Black-Box Optimization Benchmarking Template for Noiseless Function Testbed

Draft version *

Forename Name

ABSTRACT

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, Black-box optimization

1. RESULTS

Results of SMBO1 from experiments according to [**?**] on the benchmark functions given in [**?**, **?**] are presented in Figures 1, 2 and 4 and in Tables 1 and 3.

2. REFERENCES

[1] S. Finck, N. Hansen, R. Ros, and A. Auger. Real-parameter black-box optimization benchmarking 2009: Presentation of the noiseless functions. Technical Report 2009/20, Research Center PPE, 2009. Updated February 2010.

[2] N. Hansen, A. Auger, S. Finck, and R. Ros. Real-parameter black-box optimization benchmarking 2012: Experimental setup. Technical report, INRIA, 2012.

[3] N. Hansen, S. Finck, R. Ros, and A. Auger. Real-parameter black-box optimization benchmarking 2009: Noiseless functions definitions. Technical Report RR-6829, INRIA, 2009. Updated February 2010.

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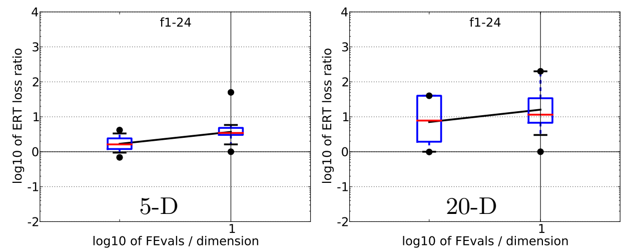
GECCO'13, July 6-10, 2013, Amsterdam, The Netherlands.



	f_1–f_{24} in 5-D, maxFE/D=10					
#FEs/D	best	10%	25%	**med**	75%	90%
2	0.69	0.90	1.2	1.6	2.4	3.3
10	1.0	1.6	2.9	3.4	4.9	6.0
100	4.2	7.0	11	17	35	1.0e2
$\mathrm{RL_{US}}$/D	10	10	10	10	10	10

	f_1–f_{24} in 20-D, maxFE/D=10					
#FEs/D	best	10%	25%	**med**	75%	90%
2	0.99	1.0	1.8	7.8	40	40
10	1.0	2.1	6.5	11	35	2.0e2
100	1.0	17	33	55	79	3.2e2
$\mathrm{RL_{US}}$/D	10	10	10	10	10	10

Figure 3: ERT **loss ratio versus the budget (both in number of f-evaluations divided by dimension). The target value f_t for a given budget** FEvals **is the best target f-value reached within the budget by the given algorithm. Shown is the** ERT **of the given algorithm divided by best** ERT **seen in GECCO-BBOB-2009 for the target f_t, or, if the best algorithm reached a better target within the budget, the budget divided by the best** ERT**. 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.**

