

# Modyfikacje/hybrydyzacje algorytmu PSO w zadaniu optymalizacji globalnej wielowymiarowej funkcji ciągłej

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 ciągłej

## 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  $8,3e^{-11}$ ,  $1,0e^{-10}$ ,  $1,4e^{-10}$ ,  $2,2e^{-10}$ ,  $3,8e^{-10}$ , and  $7,2e^{-10}$  seconds respectively.

## 2. RESULTS

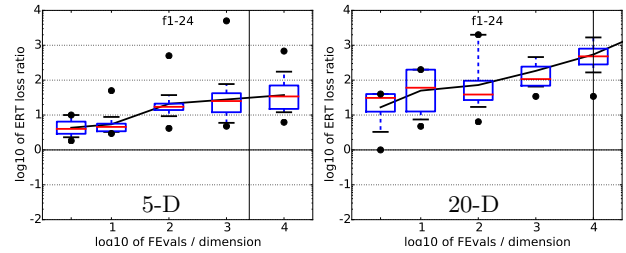
Results of Experimental Data from experiments according to [?] on the benchmark functions given in [?, ?] are presented in Figures 1, 2, 3, and 4 and in Tables 1.

\*Submission deadline: March 28th.

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

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$f_1-f_{24}$ in 5-D, maxFE/D=2491						
#FEs/D	best	10%	25%	med	75%	90%
2	1.8	2.2	2.9	4.0	6.7	10
10	3.0	3.2	3.4	4.6	5.8	14
100	4.2	8.8	14	17	21	88
1e3	4.8	5.8	12	25	42	1.1e2
1e4	6.2	11	15	34	83	1.9e2
RLUS/D	2e3	2e3	2e3	2e3	2e3	2e3
$f_1-f_{24}$ in 20-D, maxFE/D=9998						
#FEs/D	best	10%	25%	med	75%	90%
2	1.0	2.9	12	31	40	40
10	4.8	7.4	12	61	2.0e2	2.0e2
100	6.4	17	27	39	99	2.0e3
1e3	34	63	69	1.1e2	2.7e2	2.4e3
1e4	34	1.4e2	2.7e2	4.8e2	8.0e2	2.1e3
1e5	34	2.9e2	8.5e2	3.1e3	6.8e3	2.1e4
RLUS/D	1e4	1e4	1e4	1e4	1e4	1e4

**Figure 3:** ERT loss ratio versus the budget in number of  $f$ -evaluations divided by dimension. For each given budget FEvals, the target value  $f_t$  is computed as the best target  $f$ -value reached within the budget by the given algorithm. Shown is then the ERT to reach  $f_t$  for the given algorithm or the budget, if the GECCO-BBOB-2009 best algorithm reached a better target within the budget, divided by the best ERT seen in GECCO-BBOB-2009 to reach  $f_t$ . Line: geometric mean. Box-Whisker error bar: 25-75%-ile with median (box), 10-90%-ile (caps), and minimum and maximum ERT loss ratio (points). The vertical line gives the maximal number of function evaluations in a single trial in this function subset. See also Figure 4 for results on each function subgroup.

