Modyfikacje/hybrydyzacje algorytmu PSO w zadaniu optymalizacji globalnej wielowymiarowej funkcji ciaglej

PSO-DE Hybrid

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ABSTRACT

Dokumentacja uzyskanych wynikow hybrydy PSO-DE

Categories and Subject Descriptors

G.1.6 [**Numerical Analysis**]: Optimization—*global optimization, unconstrained optimization*; F.2.1 [**Analysis of Algorithms and Problem Complexity**]: Numerical Algorithms and Problems

General Terms

Algorithms

Keywords

Benchmarking, PSODE, Optymalizacja wielowymiarowej funkcji ciaglej

1. CPU TIMING

In order to evaluate the CPU timing of the algorithm, we have run the PSO-DE Hybrid on the function f_8 with restarts for at least 30 seconds and until a maximum budget equal to $400(D + 2)$ is reached. The code was run on a Mac Intel(R) Core(TM) i5-2400S CPU @ 2.50GHz with 1 processor and 4 cores. The time per function evaluation for dimensions 2, 3, 5, 10, 20, 40 equals $x.x$, $x.x$, $x.x$, xx, xxx, and xxx milliseconds respectively.

repeat the above for the second algorithm

2. RESULTS

Results from experiments according to [?] on the benchmark functions given in [?, ?] are presented in Figures 1, 2 and 3 and in Table 1. The **expected running time (ERT)**, used in the figures and table, depends on a given target function value, $f_t = f_{opt} + \Delta f$, and is computed over all relevant trials as the number of function evaluations executed during each trial while the best function value did not reach f_t, summed over all trials and divided by the number of trials that actually reached f_t [?, ?]. **Statistical significance** is tested with the rank-sum test for a given target Δf_t (10^{-8} as in Figure 1) using, for each trial, either the number of needed function evaluations to reach Δf_t (inverted and multiplied by -1), or, if the target was not reached, the best Δf-value achieved, measured only up to the smallest number of overall function evaluations for any unsuccessful trial under consideration.

GECCO'13, July 6-10, 2013, Amsterdam, The Netherlands.