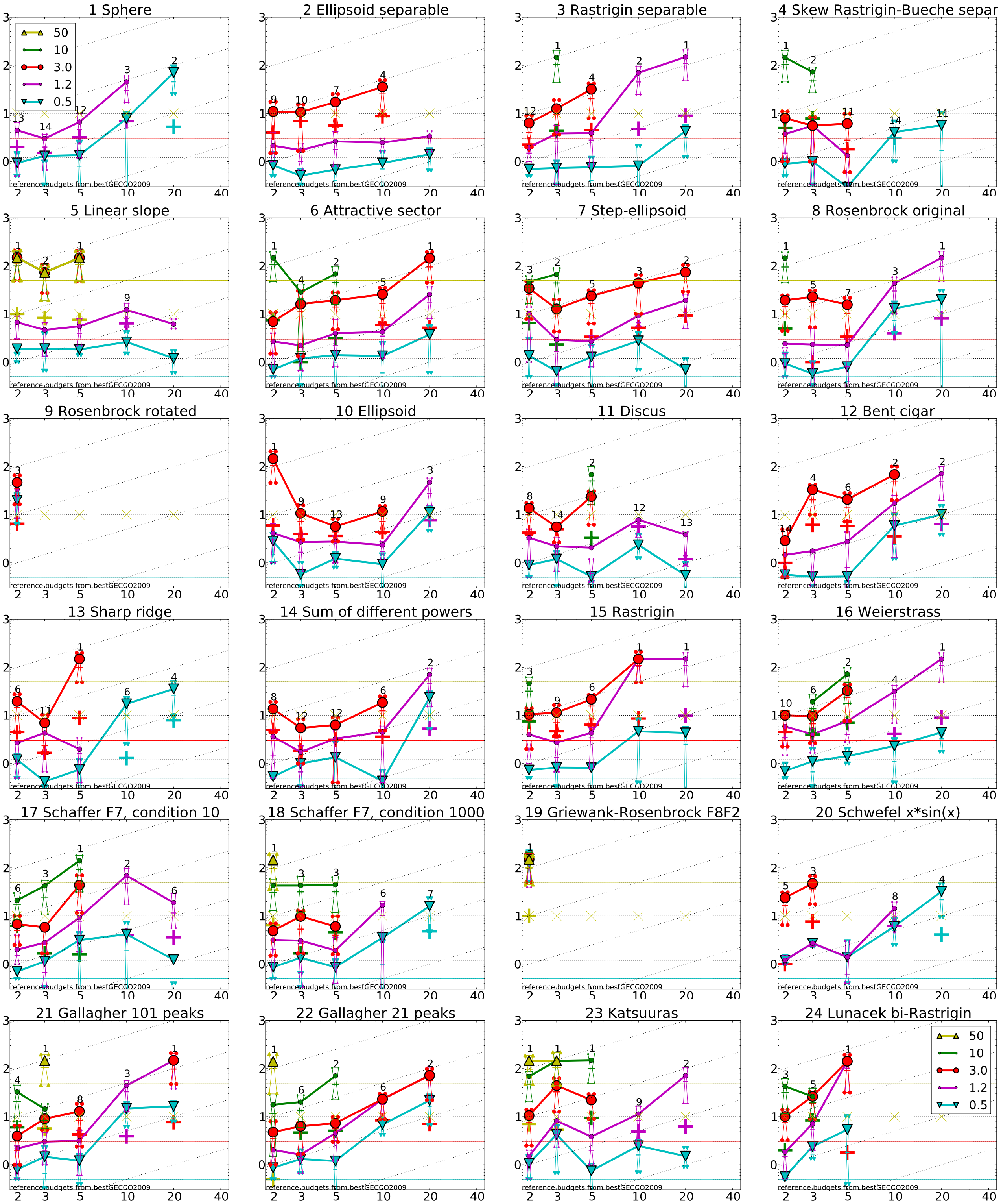


Figure 1: Expected number of f-evaluations (ERT, lines) to reach $f_{\mathrm{opt}} + \Delta f$; median number of f-evaluations (+) to reach the most difficult target that was reached not always but at least once; maximum number of f-evaluations in any trial (×); interquartile range with median (notched boxes) of simulated runlengths to reach $f_{\mathrm{opt}} + \Delta f$; all values are divided by dimension and plotted as $\log_{10}$ values versus dimension. Shown is the ERT for targets just not reached by the GECCO-BBOB-2009 best algorithm within the given budget kDIM, where k is shown in the legend. Numbers above ERT-symbols indicate the number of trials reaching the respective target. Slanted grid lines indicate a scaling with $\mathcal{O}(\mathrm{DIM})$ compared to $\mathcal{O}(1)$ when using the respective 2009 best algorithm.