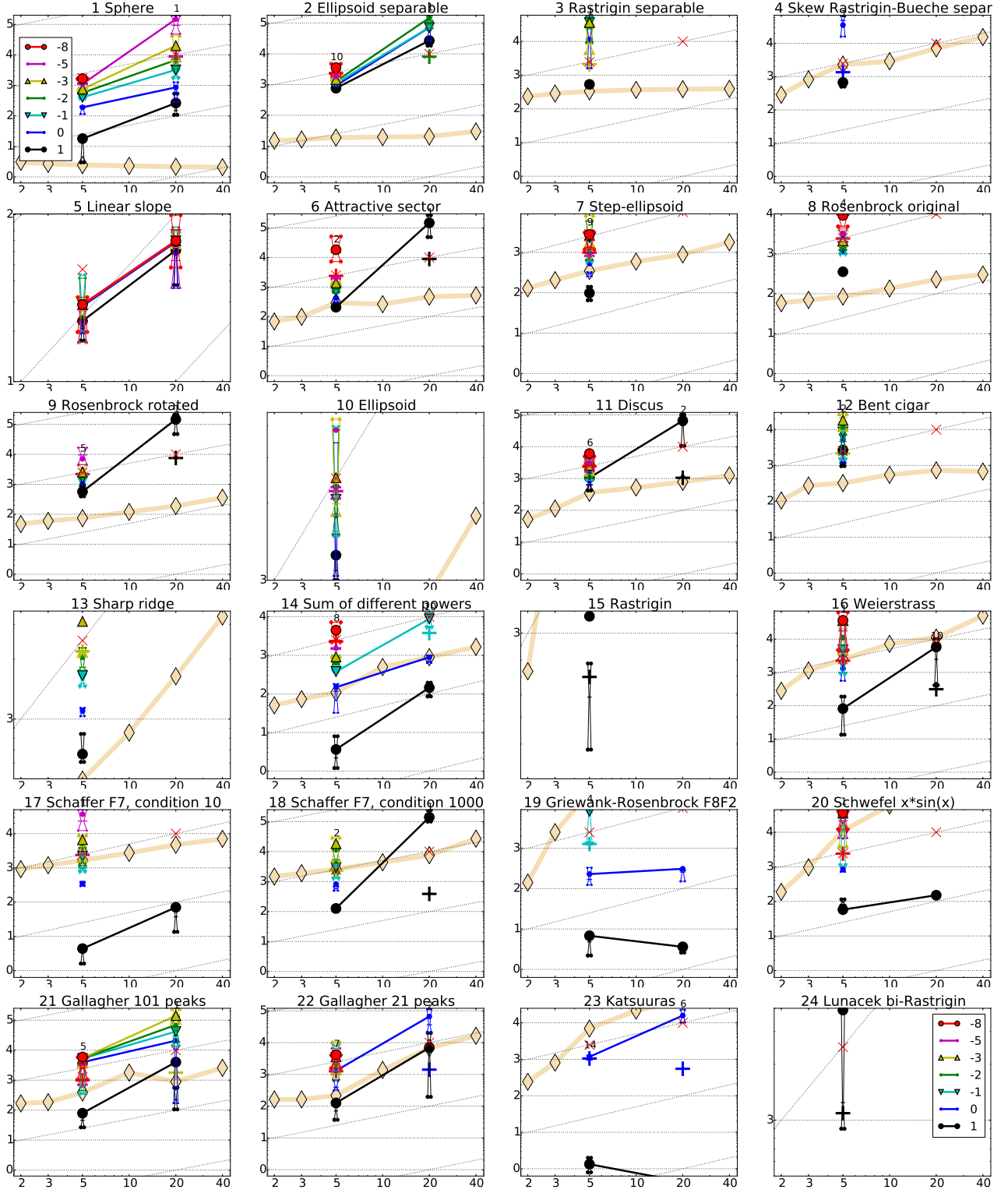
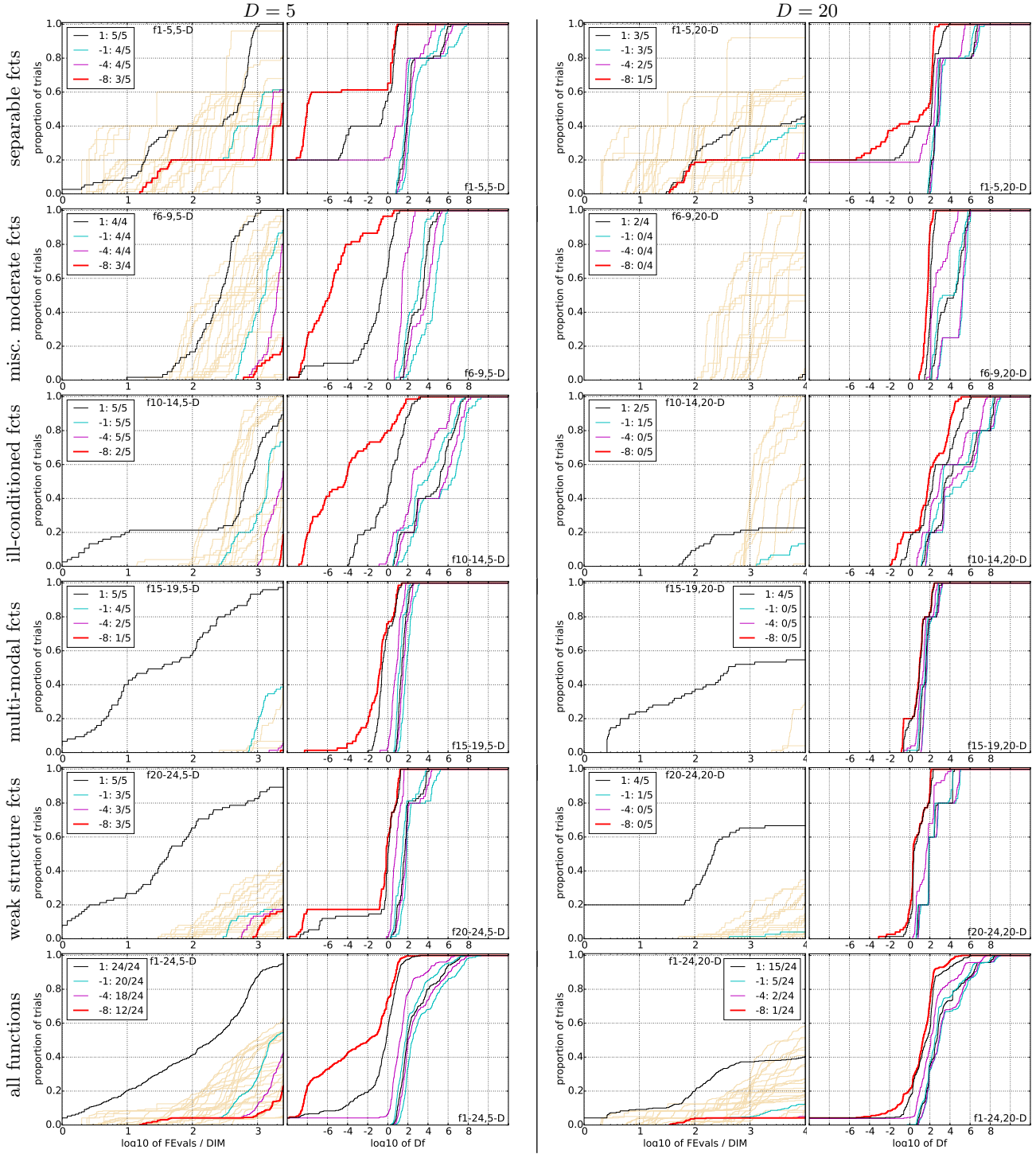