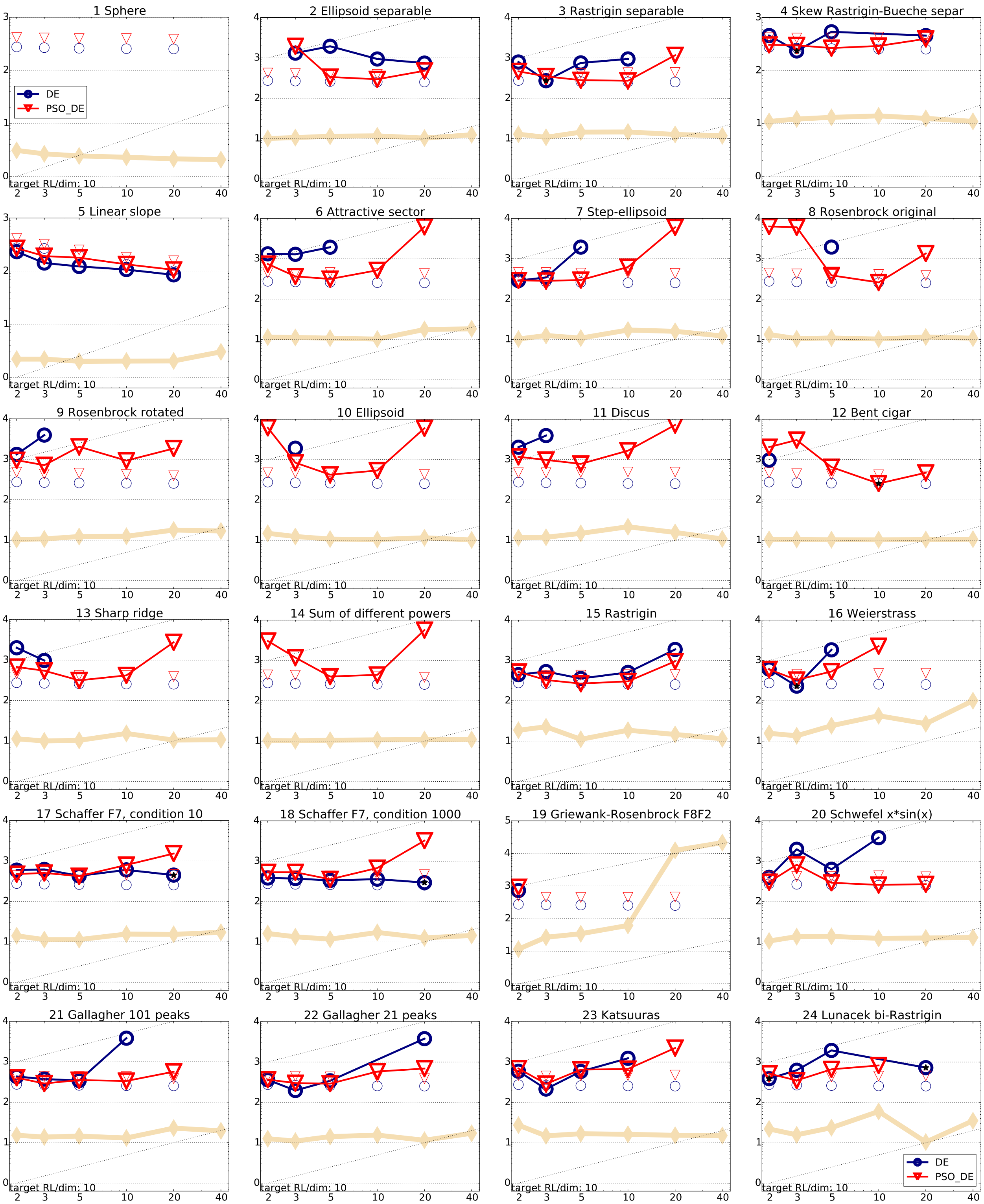

Figure 1: Expected running time (ERT in number of f-evaluations as $\log_{10}$ value) divided by dimension versus dimension. The target function value is chosen such that the bestGECCO2009 artificial algorithm just failed to achieve an ERT of $10 \times \mathrm{DIM}$. Different symbols correspond to different algorithms given in the legend of f_1 and f_{24}. Light symbols give the maximum number of function evaluations from the longest trial divided by dimension. Black stars indicate a statistically better result compared to all other algorithms with $p < 0.01$ and Bonferroni correction number of dimensions (six). Legend: ○:DE, ▽:PSO DE.