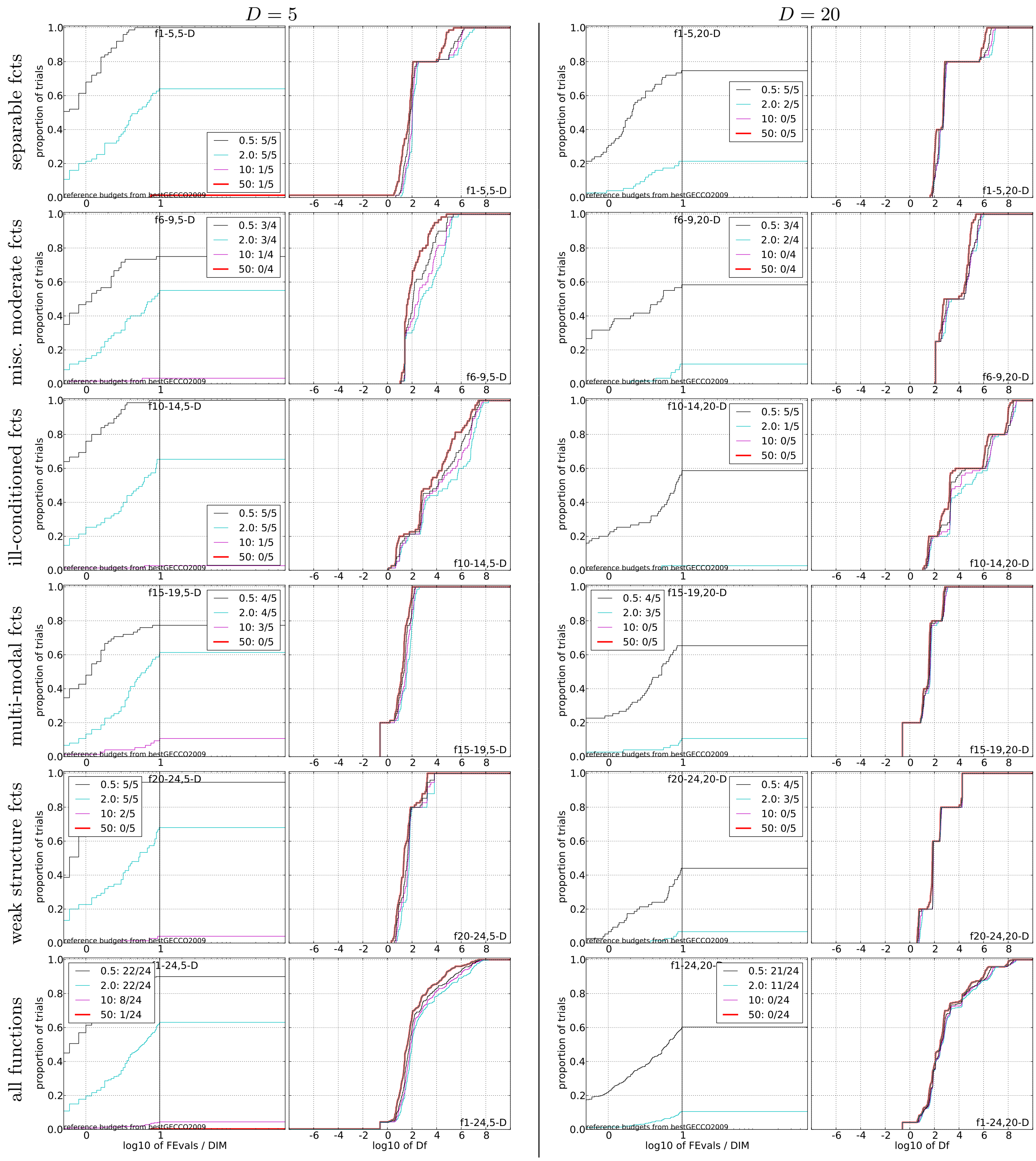


Figure 2: Empirical cumulative distribution functions (ECDF), plotting the fraction of trials with an outcome not larger than the respective value on the x-axis. Left subplots: ECDF of number of function evaluations (FEvals) divided by search space dimension D, to fall below $f_{\mathrm{opt}} + \Delta f$ where Δf is the target just not reached by the GECCO-BBOB-2009 best algorithm within a budget of $k \times \mathrm{DIM}$ evaluations, where k is the first value in the legend. 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 Δf for running times of $0.5D, 1.2D, 3D, 10D, 100D, 1000D, \ldots$ function evaluations (from right to left cycling cyan-magenta-black...) and final Δf-value (red), where Δf and Df denote the difference to the optimal function value.

