14.88748464	72.136	351.511	4.082
Egg Holder	-2604.351	581.5784116	2357.24	-2658.305	2.788
Rana	-1564.0985	421.523801	1521.263	-1584.385	3.689
Pathological	6.641959	0.560611522	2.49116	6.656755	2.774
Michalewicz	-4.823475667	0.77204586	3.22257	-4.859355	4.006
Masters Cosine Wave	-10.2657	0	0	-10.2657	2.373
Quartic	1642857300	458365001.9	1757455000	1635585000	2.564
Levy	11734.552	3214.621751	12775.78	12098.1	3.711
Step	37725.31	6347.605771	30349.6	38781.55	1.604
Alpine	398.6774667	34.33233515	138.598	402.2505	2.073

Table 3: Dimension 30 Statistics

functions	**Average**	**Std_Dev**	**Range**	**Median**	**Time**
Schwefel	10366.28867	548.6806894	2203.76	10435.5	2.991
De Jong 1	67672.15	4818.68658	22768	68222.3	2.246
Rosenbrock's Saddle	28848830000	4560099220	1.64E+10	28823650000	2.594
Rastrigin	1831957	157146.7475	657190	1831840	2.931
Griewangk	647.8761333	119.2873485	487.709	655.329	3.865
Sine Envelope Sine Wave	-18.77424667	1.018582934	4.7194	-18.59065	5.917
Stretch V Sine Wave	10.1463	0	0	10.1463	4.971
Ackley One	456.8230333	32.99021513	147.591	460.3595	4.716
Ackley Two	542.6945333	16.00234794	75.443	547.5085	5.407
Egg Holder	-3635.889333	672.5280213	2362.62	-3508.42	4.028
Rana	-2139.410467	675.999664	2935.746	-2023.875	6
Pathological	11.203864	0.65777826	2.59885	11.3231	4.671
Michalewicz	-6.143787333	0.654736173	2.6587	-6.04617	7.811
Masters Cosine Wave	-15.6688	0	0	-15.6688	3.921
Quartic	4718703333	907832406.2	3339690000	4626180000	4.925
Levy	20984.54	3144.005418	14523.2	21149.05	5.313
Step	66257.93333	5486.357712	25835.5	66916.6	2.293
Alpine	657.0533667	74.66909381	317.88	660.826	3.646

Table 4: Dimension 10 Statistics

functions	**Average**	**Std_Dev**	**Range**	**Median**	**Time**
Schwefel	58.58366667	320.8759573	1757.51	0	12.058
De Jong 1	0.001008333	0.005522869	0.03025	0	2.15
Rosenbrock's Saddle	11798766.67	64624506.54	353963000	0	13602.2
Rastrigin	4214.333333	23082.85432	126430	0	18.753
Griewangk	10.23153333	56.04041605	306.946	0	0.085
Sine Envelope Sine Wave	-0.211197667	1.156777261	6.33593	0	0.066
Stretch V Sine Wave	0.104961667	0.574898725	3.14885	0	0.065
Ackley One	3.660633333	20.05011451	109.819	0	0.814
Ackley Two	5.2554	28.78501129	157.662	0	0.081
Egg Holder	-127.2736667	697.1065821	3818.21	0	38.261
Rana	-58.382	319.7713835	1751.46	0	58.586
Pathological	0.101255333	0.554598301	3.03766	0	0.105
Michalewicz	-0.102954	0.563902282	3.08862	0	0.104
Masters Cosine Wave	-0.162090667	0.887807145	4.86272	0	0.062
Quartic	10003166.67	54789600.3	300095000	0	139.273
Levy	133.3613333	730.4501057	4000.84	0	0.089
Step	0.092407667	0.506137635	2.77223	0	0.486
Alpine	5.3369	29.23140517	160.107	0	0.051

