

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

PSO-DE Hybrid

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ABSTRACT

Dokumentacja uzyskanych wyników 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

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.

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 **$x.x$, $x.x$, $x.x$, $x.x$, 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, $f_t = f_{\text{opt}} + \Delta f$, 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

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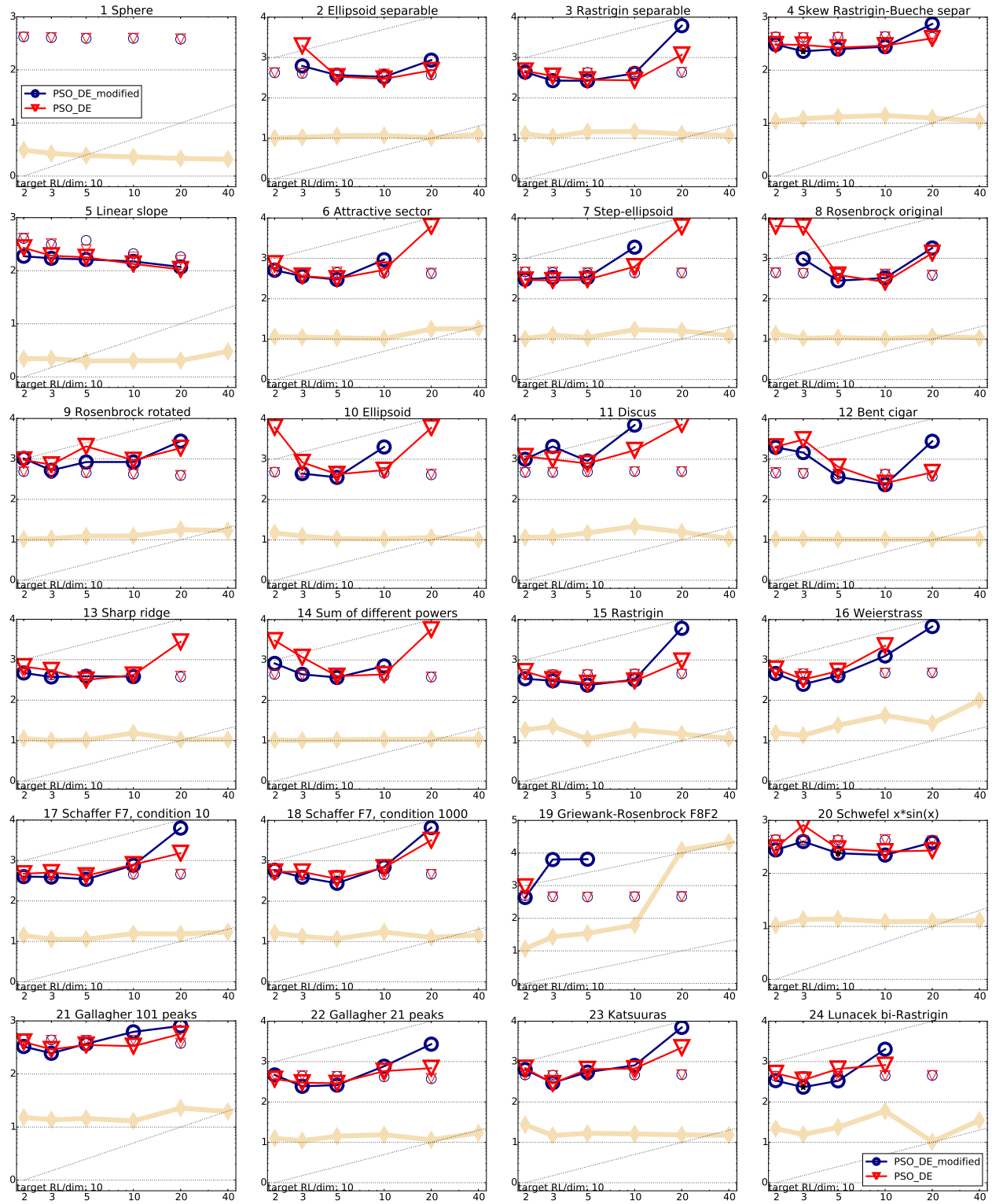


Figure 1: Expected running time (ERT in number of f -evaluations as \log_{10} value) divided by dimension versus dimension. The target function value is chosen such that the bestGECCO2009 artificial algorithm just failed to achieve an ERT of $10 \times \text{DIM}$. Different symbols correspond to different 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: \circ :PSO DE modified, ∇ :PSO DE.