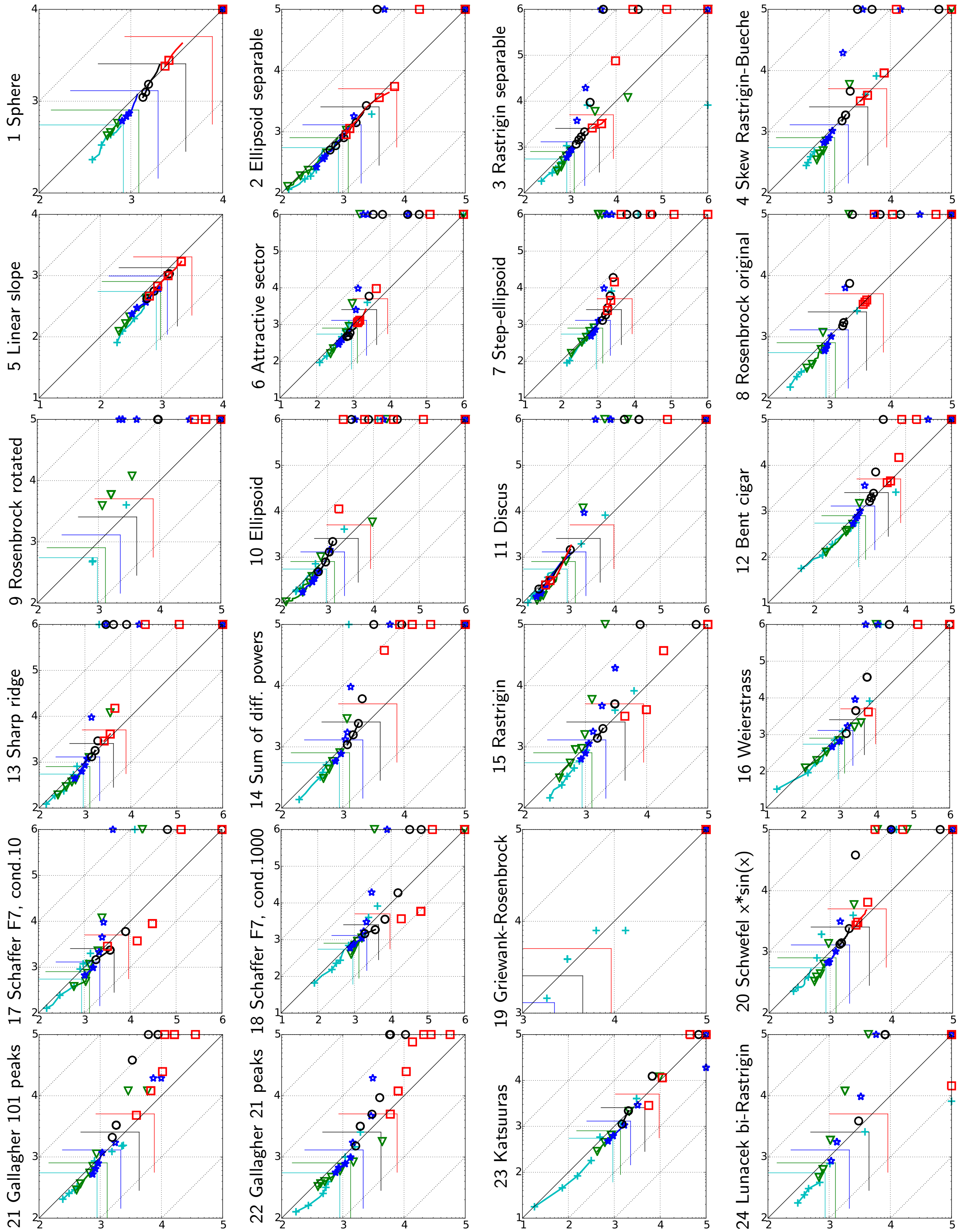

Figure 2: Expected running time (ERT in $\log_{10}$ of number of function evaluations) of DE (y-axis) versus PSO DE (x-axis) for 8 runlength-based target function values for budgets between $0.5\times\mathrm{DIM}$ and $50\times\mathrm{DIM}$ evaluations. Each runlength-based target f-value is chosen such that the ERTs of the bestGECCO2009 artificial algorithm for the given and a slightly easier target bracket the reference budget. Markers on the upper or right edge indicate that the respective target value was never reached. Markers represent dimension: 2:+, 3:▽, 5:⋆, 10:○, 20:□, 40:◇.