Figure 1: Expected number of  $f$ -evaluations (ERT, lines) to reach  $f_{\text{opt}} + \Delta f$ ; median number of  $f$ -evaluations (+) to reach the most difficult target that was reached not always but at least once; maximum number of  $f$ -evaluations in any trial ( $\times$ ); interquartile range with median (notched boxes) of simulated runlengths to reach  $f_{\text{opt}} + \Delta f$ ; all values are divided by dimension and plotted as  $\log_{10}$  values versus dimension. Shown are  $\Delta f = 10^{\{1,0,-1,-2,-3,-5,-8\}}$ . Numbers above ERT-symbols (if appearing) indicate the number of trials reaching the respective target. The light thick line with diamonds indicates the respective best result from BBOB-2009 for  $\Delta f = 10^{-8}$ . Horizontal lines mean linear scaling, slanted grid lines depict quadratic scaling.



**Figure 2: Empirical cumulative distribution functions (ECDF), plotting the fraction of trials with an outcome not larger than the respective value on the  $x$ -axis. Left subplots: ECDF of the number of function evaluations (FEvals) divided by search space dimension  $D$ , to fall below  $f_{\text{opt}} + \Delta f$  with  $\Delta f = 10^k$ , where  $k$  is the first value in the legend. The thick red line represents the most difficult target value  $f_{\text{opt}} + 10^{-8}$ . Legends indicate for each target the number of functions that were solved in at least one trial within the displayed budget. Right subplots: ECDF of the best achieved  $\Delta f$  for running times of  $0.5D, 1.2D, 3D, 10D, 100D, 1000D, \dots$  function evaluations (from right to left cycling cyan-magenta-black...) and final  $\Delta f$ -value (red), where  $\Delta f$  and  $Df$  denote the difference to the optimal function value. Light brown lines in the background show ECDFs for the most difficult target of all algorithms benchmarked during BBOB-2009.**