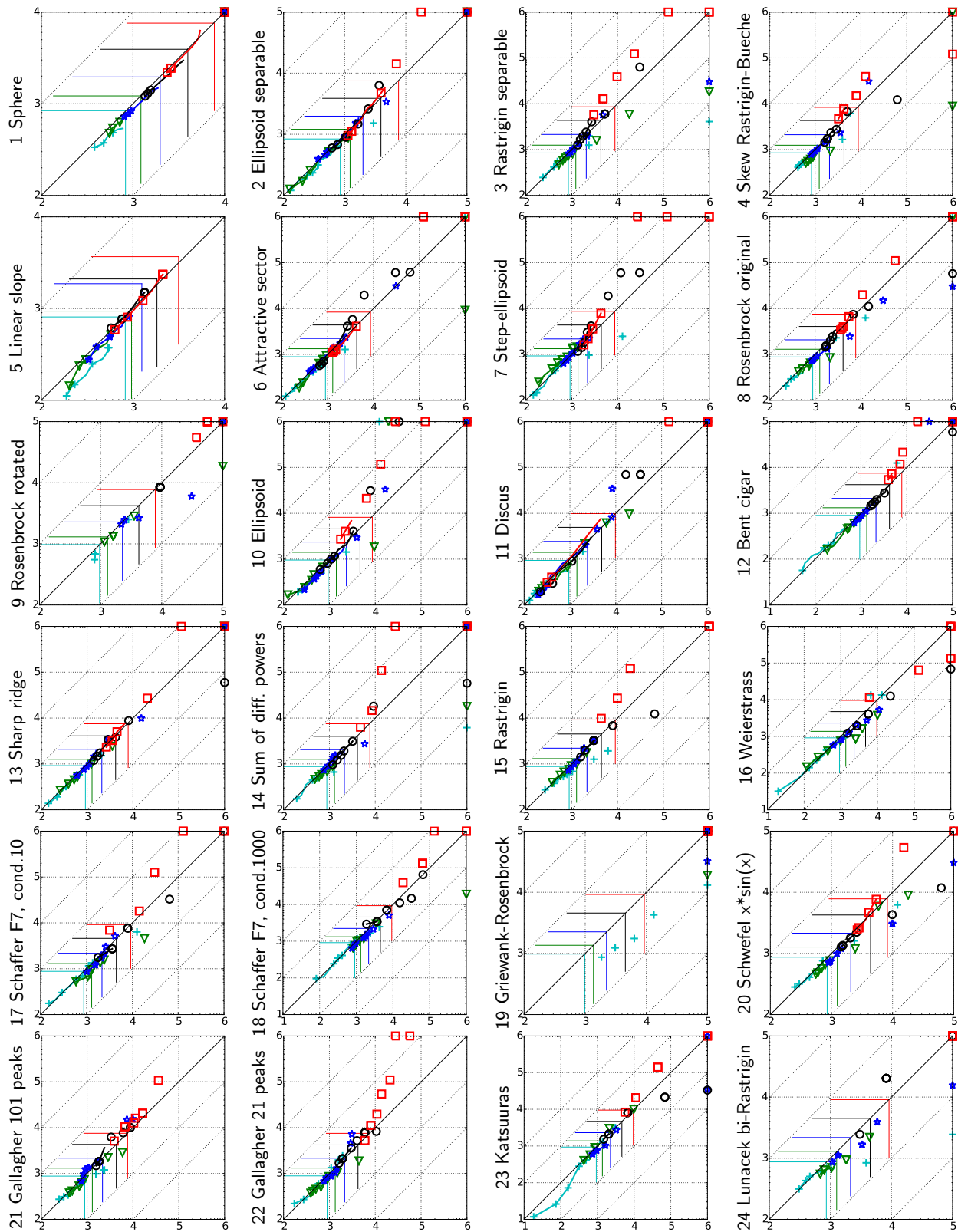


Figure 2: Expected running time (ERT in \log_{10} of number of function evaluations) of PSO DE modified (y -axis) versus PSO DE (x -axis) for 8 runlength-based target function values for budgets between $0.5 \times \text{DIM}$ and $50 \times \text{DIM}$ evaluations. Each runlength-based target f -value 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: \star , 10: \circ , 20: \square , 40: \diamond .