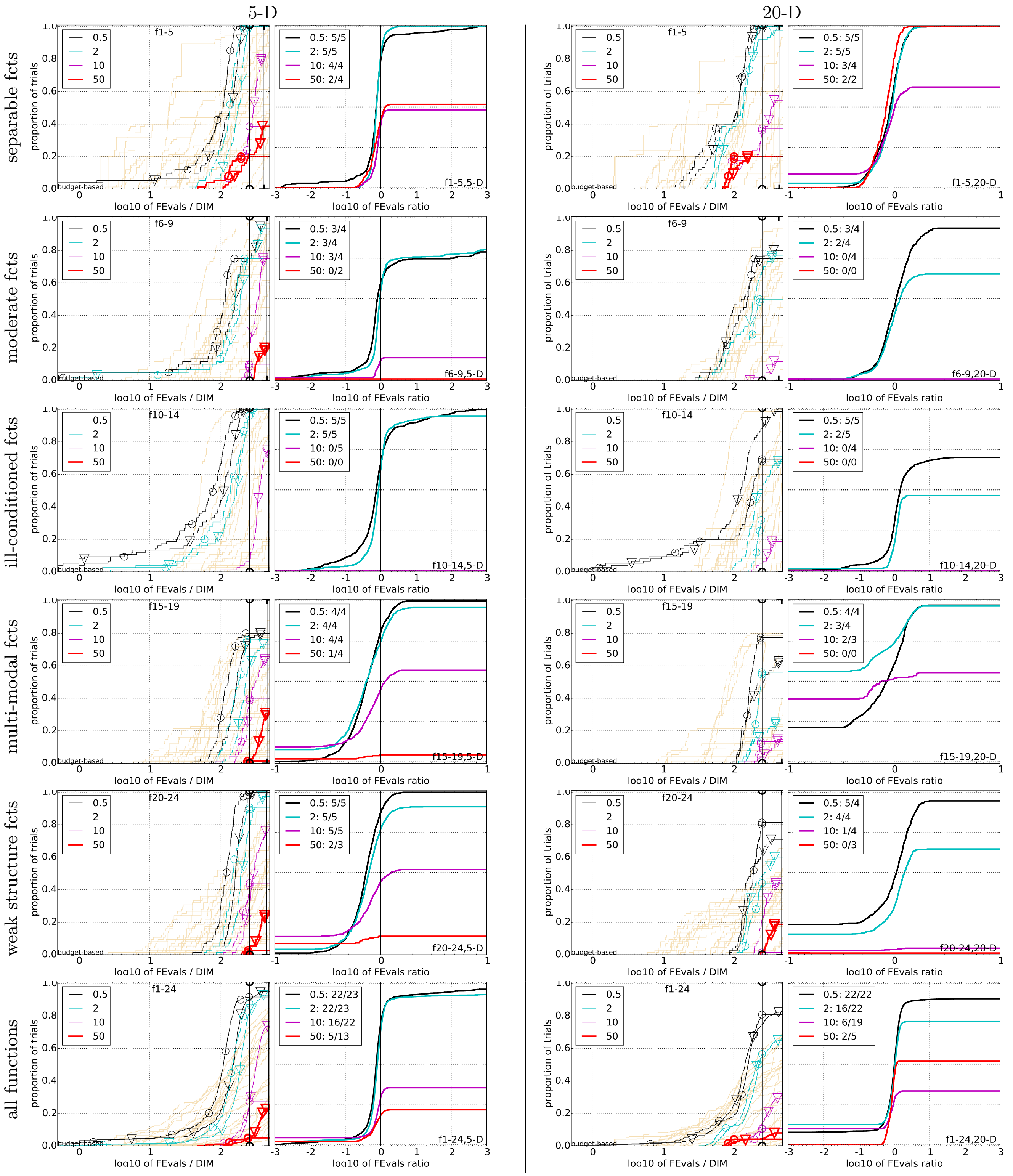

Figure 3: Empirical cumulative distributions (ECDF) of run lengths and speed-up ratios in 5-D (left) and 20-D (right). Left sub-columns: ECDF of the number of function evaluations divided by dimension D (FEvals/D) to fall below $f_{\mathrm{opt}} + \Delta f$ for DE ($\circ$) and PSO DE ($\triangledown$) where Δf is the target just not reached by the GECCO-BBOB-2009 best algorithm within a budget of $k \times \mathrm{DIM}$ evaluations, with k being the value in the legend. Right sub-columns: ECDF of FEval ratios of DE divided by PSO DE for run-length-based targets; all trial pairs for each function. Pairs where both trials failed are disregarded, pairs where one trial failed are visible in the limits being > 0 or < 1. The legends indicate the target budget of $k \times \mathrm{DIM}$ evaluations and, after the colon, the number of functions that were solved in at least one trial (DE first).