5-D									20-D								
$\Delta f$	1e+1	1e+0	1e-1	1e-2	1e-3	1e-5	1e-7	#succ	$\Delta f$	1e+1	1e+0	1e-1	1e-2	1e-3	1e-5	1e-7	#succ
$f_1$	11 8.2(9)	12 78(28)	12 167(18)	12 233(21)	12 310(37)	12 456(22)	12 601(26)	15/15 15/15	$f_1$	43 122(71)	43 400(292)	43 1498(813)	43 3160(2499)	43 9316(15057)	43 68996(96179)	43 $\infty 2.0e5$	15/15 0/15
$f_2$	83 46(7)	87 53(4)	88 62(4)	89 72(5)	90 81(5)	92 99(6)	94 117(7)	15/15 10/15	$f_2$	385 1394(703)	386 3697(7117)	387 3710(2840)	388 7619(2958)	390 $\infty$	391 $\infty 2.0e5$	393 $\infty 2.0e5$	15/15 0/15
$f_3$	716 3.7(2)	1622 35(28)	1637 110(104)	1642 110(171)	1646 110(297)	1650 $\infty$	1654 $\infty 1.2e4$	15/15 0/15	$f_3$	5066 $\infty$	7626 $\infty$	7635 $\infty$	7637 $\infty$	7643 $\infty$	7646 $\infty$	7651 $\infty 2.0e5$	15/15 0/15
$f_4$	809 4.1(0.8)	1633 108(86)	1688 $\infty$	1758 $\infty$	1817 $\infty$	1886 $\infty$	1903 $\infty 1.2e4$	15/15 0/15	$f_4$	4722 $\infty$	7628 $\infty$	7666 $\infty$	7686 $\infty$	7700 $\infty$	7758 $\infty$	1.4e5 $\infty 2.0e5$	9/15 0/15
$f_5$	10 12(3)	10 14(8)	10 14(7)	10 14(7)	10 14(6)	10 14(8)	10 14(5)	15/15 15/15	$f_5$	41 30(17)	41 34(20)	41 34(10)	41 34(10)	41 34(11)	41 34(14)	41 34(8)	15/15 15/15
$f_6$	114 9.1(5)	214 10(3)	281 13(3)	404 12(4)	580 12(3)	1038 10(1)	1332 19(12)	15/15 2/15	$f_6$	1296 2295(3353)	2343 $\infty$	3413 $\infty$	4255 $\infty$	5220 $\infty$	6728 $\infty$	8409 $\infty 2.0e5$	15/15 0/15
$f_7$	24 21(10)	324 8.2(21)	1171 10(11)	1451 8.9(5)	1572 8.5(14)	1572 8.5(15)	1597 8.5(7)	15/15 9/15	$f_7$	1351 $\infty$	4274 $\infty$	9503 $\infty$	16523 $\infty$	16524 $\infty$	16524 $\infty$	16969 $\infty 2.0e5$	15/15 0/15
$f_8$	73 24(4)	273 22(5)	336 23(14)	372 26(13)	391 27(12)	410 40(27)	422 85(110)	15/15 4/15	$f_8$	2039 $\infty$	3871 $\infty$	4040 $\infty$	4148 $\infty$	4219 $\infty$	4371 $\infty$	4484 $\infty 2.0e5$	15/15 0/15
$f_9$	35 82(56)	127 49(18)	214 37(11)	263 35(5)	300 43(22)	335 105(119)	369 $\infty 1.2e4$	15/15 0/15	$f_9$	1716 1713(1480)	3102 $\infty$	3277 $\infty$	3379 $\infty$	3455 $\infty$	3594 $\infty$	3727 $\infty 2.0e5$	15/15 0/15
$f_{10}$	349 18(3)	500 18(10)	574 18(11)	607 19(12)	626 20(16)	829 23(12)	880 211(183)	15/15 0/15	$f_{10}$	7413 $\infty$	8661 $\infty$	10735 $\infty$	13641 $\infty$	14920 $\infty$	17073 $\infty$	17476 $\infty 2.0e5$	15/15 0/15
$f_{11}$	143 37(44)	202 39(26)	763 14(13)	977 12(0.5)	1177 12(0.5)	1467 11(8)	1673 10(7)	15/15 6/15	$f_{11}$	1002 1317(1791)	2228 $\infty$	6278 $\infty$	8586 $\infty$	9762 $\infty$	12285 $\infty$	14831 $\infty 2.0e5$	15/15 0/15
$f_{12}$	108 125(144)	268 98(106)	371 114(75)	413 145(148)	461 197(249)	1303 $\infty$	1494 $\infty 1.2e4$	15/15 0/15	$f_{12}$	1042 $\infty$	1938 $\infty$	2740 $\infty$	3156 $\infty$	4140 $\infty$	12407 $\infty$	13827 $\infty 2.0e5$	15/15 0/15