3.3 Iterative Local Search

Table 5: Dimension 20 Statistics

functions	**Average**	**Std_Dev**	**Range**	**Median**	**Time**
Schwefel	150.7426667	825.6515891	4522.28	0	28.716
De Jong 1	0.001999083	0.01094943	0.0599725	0	1.783
Rosenbrock's Saddle	254812666.7	1395666455	7644380000	0	47623.3
Rastrigin	28142.73333	154144.0988	844282	0	131.54
Griewangk	10.63853333	58.26964685	319.156	0	0.117
Sine Envelope Sine Wave	-0.4249	2.327273147	12.747	0	0.158
Stretch V Sine Wave	0.221586	1.213676506	6.64758	0	0.193
Ackley One	7.901266667	43.27701986	237.038	0	9.043
Ackley Two	10.52043333	57.62278651	315.613	0	0.341
Egg Holder	-334.96	1834.651479	10048.8	0	14.048
Rana	-124.6566667	682.7726828	3739.7	0	114.051
Pathological	0.16766	0.91831164	5.0298	0	0.173
Michalewicz	-0.147975667	0.810496106	4.43927	0	0.19
Masters Cosine Wave	-0.34219	1.87425182	10.2657	0	0.118
Quartic	49359000	270350377.2	1480770000	0	268.579
Levy	290.802	1592.788152	8724.06	0	0.181
Step	0.195082667	1.068511771	5.85248	0	1.53
Alpine	11.61853333	63.63732792	348.556	0	0.114

4 analysis

From the results above, we can see that

- Blind Search produced better results than what we obtained in project1 and it took more time to run
- A a huge improvement in the results for Local search especially for functions such as De Jong 1 and Step. However functions such as Rosenbrock's Saddle have an important increase in running time as the dimension increases.
- A huge improvement in the results for Iterative Local Search especially for functions such as De Jong 1 and Step. However functions such as Rosenbrock's Saddle have an important increase in running time as the dimension increases.

Table 6: Dimension 30 Statistics

functions	**Average**	**Std_Dev**	**Range**	**Median**	**Time**
Schwefel	348.4533333	1908.557509	10453.6	0	0.814
De Jong 1	0.003014107	0.016508942	0.0904232	0	3.776
Rosenbrock's Saddle	630606666.7	3453974962	18918200000	0	170847
Rastrigin	51346.33333	281235.4501	1540390	0	850.817
Griewangk	20.37886667	111.6196497	611.366	0	0.412
Sine Envelope Sine Wave	-0.64229	3.517967215	19.2687	0	0.247
Stretch V Sine Wave	0.33821	1.852452462	10.1463	0	0.244
Ackley One	4.318066667	23.65102518	129.542	0	368.024
Ackley Two	16.78063333	91.91131406	503.419	0	1.653
Egg Holder	-126.1816667	691.1254518	3785.45	0	0.466
Rana	-188.9333333	1034.830485	5668	0	1847.03
Pathological	0.315669333	1.728992146	9.47008	0	0.226
Michalewicz	-0.23299	1.276138787	6.9897	0	0.315
Masters Cosine Wave	-0.522293333	2.860718403	15.6688	0	0.211
Quartic	116780000	639630402.7	3503400000	0	3530.86
Levy	508.04	2782.649681	15241.2	0	0.251
Step	0.297757667	1.630885907	8.93273	0	3.333
Alpine	14.5425	79.65255293	436.275	0	0.159