5-D

#FEs/D	0.5	1.2	3	10	50	#succ
f1	*2.5e+1*:4.8	*1.6e+1*:7.6	*1.0e-8*:12	*1.0e-8*:12	*1.0e-8*:12	15/15
1: DE	127(38)	90(22)	∞	∞	∞ *1300*	0/15
2: PSO	168(40)	118(14)	∞	∞	∞ *1900*	0/15
f2	*1.6e+6*:2.9	*4.0e+5*:11	*4.0e+4*:15	*6.3e+2*:58	*1.0e-8*:95	15/15
1: DE	93(50)	36(10)	45(15)	169(187)	∞ ***1300***$^{\star 2}$	0/15
2: PSO	129(54)	46(20)	53(5)	29(4)	∞ *2000*	0/15
f3	*1.6e+2*:4.1	*1.0e+2*:15	*6.3e+1*:23	*2.5e+1*:73	*1.0e+1*:716	15/15
1: DE	**144**(35)$^{\star 2}$	**51**(6)*	38(8)	52(18)	∞ *1300*	0/15
2: PSO	205(36)	65(7)	46(11)	19(4)	6.6(6)	6/15
f4	*2.5e+2*:2.6	*1.6e+2*:10	*1.0e+2*:19	*4.0e+1*:65	*1.6e+1*:434	15/15
1: DE	255(33)	**74**(7)*	42(6)	41(10)	∞ *1300*	0/15
2: PSO	316(43)	93(31)	53(19)	20(3)	8.2(4)	8/15
f5	*6.3e+1*:4.0	*4.0e+1*:10	*1.0e-8*:10	*1.0e-8*:10	*1.0e-8*:10	15/15
1: DE	59(45)	30(17)	61(17)	61(17)	61(26)	15/15
2: PSO	82(56)	40(34)	90(34)	90(35)	90(25)	15/15
f6	*1.0e+5*:3.0	*2.5e+4*:8.4	*1.0e+2*:16	*2.5e+1*:54	*2.5e-1*:254	15/15
1: DE	96(97)	42(40)	81(7)	179(212)	∞ *1300*	0/15
2: PSO	133(143)	53(46)	66(17)	29(6)	123(159)	1/15
f7	*1.6e+2*:4.2	*1.0e+2*:6.2	*2.5e+1*:20	*4.0e+0*:54	*1.0e+0*:324	15/15
1: DE	115(36)	101(13)	63(26)	179(222)	∞ *1300*	0/15
2: PSO	157(76)	125(28)	52(13)	27(6)	7.4(4)	11/15
f8	*1.0e+4*:4.6	*6.3e+3*:6.8	*1.0e+3*:18	*6.3e+1*:54	*1.6e+0*:258	15/15
1: DE	**129**(23)$^{\star 2}$	**95**(19)$^{\star 2}$	52(9)	178(221)	∞ *1300*	0/15
2: PSO	183(40)	131(26)	58(7)	36(25)	∞ *2000*	0/15
f9	*2.5e+1*:20	*1.6e+1*:26	*1.0e+1*:35	*4.0e+0*:62	*1.6e-2*:256	15/15
1: DE	∞	∞	∞	∞	∞ *1300*	0/15
2: PSO	111(66)	96(148)	102(77)	166(153)	∞ *2000*	0/15
f10	*2.5e+6*:2.9	*6.3e+5*:7.0	*2.5e+5*:17	*6.3e+3*:54	*2.5e+1*:297	15/15
1: DE	60(59)	41(41)	24(17)	∞	∞ *1300*	0/15
2: PSO	99(58)	67(40)	35(18)	39(59)	∞ *2200*	0/15
f11	*1.0e+6*:3.0	*6.3e+4*:6.2	*6.3e+2*:16	*6.3e+1*:74	*6.3e-1*:298	15/15
1: DE	46(66)	32(38)	46(28)	∞	∞ *1300*	0/15
2: PSO	68(117)	47(55)	42(36)	53(57)	∞ *2300*	0/15
f12	*4.0e+7*:3.6	*1.6e+7*:7.6	*4.0e+6*:19	*1.6e+4*:52	*1.0e+0*:268	15/15
1: DE	148(69)	94(27)	53(8)	∞	∞ *1300*	0/15
2: PSO	199(54)	110(30)	53(14)	63(21)	∞ *2100*	0/15
