

Multimodal Optimization Using Particle Swarm Optimization Algorithms: CEC 2015 Competition on Single Objective Multi-Niche Optimization

Shi Cheng*, Quande Qin[†], Zhou Wu[‡], Yuhui Shi[§], and Qingyu Zhang[‡]

*Division of Computer Science, University of Nottingham Ningbo, China

[†]Department of Management Science, Shenzhen University, Shenzhen, China

[‡]Department of Electrical Electronic and Computer Engineering, University of Pretoria, Hatfield, Pretoria, South Africa

[§]Department of Electrical & Electronic Engineering, Xi'an Jiaotong-Liverpool University, Suzhou, China

shi.cheng@nottingham.edu.cn, yuhui.shi@xjtlu.edu.cn

Abstract—The aim of multimodal optimization is to locate multiple peaks/optima in a single run and to maintain these found optima until the end of a run. The results of seven variants of particle swarm optimization (PSO) algorithms on IEEE Congress on Evolutionary Computation (CEC) 2015 single objective multi-niche optimization problems are reported in this paper. The PSO algorithms include PSO with star structure, PSO with ring structure, PSO with four clusters structure, PSO with Von Neumann structure, social-only PSO with star structure, social-only PSO with ring structure, and cognition-only PSO. The experimental tests are conducted on fifteen benchmark functions. Based on the experimental results, the conclusions could be made that the PSO with ring structure performs better than the other PSO variants on multimodal optimization. To obtain good performance on the multimodal optimization problems, an algorithm needs to converge the candidate solutions to the global optima while keep the population diversity during whole search process.

I. AVERAGE NUMBER OF OPTIMA FOUND

TABLE I
THE RESULTS OF PSO WITH STAR STRUCTURE ON AVERAGE NUMBER OF OPTIMA FOUND (FUNCTIONS 1-8).

Func.	Dimension	Best	Worst	Median	Mean	Total	Std
f_1	5	1	0	0	0.3529	18	0.4778
	10	1	0	0	0.0196	1	0.1386
	20	0	0	0	0	0	0
f_2	2	1	1	1	1	51	0
	5	1	1	1	1	51	0
	8	1	1	0	0.9215	47	0.2688
f_3	2	3	1	1	1.4117	72	0.5304
	3	2	1	1	1.0196	52	0.1386
	4	2	1	1	1.0196	52	0.1386
f_4	5	1	0	0	0.0784	4	0.2688
	10	0	0	0	0	0	0
	20	0	0	0	0	0	0
f_5	2	3	1	1	1.2156	62	0.45648
	3	2	1	1	1.05882	54	0.23529
	4	2	1	1	1.01960	52	0.13864
f_6	4	1	1	1	1	51	0
	6	1	1	1	1	51	0
	8	1	1	1	1	51	0
f_7	6	1	1	0	0.90196	46	0.29736
	10	1	1	0	0.64705	33	0.47788
	16	1	0	0	0.37254	19	0.48348
f_8	2	3	1	1	1.3529	69	0.62067
	3	2	1	1	1.09803	56	0.29736
	4	1	1	1	1	51	0

TABLE II
THE RESULTS OF PSO WITH RING STRUCTURE ON AVERAGE NUMBER OF OPTIMA FOUND (FUNCTIONS 1-8).

Func.	Dimension	Best	Worst	Median	Mean	Total	Std
f_1	5	1	1	0	0.7058	36	0.45564
	10	1	0	0	0.11764	6	0.32218
	20	0	0	0	0	0	0
f_2	2	4	4	3	3.9803	203	0.13864
	5	18	14	9	13.6470	696	1.96861
	8	22	16	9	15.8823	810	2.9147
f_3	2	21	17	12	16.705	852	1.68376
	3	47	39	30	39.3529	2007	3.0151
	4	138	119	107	119.7254	6106	6.8372
f_4	5	1	0	0	0.39215	20	0.48823
	10	0	0	0	0	0	0
	20	0	0	0	0	0	0
f_5	2	21	16	11	16.2745	830	1.9105
	3	47	39	34	39.0784	1993	2.8754
	4	130	117	108	118.3529	6036	4.9579
f_6	4	11	9	6	8.9803	458	1.2125
	6	25	19	15	18.9215	965	2.1036
	8	45	39	32	38.7843	1978	2.76046
f_7	6	8	6	3	5.7450	293	1.1174
	10	10	7	3	6.6274	338	1.7145
	16	10	6	1	6.4117	327	2.0309
f_8	2	15	11	5	10.5686	539	1.9428
	3	37	29	24	29.2352	1491	2.8394
	4	98	87	74	87.1960	4447	5.3979

TABLE III
THE RESULTS OF PSO WITH FOUR CLUSTERS STRUCTURE ON AVERAGE NUMBER OF OPTIMA FOUND (FUNCTIONS 1-8).