$f_{13}$	132 25(8)	195 28(3)	250 33(13)	319 32(12)	1310 12(5)	1752 $\infty$	2255 $\infty 1.2e4$	15/15 0/15	$f_{13}$	652 $\infty$	2021 $\infty$	2751 $\infty$	3507 $\infty$	18749 $\infty$	24455 $\infty$	30201 $\infty 2.0e5$	15/15 0/15
$f_{14}$	10 1.9(2)	41 18(10)	58 33(10)	90 36(8)	139 33(4)	251 30(3)	476 26(15)	15/15 8/15	$f_{14}$	75 39(21)	239 74(35)	304 576(772)	451 $\infty$	932 $\infty$	1648 $\infty$	15661 $\infty 2.0e5$	15/15 0/15
$f_{15}$	511 11(10)	9310 $\infty$	19369 $\infty$	19743 $\infty$	20073 $\infty$	20769 $\infty$	21359 $\infty 1.2e4$	14/15 0/15	$f_{15}$	30378 $\infty$	1.5e5 $\infty$	3.1e5 $\infty$	3.2e5 $\infty$	3.2e5 $\infty$	4.5e5 $\infty$	4.6e5 $\infty 2.0e5$	15/15 0/15
$f_{16}$	120 3.4(4)	612 11(8)	2662 8.9(7)	10163 5.6(7)	10449 17(18)	11644 16(18)	12095 15(11)	15/15 1/15	$f_{16}$	1384 84(252)	27265 $\infty$	77015 $\infty$	1.4e5 $\infty$	1.9e5 $\infty$	2.0e5 $\infty$	2.2e5 $\infty 2.0e5$	15/15 0/15
$f_{17}$	5.2 4.2(4)	215 8.1(3)	899 12(11)	2861 7.3(4)	3669 9.0(11)	6351 29(28)	7934 $\infty 1.2e4$	15/15 0/15	$f_{17}$	63 22(14)	1030 $\infty$	4005 $\infty$	12242 $\infty$	30677 $\infty$	56288 $\infty$	80472 $\infty 2.0e5$	15/15 0/15
$f_{18}$	103 6.1(3)	378 11(2)	3968 3.7(4)	8451 6.8(5)	9280 10(7)	10905 $\infty$	12469 $\infty 1.2e4$	15/15 0/15	$f_{18}$	621 4511(5463)	3972 $\infty$	19561 $\infty$	28555 $\infty$	67569 $\infty$	1.3e5 $\infty$	1.5e5 $\infty 2.0e5$	15/15 0/15
$f_{19}$	1 34(20)	1 1143(779)	242 170(121)	1.0e5 $\infty$	1.2e5 $\infty$	1.2e5 $\infty$	1.2e5 $\infty 1.2e4$	15/15 0/15	$f_{19}$	1 72(19)	1 6185(9153)	3.4e5 $\infty$	4.7e6 $\infty$	6.2e6 $\infty$	6.7e6 $\infty$	6.7e6 $\infty 2.0e5$	15/15 0/15
$f_{20}$	16 18(15)	851 5.1(0.8)	38111 4.6(5)	51362 3.5(4)	54470 3.3(4)	54861 3.3(3)	55313 3.3(4)	14/15 1/15	$f_{20}$	82 37(13)	46150 $\infty$	3.1e6 $\infty$	5.5e6 $\infty$	5.5e6 $\infty$	5.6e6 $\infty$	5.6e6 $\infty 2.0e5$	14/15 0/15
$f_{21}$	41 10(5)	1157 17(24)	1674 16(16)	1692 16(18)	1705 16(16)	1729 16(16)	1757 16(19)	14/15 5/15	$f_{21}$	561 142(267)	6541 64(99)	14103 59(96)	14318 97(205)	14643 193(133)	15567 $\infty$	17589 $\infty 2.0e5$	15/15 0/15
$f_{22}$	71 8.9(17)	386 17(24)	938 18(27)	980 18(7)	1008 18(24)	1040 18(8)	1068 19(22)	14/15 7/15	$f_{22}$	467 297(534)	5580 237(420)	23491 $\infty$	24163 $\infty$	24948 $\infty$	26847 $\infty$	1.3e5 $\infty 2.0e5$	12/15 0/15
$f_{23}$	3.0 2.2(1)	518 11(7)	14249 $\infty$	27890 $\infty$	31654 $\infty$	33030 $\infty$	34256 $\infty 1.2e4$	15/15 0/15	$f_{23}$	3.2 2.8(2)	1614 196(280)	67457 $\infty$	3.7e5 $\infty$	4.9e5 $\infty$	8.1e5 $\infty$	8.4e5 $\infty 2.0e5$	15/15 0/15
$f_{24}$	1622 12(11)	2.2e5 $\infty$	6.4e6 $\infty$	9.6e6 $\infty$	9.6e6 $\infty$	1.3e7 $\infty$	1.3e7 $\infty 1.2e4$	3/15 0/15	$f_{24}$	1.3e6 $\infty$	7.5e6 $\infty$	5.2e7 $\infty$	5.2e7 $\infty$	5.2e7 $\infty$	5.2e7 $\infty$	5.2e7 $\infty 2.0e5$	3/15 0/15