f13	*1.0e+3*:2.8	*6.3e+2*:8.4	*4.0e+2*:17	*6.3e+1*:52	*6.3e-2*:264	15/15
1: DE	158(30)	**75**(19)*	51(15)	∞	∞ *1300*	0/15
2: PSO	214(120)	101(17)	59(10)	30(4)	∞ *2000*	0/15
f14	*1.6e+1*:3.0	*1.0e+1*:10	*6.3e+0*:15	*2.5e-1*:53	*1.0e-5*:251	15/15
1: DE	195(40)	79(20)	86(107)	∞	∞ *1300*	0/15
2: PSO	252(55)	96(20)	71(20)	38(13)	∞ *2000*	0/15
f15	*1.6e+2*:3.0	*1.0e+2*:13	*6.3e+1*:24	*4.0e+1*:55	*1.6e+1*:289	5/5
1: DE	210(71)	61(21)	46(34)	32(23)	67(92)	1/15
2: PSO	282(49)	77(22)	47(8)	24(6)	11(8)	9/15
f16	*4.0e+1*:4.8	*2.5e+1*:16	*1.6e+1*:46	*1.0e+1*:120	*4.0e+0*:334	15/15
1: DE	97(28)	42(11)	37(16)	76(162)	∞ *1300*	0/15
2: PSO	130(53)	65(23)	36(9)	22(39)	33(16)	3/15
f17	*1.0e+1*:5.2	*6.3e+0*:26	*4.0e+0*:57	*2.5e+0*:110	*6.3e-1*:412	15/15
1: DE	**128**(23)$^{\star 2}$	38(9)	38(16)	41(66)	∞ *1300*	0/15
2: PSO	196(60)	60(34)	37(30)	22(21)	10(12)	7/15
f18	*6.3e+1*:3.4	*4.0e+1*:7.2	*2.5e+1*:20	*1.6e+1*:58	*1.6e+0*:318	15/15
1: DE	175(27)	106(38)	55(21)	29(12)	∞ *1300*	0/15
2: PSO	225(98)	132(61)	80(64)	31(38)	24(22)	4/15
f19	*1.6e-1*:172	*1.0e-1*:242	*6.3e-2*:675	*4.0e-2*:3078	*2.5e-2*:4946	15/15
1: DE	∞	∞	∞	∞	∞ *1300*	0/15
2: PSO	∞	∞	∞	∞	∞ *2100*	0/15
f20	*6.3e+3*:5.1	*4.0e+3*:8.4	*4.0e+1*:15	*2.5e+0*:69	*1.0e+0*:851	15/15
1: DE	**129**(26)$^{\star 2}$	**81**(22)$^{\star 2}$	**57**(15)*	46(38)	∞ ***1300****	0/15
2: PSO	177(19)	113(17)	75(15)	21(5)	∞ *2000*	0/15
f21	*4.0e+1*:3.9	*2.5e+1*:11	*1.6e+1*:31	*6.3e+0*:73	*1.6e+0*:347	5/5
1: DE	**133**(27)*	60(27)	25(4)	24(11)	56(45)	1/15
2: PSO	191(34)	79(31)	30(13)	24(25)	21(23)	4/15
f22	*6.3e+1*:3.6	*4.0e+1*:15	*2.5e+1*:32	*1.0e+1*:71	*1.6e+0*:341	5/5
1: DE	**155**(46)*	45(12)	24(4)	24(38)	57(82)	1/15
2: PSO	212(36)	58(16)	34(26)	20(15)	9.1(4)	9/15
f23	*1.0e+1*:3.0	*6.3e+0*:9.0	*4.0e+0*:33	*2.5e+0*:84	*1.0e+0*:518	15/15
1: DE	**159**(49)$^{\star 2}$	**69**(32)*	32(19)	35(34)	∞ *1300*	0/15
2: PSO	244(60)	105(27)	50(44)	39(36)	∞ *2200*	0/15
f24	*6.3e+1*:15	*4.0e+1*:37	*4.0e+1*:37	*2.5e+1*:118	*1.6e+1*:692	15/15
1: DE	59(20)	48(13)	48(40)	82(116)	∞ *1300*	0/15
2: PSO	74(19)	37(7)	37(5)	28(24)	8.5(10)	5/15