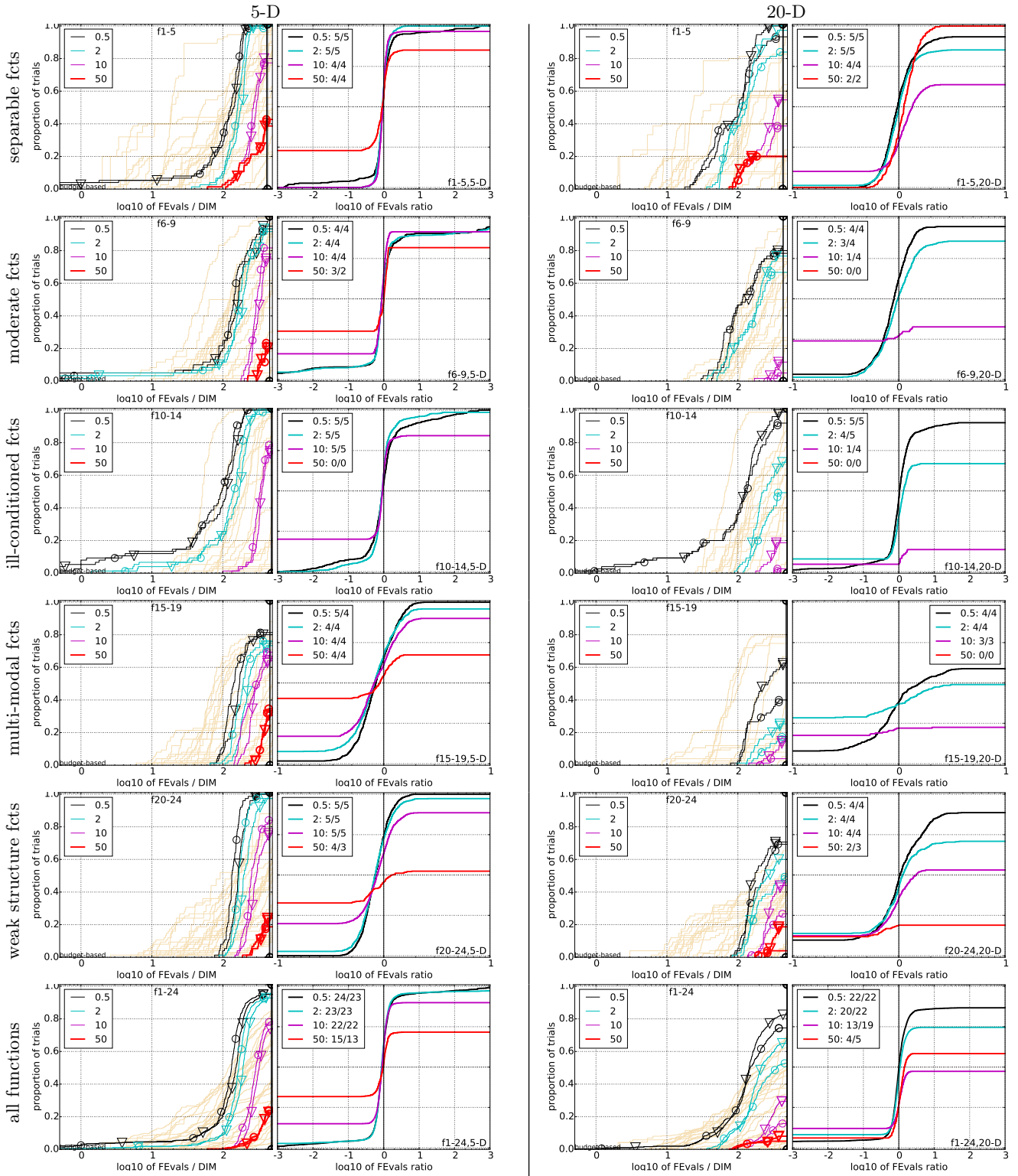


Figure 3: Empirical cumulative distributions (ECDF) of run lengths and speed-up ratios in 5-D (left) and 20-D (right). Left sub-columns: ECDF of the number of function evaluations divided by dimension D (FEvals/ D) to fall below $f_{\text{opt}} + \Delta f$ for PSO DE modified (\circ) and PSO DE (∇) where Δf is the target just not reached by the GECCO-BBOB-2009 best algorithm within a budget of $k \times \text{DIM}$ evaluations, with k being the value in the legend. Right sub-columns: ECDF of FEval ratios of PSO DE modified 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 $k \times \text{DIM}$ evaluations and, after the colon, the number of functions that were solved in at least one trial (PSO DE modified first).