Table 1: Expected running time (ERT in number of function evaluations) divided by the best ERT measured during BBOB-2009. The ERT and in braces, as dispersion measure, the half difference between 90 and 10%-tile of bootstrapped run lengths appear in the second row of each cell, the best ERT in the first. The different target  $\Delta f$ -values are shown in the top row. #succ is the number of trials that reached the (final) target  $f_{\text{opt}} + 10^{-8}$ . The median number of conducted function evaluations is additionally given in *italics*, if the target in the last column was never reached. Bold entries are statistically significantly better (according to the rank-sum test) compared to the best algorithm in BBOB-2009, with  $p = 0.05$  or  $p = 10^{-k}$  when the number  $k > 1$  is following the  $\downarrow$  symbol, with Bonferroni correction by the number of functions.

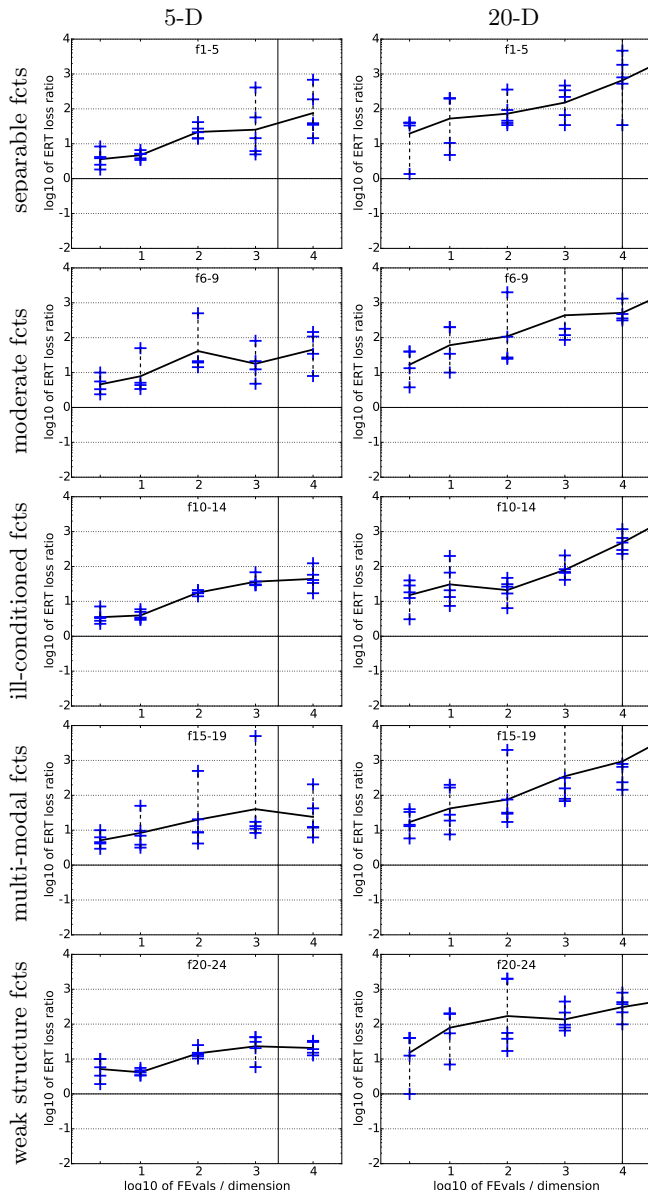


Figure 4: ERT loss ratios (see Figure 3 for details). Each cross (+) represents a single function, the line is the geometric mean.