20-D

#FEs/D	0.5	1.2	3	10	50	#succ
f1	*6.3e+1*:24	*4.0e+1*:42	*1.0e-8*:43	*1.0e-8*:43	*1.0e-8*:43	15/15
1: DE	100(6)	67(4)	∞	∞	∞ *5100*	0/15
2: PSO	97(14)	62(10)	∞	∞	∞ *7700*	0/15
f2	*4.0e+6*:29	*2.5e+6*:42	*1.0e+5*:65	*1.0e+4*:207	*1.0e-8*:412	15/15
1: DE	31(6)	27(4)	49(6)	72(56)	∞ *5100*	0/15
2: PSO	40(4)	31(6)	51(8)	46(22)	∞ *7600*	0/15
f3	*6.3e+2*:33	*4.0e+2*:44	*1.6e+2*:109	*1.0e+2*:255	*2.5e+1*:3277	15/15
1: DE	79(9)	74(13)	693(775)	∞	∞ *5100*	0/15
2: PSO	92(28)	110(60)	89(51)	91(235)	∞ *8500*	0/15
f4	*6.3e+2*:22	*4.0e+2*:91	*2.5e+2*:250	*1.6e+2*:332	*6.3e+1*:1927	15/15
1: DE	147(24)	43(5)	37(21)	∞	∞ *5100*	0/15
2: PSO	150(45)	47(15)	32(17)	38(13)	∞ *8300*	0/15
f5	*2.5e+2*:19	*1.6e+2*:34	*1.0e-8*:41	*1.0e-8*:41	*1.0e-8*:41	15/15
1: DE	24(6)	20(6)	42(5)	42(5)	42(4)	15/15
2: PSO	33(12)	25(6)	52(11)	52(20)	52(12)	15/15
f6	*2.5e+5*:16	*6.3e+4*:43	*1.6e+4*:62	*1.6e+2*:353	*1.6e+1*:1078	15/15
1: DE	70(24)	30(10)	25(7)	∞	∞ *5100*	0/15
2: PSO	81(11)	35(8)	27(7)	349(502)	∞ *8400*	0/15
f7	*1.0e+3*:11	*4.0e+2*:39	*2.5e+2*:74	*6.3e+1*:319	*1.0e+1*:1351	15/15
1: DE	228(62)	372(452)	∞	∞	∞ *5100*	0/15
2: PSO	174(25)	**73**(17)$^{\star 3}$	**59**(44)$^{\star 3}$	377(347)	∞ *8400*	0/15
f8	*4.0e+4*:19	*2.5e+4*:35	*4.0e+3*:67	*2.5e+2*:231	*1.6e+1*:1470	15/15
1: DE	181(20)	105(5)	185(170)	∞	∞ *5100*	0/15
2: PSO	191(45)	110(28)	75(17)	117(123)	∞ *7600*	0/15
f9	*1.0e+2*:357	*6.3e+1*:560	*4.0e+1*:684	*2.5e+1*:756	*1.0e+1*:1716	15/15
1: DE	∞	∞	∞	∞	∞ *5100*	0/15
2: PSO	104(120)	101(131)	169(158)	∞	∞ *7700*	0/15
f10	*1.6e+6*:15	*1.0e+6*:27	*4.0e+5*:70	*6.3e+4*:231	*4.0e+3*:1015	15/15
1: DE	748(626)	∞	∞	∞	∞ *5100*	0/15
2: PSO	**117**(53)$^{\star 3}$	**80**(23)$^{\star 3}$	**92**(124)$^{\star 3}$	517(698)	∞ *8300*	0/15
f11	*4.0e+4*:11	*2.5e+3*:27	*1.6e+2*:313	*1.0e+2*:481	*1.0e+1*:1002	15/15
1: DE	22(21)	67(130)	∞	∞	∞ *5100*	0/15
2: PSO	28(26)	43(39)	461(767)	∞	∞ *9700*	0/15
f12	*1.0e+8*:23	*6.3e+7*:39	*2.5e+7*:76	*4.0e+6*:209	*1.0e+1*:1042	15/15
1: DE	181(71)	116(20)	196(103)	∞	∞ *5100*	0/15
2: PSO	171(70)	119(68)	94(132)	45(13)	∞ *7600*	0/15
f13	*1.6e+3*:28	*1.0e+3*:64	*6.3e+2*:79	*4.0e+1*:211	*2.5e+0*:1724	15/15
1: DE	105(20)	64(6)	190(193)	∞	∞ *5100*	0/15
2: PSO	95(24)	55(17)	57(17)	262(126)	∞ *7600*	0/15
f14	*2.5e+1*:15	*1.6e+1*:42	*1.0e+1*:75	*1.6e+0*:219	*6.3e-4*:1106	15/15
1: DE	2587(1819)	∞	∞	∞	∞ *5100*	0/15
2: PSO	326(99)	200(174)	182(353)	515(260)	∞ *7600*	0/15
f15	*6.3e+2*:15	*4.0e+2*:67	*2.5e+2*:292	*1.6e+2*:846	*1.0e+2*:1671	15/15
1: DE	206(15)	60(10)	128(104)	∞	∞ *5100*	0/15
2: PSO	286(320)	147(85)	65(54)	∞	∞ *8600*	0/15