5-D

#FEs/D	0.5	1.2	3	10	50	#succ
f₁	<i>2.5e+1:4.8</i>	<i>1.6e+1:7.6</i>	<i>1.0e-8:12</i>	<i>1.0e-8:12</i>	<i>1.0e-8:12</i>	15/15
1: PSO	151(31)	102(12)	∞^*2	∞^*2	∞^{1900*2}	0/15
2: PSO	168(49)	118(26)	∞	∞	∞^{1900}	0/15
f₂	<i>1.6e+6:2.9</i>	<i>4.0e+5:11</i>	<i>4.0e+4:15</i>	<i>6.3e+2:58</i>	<i>1.0e-8:95</i>	15/15
1: PSO	138(59)	46(16)	52(7)	32(25)	∞^{1900}	0/15
2: PSO	129(58)	46(14)	53(8)	29(3)	∞^{2000}	0/15
f₃	<i>1.6e+2:4.1</i>	<i>1.0e+2:15</i>	<i>6.3e+1:23</i>	<i>2.5e+1:73</i>	<i>1.0e+1:716</i>	15/15
1: PSO	198(41)	61(13)	43(9)	18(3)	7.9(8)	5/15
2: PSO	205(58)	65(7)	46(11)	19(2)	6.6(7)	6/15
f₄	<i>2.5e+2:2.6</i>	<i>1.6e+2:10</i>	<i>1.0e+2:19</i>	<i>4.0e+1:65</i>	<i>1.6e+1:434</i>	15/15
1: PSO	301(39)	86(18)	49(12)	19(3)	5.4(4)	12/15
2: PSO	316(57)	93(10)	53(14)	20(4)	8.2(9)	8/15
f₅	<i>6.3e+1:4.0</i>	<i>4.0e+1:10</i>	<i>1.0e-8:10</i>	<i>1.0e-8:10</i>	<i>1.0e-8:10</i>	15/15
1: PSO	69(64)	39(32)	82(46)	82(28)	82(24)	15/15
2: PSO	82(68)	40(30)	90(28)	90(28)	90(31)	15/15
f₆	<i>1.0e+5:3.0</i>	<i>6.3e+3:8.4</i>	<i>1.0e+2:16</i>	<i>2.5e+1:54</i>	<i>2.5e+1:254</i>	15/15
1: PSO	140(129)	56(56)	65(12)	28(11)	122(98)	1/15
2: PSO	133(143)	53(47)	66(21)	29(21)	123(231)	1/15
f₇	<i>1.6e+2:4.2</i>	<i>1.0e+2:6.2</i>	<i>2.5e+1:20</i>	<i>4.0e+0:54</i>	<i>1.0e+0:324</i>	15/15
1: PSO	152(27)	121(19)	52(20)	31(22)	6.9(7)	12/15
2: PSO	157(54)	125(38)	52(14)	27(4)	7.4(8)	11/15
f₈	<i>1.0e+4:4.6</i>	<i>6.3e+3:6.8</i>	<i>1.0e+3:18</i>	<i>6.3e+1:54</i>	<i>1.6e+0:258</i>	15/15
1: PSO	158(37)	112(37)	49(8)	26(4)	117(110)	1/15
2: PSO	183(35)	131(14)	58(18)	36(7)	∞^{2000}	0/15
f₉	<i>2.5e+1:20</i>	<i>1.6e+1:26</i>	<i>1.0e+1:35</i>	<i>4.0e+0:62</i>	<i>1.6e-2:256</i>	15/15
1: PSO	106(108)	96(95)	75(65)	68(60)	∞^{2000}	0/15
2: PSO	111(35)	96(48)	102(92)	166(160)	∞^{2000}	0/15
f₁₀	<i>2.5e+6:2.9</i>	<i>6.3e+5:7.0</i>	<i>2.5e+5:17</i>	<i>6.3e+3:54</i>	<i>2.5e+1:297</i>	15/15
1: PSO	76(70)	53(39)	28(21)	33(8)	∞^{2200}	0/15
2: PSO	99(83)	67(48)	35(26)	39(39)	∞^{2200}	0/15
f₁₁	<i>1.0e+6:3.0</i>	<i>6.3e+4:6.2</i>	<i>6.3e+2:16</i>	<i>6.3e+1:74</i>	<i>6.3e-1:298</i>	15/15
1: PSO	55(77)	35(45)	49(25)	61(36)	∞^{2300}	0/15
2: PSO	68(117)	47(45)	42(29)	53(36)	∞^{2300}	0/15
f₁₂	<i>4.0e+7:3.6</i>	<i>1.6e+7:7.6</i>	<i>4.0e+6:19</i>	<i>1.6e+4:52</i>	<i>1.0e+0:268</i>	15/15
1: PSO	172(41)	98(40)	46(13)	36(5)	∞^{2000}	0/15
2: PSO	199(66)	110(34)	53(12)	63(23)	∞^{2100}	0/15
f₁₃	<i>1.0e+3:2.8</i>	<i>6.3e+2:8.4</i>	<i>4.0e+2:17</i>	<i>6.3e+1:52</i>	<i>6.3e-2:264</i>	15/15
1: PSO	202(97)	90(20)	52(8)	37(21)	∞^{2000}	0/15
2: PSO	214(109)	101(16)	59(6)	30(5)	∞^{2000}	0/15
f₁₄	<i>1.6e+1:3.0</i>	<i>1.0e+1:10</i>	<i>6.3e+0:15</i>	<i>2.5e-1:53</i>	<i>1.0e-5:251</i>	15/15