Table 7: Dimension 10 Statistics

functions	**Average**	**Std_Dev**	**Range**	**Median**	**Time**
Schwefel	2003.243333	474.2111143	1786.18	1919.765	261.032
De Jong 1	0.028802637	0.003862826	0.0191893	0.03025	45.636
Rosenbrock's Saddle	2630588033	2006474690	10097728000	2094715000	452716
Rastrigin	140977.8267	33841.44393	138324.1	143023	198.816
Griewangk	191.76939	51.19340152	195.0953	192.833	2.032
Sine Envelope Sine Wave	-6.939682	0.713454114	3.39156	-6.84324	1.712
Stretch V Sine Wave	3.14885	0	0	3.14885	1.742
Ackley One	80.06737667	22.8015399	101.0331	83.3242	190.95
Ackley Two	145.7989	9.034239465	43.696	145.394	10.09
Egg Holder	-3789.828667	871.01063	3586.89	-4003.63	861.046
Rana	-2523.165333	438.0029619	2036.1	-2514.12	3408.66
Pathological	2.533137	0.582381215	1.66895	2.84279	2.378
Michalewicz	-3.167197333	0.522815259	2.32004	-3.03604	3.053
Masters Cosine Wave	-4.86272	0	0	-4.86272	1.601
Quartic	205903215.3	134721802.8	595511840	212273500	4469.49
Levy	3529.281	1341.583186	5591.29	3477.88	2.478
Step	2.742326	0.034906845	0.11254	2.77223	12.526
Alpine	112.87565	37.74860018	128.3744	115.07	1.464

Table 8: Dimension 20 Statistics

functions	**Average**	**Std_Dev**	**Range**	**Median**	**Time**
Schwefel	5349.959333	833.0708793	3215.12	5427.575	88.168
De Jong 1	0.05861557	0.003440556	0.0144963	0.06049525	128.441
Rosenbrock's Saddle	13890126000	4353422851	13696690000	13879200000	2083430
Rastrigin	679651.0667	118911.6049	403302	709955.5	4251.21
Griewangk	401.0995333	88.40290025	409.522	376.792	4.832
Sine Envelope Sine Wave	-12.92433	0.902936084	3.97	-12.7076	4.524
Stretch V Sine Wave	6.64758	0	0	6.64758	4.848
Ackley One	108.84064	61.77663165	289.4516	97.21155	2354.53
Ackley Two	322.5091333	11.07080453	50.513	323.639	19.793
Egg Holder	-6305.350333	1772.180963	6634.7	-6368.3	2049.19
Rana	-4174.622667	1437.45537	4448.15	-4881.995	6065.86
Pathological	6.662634	0.728605562	3.16817	6.83328	4.897
Michalewicz	-4.703353	0.80069119	3.38948	-4.642095	6.553
Masters Cosine Wave	-10.2657	0	0	-10.2657	4.584
Quartic	1536148800	457643739.1	1819939000	1515630000	17005
Levy	10592.45333	2298.647743	10042.47	10707.9	6.561
Step	5.830438333	0.036700114	0.1668	5.85248	41.501
Alpine	335.3355667	76.88795167	321.078	335.2905	2.813

Table 9: Dimension 30 Statistics

functions	**Average**	**Std_Dev**	**Range**	**Median**	**Time**
Schwefel	8524.176333	1534.019548	5645.07	8900.215	531.589
De Jong 1	0.08841921	0.004873262	0.0204715	0.09064685	257.946
Rosenbrock's Saddle	30261086667	5284273518	20748900000	31175950000	5027350
Rastrigin	1807029.333	218190.8544	962950	1844870	22638.3
Griewangk	624.0755667	102.2444293	468.442	617.383	8.409
Sine Envelope Sine Wave	-18.74105333	0.938625765	4.1451	-18.7994	8.013
Stretch V Sine Wave	10.1463	0	0	10.1463	7.366
Ackley One	134.70534	61.93493793	246.6545	123.982	7887.24
Ackley Two	509.1312	17.83768659	72.902	511.361	39.245
Egg Holder	-8374.537333	2328.901041	8591.22	-8846.365	3427.19
Rana	-5716.058	2287.012655	7621.78	-6208.22	25106.8
Pathological	10.77505467	0.900178638	3.51734	11.07975	8.148
Michalewicz	-6.438007333	0.898783791	3.2804	-6.27621	10.194
Masters Cosine Wave	-15.6688	0	0	-15.6688	7.349
Quartic	4610232667	889375037.1	4112990000	4864860000	26865.2
Levy	17516.24667	3715.052894	14714.9	16791.6	10.186
Step	8.912498	0.032293924	0.14115	8.93273	87.146
Alpine	507.1146	120.48491	365.012	491.329	5.231