f16	*4.0e+1*:26	*2.5e+1*:127	*1.6e+1*:540	*1.6e+1*:540	*1.0e+1*:1384	15/15
1: DE	157(224)	∞	∞	∞	∞ *5100*	0/15
2: PSO	229(202)	1063(1390)	∞	∞	∞ *9300*	0/15
f17	*1.6e+1*:11	*1.0e+1*:63	*6.3e+0*:305	*4.0e+0*:468	*1.0e+0*:1030	15/15
1: DE	270(40)	59(14)	**29**(26)$^{\star 2}$	∞	∞ ***5100***$^{\star 2}$	0/15
2: PSO	302(138)	226(459)	100(70)	275(321)	∞ *8800*	0/15
f18	*4.0e+1*:116	*2.5e+1*:252	*1.6e+1*:430	*1.0e+1*:621	*4.0e+0*:1090	15/15
1: DE	**32**(5)$^{\star 2}$	**23**(31)$^{\star 2}$	∞	∞$^{\star 2}$	∞ ***5100***$^{\star 2}$	0/15
2: PSO	162(204)	256(227)	309(672)	∞	∞ *9100*	0/15
f19	*1.6e-1*:2.5e5	*1.0e-1*:3.4e5	*6.3e-2*:3.4e5	*4.0e-2*:3.4e5	*2.5e-2*:3.4e5	3/15
1: DE	∞	∞	∞	∞	∞ *5100*	0/15
2: PSO	∞	∞	∞	∞	∞ *9200*	0/15
f20	*1.6e+4*:38	*1.0e+4*:42	*2.5e+2*:62	*2.5e+0*:250	*1.6e+0*:2536	15/15
1: DE	71(12)	72(5)	77(27)	∞	∞ *5100*	0/15
2: PSO	69(6)	67(10)	62(13)	22(5)	6.0(7)	7/15
f21	*6.3e+1*:36	*4.0e+1*:77	*4.0e+1*:77	*1.6e+1*:456	*4.0e+0*:1094	15/15
1: DE	134(48)	158(100)	158(99)	∞	∞ *5100*	0/15
2: PSO	109(19)	88(75)	88(108)	25(18)	33(35)	3/15
f22	*6.3e+1*:45	*4.0e+1*:68	*4.0e+1*:68	*1.6e+1*:231	*6.3e+0*:1219	15/15
1: DE	111(68)	177(206)	177(303)	328(498)	∞ *5100*	0/15
2: PSO	133(104)	119(59)	119(67)	60(85)	23(22)	4/15
f23	*6.3e+0*:29	*4.0e+0*:118	*2.5e+0*:306	*2.5e+0*:306	*1.0e+0*:1614	15/15
1: DE	100(22)	97(76)	∞	∞	∞ *5100*	0/15
2: PSO	196(311)	94(201)	146(305)	146(177)	∞ *9400*	0/15
f24	*2.5e+2*:208	*1.6e+2*:918	*1.0e+2*:6628	*6.3e+1*:9885	*4.0e+1*:31629	15/15
1: DE	**70**(79)$^{\star 3}$	∞$^{\star 3}$	∞$^{\star 3}$	∞$^{\star 3}$	∞ ***5100***$^{\star 3}$	0/15
2: PSO	∞	∞	∞	∞	∞ *8800*	0/15

Table 1: Expected running time (ERT in number of function evaluations) divided by the respective best ERT measured during BBOB-2009 in dimensions 5 (left) and 20 (right). The ERT and in braces, as dispersion measure, the half difference between 90 and 10%-tile of bootstrapped run lengths appear for each algorithm and run-length based target, the corresponding best ERT (preceded by the target Δf-value in *italics*) in the first row. #succ is the number of trials that reached the target value of the last column. The median number of conducted function evaluations is additionally given in *italics*, if the target in the last column was never reached. 1:DE is DE and 2:PSO is PSO DE. Bold entries are statistically significantly better compared to the other algorithm, with $p = 0.05$ or $p = 10^{-k}$ where $k \in \{2, 3, 4, \dots\}$ is the number following the $\star$ symbol, with Bonferroni correction of 48. A ↓ indicates the same tested against the best algorithm of BBOB-2009.