1: PSO	246(75)	93(46)	77(73)	35(22)	∞^{2000}	0/15
2: PSO	252(61)	96(20)	71(17)	38(21)	∞^{2000}	0/15
f₁₅	<i>1.6e+2:3.0</i>	<i>1.0e+2:13</i>	<i>6.3e+1:24</i>	<i>4.0e+1:55</i>	<i>1.6e+1:289</i>	5/5
1: PSO	242(115)	66(26)	42(18)	22(7)	12(10)	8/15
2: PSO	282(60)	77(21)	47(9)	24(6)	11(4)	9/15
f₁₆	<i>4.0e+1:4.8</i>	<i>2.5e+1:16</i>	<i>1.6e+1:46</i>	<i>1.0e+1:120</i>	<i>4.0e+0:334</i>	15/15
1: PSO	120(43)	52(20)	28(11)	17(17)	16(12)	6/15
2: PSO	130(49)	65(15)	36(22)	22(14)	33(20)	3/15
f₁₇	<i>1.0e+1:5.2</i>	<i>6.3e+0:26</i>	<i>4.0e+0:57</i>	<i>2.5e+0:110</i>	<i>6.3e-1:412</i>	15/15
1: PSO	167(89)	46(19)	30(22)	20(29)	13(8)	6/15
2: PSO	196(13)	60(19)	37(2)	22(6)	10(7)	7/15
f₁₈	<i>6.3e+1:3.4</i>	<i>4.0e+1:7.2</i>	<i>2.5e+1:20</i>	<i>1.6e+1:58</i>	<i>1.6e+0:318</i>	15/15
1: PSO	189(40)	120(86)	62(40)	24(22)	16(25)	6/15
2: PSO	225(58)	132(46)	80(85)	31(24)	24(51)	4/15
f₁₉	<i>1.6e-1:172</i>	<i>1.0e-1:242</i>	<i>6.3e-2:675</i>	<i>4.0e-2:3078</i>	<i>2.5e-2:4946</i>	15/15
1: PSO	188(219)	∞	∞	∞	∞^{2200}	0/15
2: PSO	∞	∞	∞	∞	∞^{2100}	0/15
f₂₀	<i>6.3e+3:5.1</i>	<i>4.0e+3:8.4</i>	<i>4.0e+1:15</i>	<i>2.5e+0:69</i>	<i>1.0e+0:851</i>	15/15
1: PSO	138(50)	88(19)*	60(18)	17(3)	36(15)	1/15
2: PSO	177(23)	113(15)	75(4)	21(5)	∞^{2000}	0/15
f₂₁	<i>4.0e+1:3.9</i>	<i>2.5e+1:11</i>	<i>1.6e+1:31</i>	<i>6.3e+0:73</i>	<i>1.6e+0:347</i>	5/5
1: PSO	173(36)	91(48)	40(25)	25(24)	43(53)	2/15
2: PSO	191(39)	79(35)	30(12)	24(3)	21(29)	4/15
f₂₂	<i>6.3e+1:3.6</i>	<i>4.0e+1:15</i>	<i>2.5e+1:32</i>	<i>1.0e+1:71</i>	<i>1.6e+0:341</i>	5/5
1: PSO	189(49)	54(14)	28(6)	18(3)	21(16)	4/15
2: PSO	212(57)	58(15)	34(21)	20(8)	9.1(7)	9/15
f₂₃	<i>1.0e+1:3.0</i>	<i>6.3e+0:9.0</i>	<i>4.0e+0:33</i>	<i>2.5e+0:84</i>	<i>1.0e+0:518</i>	15/15
1: PSO	200(43)	84(24)	31(10)	33(26)	∞^{2300}	0/15
2: PSO	244(60)	105(15)	50(45)	39(37)	∞^{2200}	0/15
f₂₄	<i>6.3e+1:15</i>	<i>4.0e+1:37</i>	<i>4.0e+1:37</i>	<i>2.5e+1:118</i>	<i>1.6e+1:692</i>	15/15
1: PSO	59(15)	31(16)*	31(33)*	14(6)	5.7(3)	7/15
2: PSO	74(16)	37(11)	37(7)	28(28)	8.5(12)	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: PSO	91(18)	58(10)	∞	∞	∞7500	0/15
2: PSO	97(14)	62(7)	∞	∞	∞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: PSO	33(6)	27(5)	58(16)	83(27)	∞7400	0/15
2: PSO	40(9)	31(7)	51(34)	46(58)	∞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: PSO	174(145)	292(290)	356(384)	483(364)	∞8300	0/15
2: PSO	92(19)	110(21)	89(117)	91(150)	∞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: PSO	218(114)	85(36)	60(42)	119(98)	∞8100	0/15
2: PSO	150(40)	47(23)	32(19)	38(32)	∞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: PSO	31(5)	24(5)	58(11)	58(16)	58(11)	15/15