Func.	Dimension	Best	Worst	Median	Mean	Total	Std
f_1	5	1	0	0	0.43137	22	0.49526
	10	0	0	0	0	0	0
	20	0	0	0	0	0	0
f_2	2	4	3	1	2.5882	132	0.66203
	5	4	4	2	3.5882	183	0.53049
	8	4	3	2	3.1960	163	0.74147
f_3	2	6	4	2	4.0196	205	0.828184
	3	4	4	3	3.94117	201	0.23529
	4	4	4	3	3.98039	203	0.13864
f_4	5	1	0	0	0.23529	12	0.424182
	10	0	0	0	0	0	0
	20	0	0	0	0	0	0
f_5	2	6	4	3	3.96078	202	0.655617
	3	5	4	3	3.90196	199	0.35727
	4	5	4	3	4	204	0.19802
f_6	4	4	3	2	3.3725	172	0.5927
	6	4	4	3	3.78431	193	0.41129
	8	4	4	3	3.96078	202	0.19410
f_7	6	4	3	1	2.45098	125	0.7749
	10	4	1	0	1.54901	79	1.05372
	16	2	1	0	0.64705	33	0.65149
f_8	2	5	4	2	3.52941	180	0.66724
	3	6	4	2	3.8039	194	0.65737
	4	5	4	3	3.96078	202	0.34074

TABLE IV
THE RESULTS OF PSO WITH VON NEUMANN STRUCTURE ON AVERAGE NUMBER OF OPTIMA FOUND (FUNCTIONS 1-8).

Func.	Dimension	Best	Worst	Median	Mean	Total	Std
f_1	5	1	1	0	0.686274	35	0.46400
	10	1	0	0	0.03921	2	0.19410
	20	0	0	0	0	0	0
f_2	2	4	4	2	3.68627	188	0.50449
	5	13	9	5	9.47058	483	1.85083
	8	18	14	9	13.254	676	2.1221
f_3	2	13	11	7	10.5294	537	1.51272
	3	25	20	17	20.1764	1029	2.05517
	4	89	72	67	74.0588	3777	4.81994
f_4	5	1	0	0	0.29411	15	0.45564
	10	0	0	0	0	0	0
	20	0	0	0	0	0	0
f_5	2	15	11	5	10.3333	527	1.85415
	3	27	20	16	19.8039	1010	2.15132
	4	82	74	65	73.1372	3730	4.29326
f_6	4	7	5	2	5	255	1.13759
	6	13	10	5	10.0392	512	1.48139
	8	24	20	15	19.9607	1018	1.9599
f_7	6	6	4	2	4.01960	205	0.89640
	10	7	5	2	4.96078	253	1.20392
	16	12	6	1	5.54901	283	2.19905
f_8	2	8	5	3	5.2549	268	1.43954
	3	20	13	9	13.5098	689	2.66695
	4	61	48	37	47.5882	2427	5.47069

TABLE V
THE RESULTS OF SOCIAL-ONLY PSO WITH STAR STRUCTURE ON AVERAGE NUMBER OF OPTIMA FOUND (FUNCTIONS 1-8).

Func.	Dimension	Best	Worst	Median	Mean	Total	Std
f_1	5	1	0	0	0.17647	9	0.38122
	10	0	0	0	0	0	0
	20	0	0	0	0	0	0
f_2	2	1	1	1	1	51	0
	5	1	1	0	0.9803	50	0.13864
	8	1	1	0	0.88235	45	0.32218
f_3	2	1	1	1	1	51	0
	3	1	1	1	1	51	0
	4	1	1	1	1	51	0
f_4	5	1	0	0	0.03921	2	0.19410
	10	0	0	0	0	0	0
	20	0	0	0	0	0	0
f_5	2	1	1	1	1	51	0
	3	1	1	1	1	51	0
	4	1	1	1	1	51	0
f_6	4	1	1	1	1	51	0
	6	1	1	1	1	51	0
	8	1	1	0	0.9803	50	0.13864
f_7	6	1	1	0	0.92156	47	0.26884
	10	1	1	0	0.54901	28	0.49759
	16	1	0	0	.23529	12	0.42418
f_8	2	1	1	1	1	51	0
	3	1	1	1	1	51	0
	4	1	1	1	1	51	0

TABLE VI
THE RESULTS OF SOCIAL-ONLY PSO WITH RING STRUCTURE ON AVERAGE NUMBER OF OPTIMA FOUND (FUNCTIONS 1-8).

Func.	Dimension	Best	Worst	Median	Mean	Total	Std
f_1	5	1	1	0	0.5882	30	0.4921
	10	1	0	0	0.01960	1	0.13864
	20	0	0	0	0	0	0
f_2	2	4	4	4	4	204	0
	5	18	13	10	12.8823	657	1.85395
	8	18	12	4	11.7647	600	2.9076
f_3	2	19	14	11	14.3333	731	1.52966
	3	31	27	21	26.5294	1353	1.82952
	4	103	89	80	89.5294	4566	4.0552
f_4	5	1	0	0	0.1960	10	0.3970
	10	0	0	0	0	0	0
	20	0	0	0	0	0	0
f_5	2	17	14	11	13.9215	710	1.45309
	3	30	26	22	25.9019	1321	1.9629
	4	96	88	79	88.0588	4491	4.1321
f_6	4	11	8	5	7.80392	398	1.45547
	6	19	15	11	14.7450	752	1.64308
	8	30	26	22	26.0588	1329	1.8620
f_7	6	7	5	2	5.05882	258	1.2432
	10	8	5	2	4.96078	253	1.5334
	16	8	4	0	3.8627	197	1.6688
f_8	2	12	9	6	8.8235	450	1.50431
	3	26	19	15	19.3529	987	2.33325
	4	90	77	65	76.2941	3891	5.72334