2: PSO	33(11)	25(8)	52(15)	52(13)	52(11)	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: PSO	70(36)	30(10)	23(6)	∞	∞8100	0/15
2: PSO	81(16)	35(8)	27(3)	349(224)	∞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: PSO	152(51)	92(128)	107(66)	∞	∞8400	0/15
2: PSO	174(33)	73(14)	59(53)	377(397)	∞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: PSO	181(53)	105(30)	83(50)	157(209)	∞7400	0/15
2: PSO	191(45)	110(21)	75(19)	117(49)	∞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: PSO	154(236)	∞	∞	∞	∞7500	0/15
2: PSO	104(163)	101(254)	169(298)	∞	∞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: PSO	182(171)	149(146)	301(274)	∞	∞7900	0/15
2: PSO	117(19)	80(33)	92(108)	517(618)	∞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: PSO	28(24)	46(37)	∞	∞	∞9700	0/15
2: PSO	28(34)	43(13)	461(520)	∞	∞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: PSO	235(280)	185(69)	157(132)	266(240)	∞7400	0/15
2: PSO	171(81)	119(26)	94(80)	45(22)	∞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: PSO	85(19)	51(13)	64(33)	∞	∞7400	0/15
2: PSO	95(32)	55(20)	57(18)	262(117)	∞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: PSO	433(355)	345(841)	1460(1882)	∞	∞7400	0/15
2: PSO	326(78)	200(232)	182(153)	515(536)	∞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: PSO	640(478)	403(540)	416(531)	∞	∞8400	0/15
2: PSO	286(200)	147(167)	65(50)	∞	∞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: PSO	437(516)	505(696)	250(391)	250(261)	∞9200	0/15
2: PSO	229(31)	1063(1813)	∞	∞	∞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: PSO	653(455)	288(169)	415(542)	∞	∞8700	0/15
2: PSO	302(77)	226(148)	100(106)	275(354)	∞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: PSO	340(534)	524(654)	∞	∞	∞9000	0/15
2: PSO	162(168)	256(216)	309(248)	∞	∞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: PSO	∞	∞	∞	∞	∞9100	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: PSO	63(12)	62(19)	63(23)	31(33)	21(18)	2/15
2: PSO	69(17)	67(7)	62(13)	22(3)	6(0.5)	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: PSO	142(103)	136(122)	136(97)	35(51)	98(144)	1/15
2: PSO	109(84)	88(53)	88(52)	25(21)	33(33)	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: PSO	117(44)	165(195)	165(71)	234(289)	∞7400	0/15
2: PSO	133(106)	119(95)	119(91)	60(38)	23(23)	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: PSO	291(390)	175(176)	460(725)	460(795)	∞9400	0/15
2: PSO	196(49)	94(86)	146(231)	146(107)	∞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: PSO	∞	∞	∞	∞	∞8000	0/15
2: PSO	∞*	∞*	∞*	∞*	∞9800*	0/15