5-D

#FEs/D	0.5	1.2	3.0	10	50	#succ
$\mathbf{f_1}$	*2.5e+1*:4.8	*1.6e+1*:7.6	*1.0e-8*:12	*1.0e-8*:12	*1.0e-8*:12	15/15
	1.4(2)	4.4(5)	∞	∞	∞*50*	0/15
$\mathbf{f_2}$	*1.6e+6*:2.9	*4.0e+5*:11	*4.0e+4*:15	*6.3e+2*:58	*1.0e-8*:95	15/15
	1.2(0.7)	1.2(1)	5.7(5)	∞	∞*50*	0/15
$\mathbf{f_3}$	*1.6e+2*:4.1	*1.0e+2*:15	*6.3e+1*:23	*2.5e+1*:73	*1.0e+1*:716	15/15
	0.92(1)	1.3(2)	6.8(8)	∞	∞*50*	0/15
$\mathbf{f_4}$	*2.5e+2*:2.6	*1.6e+2*:10	*1.0e+2*:19	*4.0e+1*:65	*1.6e+1*:434	15/15
	0.56(0.6)	0.69(0.9)	1.6(2)	∞	∞*50*	0/15
$\mathbf{f_5}$	*6.3e+1*:4.0	*4.0e+1*:10	*1.0e-8*:10	*1.0e-8*:10	*1.0e-8*:10	15/15
	2.3(1)	2.8(2)	74(82)	74(81)	74(78)	1/15
$\mathbf{f_6}$	*1.0e+5*:3.0	*2.5e+4*:8.4	*1.0e+2*:16	*2.5e+1*:54	*2.5e-1*:254	15/15
	2.3(2)	2.4(2)	6.1(7)	6.3(7)	∞*50*	0/15
$\mathbf{f_7}$	*1.6e+2*:4.2	*1.0e+2*:6.2	*2.5e+1*:20	*4.0e+0*:54	*1.0e+0*:324	15/15
	1.5(2)	2.2(2)	5.9(6)	∞	∞*50*	0/15
$\mathbf{f_8}$	*1.0e+4*:4.6	*6.3e+3*:6.8	*1.0e+3*:18	*6.3e+1*:54	*1.6e+0*:258	15/15
	0.87(2)	1.7(3)	4.4(5)	∞	∞*50*	0/15
$\mathbf{f_9}$	*2.5e+1*:20	*1.6e+1*:26	*1.0e+1*:35	*4.0e+0*:62	*1.6e-2*:256	15/15
	∞	∞	∞	∞	∞*50*	0/15
$\mathbf{f_{10}}$	*2.5e+6*:2.9	*6.3e+5*:7.0	*2.5e+5*:17	*6.3e+3*:54	*2.5e+1*:297	15/15
	2.1(2)	2.0(2)	1.7(2)	∞	∞*50*	0/15
$\mathbf{f_{11}}$	*1.0e+6*:3.0	*6.3e+4*:6.2	*6.3e+2*:16	*6.3e+1*:74	*6.3e-1*:298	15/15
	0.87(0.7)	1.7(3)	7.5(9)	4.6(5)	∞*50*	0/15
$\mathbf{f_{12}}$	*4.0e+7*:3.6	*1.6e+7*:7.6	*4.0e+6*:19	*1.6e+4*:52	*1.0e+0*:268	15/15
	0.72(1)	1.8(3)	5.4(6)	∞	∞*50*	0/15
$\mathbf{f_{13}}$	*1.0e+3*:2.8	*6.3e+2*:8.4	*4.0e+2*:17	*6.3e+1*:52	*6.3e-2*:264	15/15
	1.3(2)	1.2(1)	44(49)	∞	∞*50*	0/15
$\mathbf{f_{14}}$	*1.6e+1*:3.0	*1.0e+1*:10	*6.3e+0*:15	*2.5e-1*:53	*1.0e-5*:251	15/15
	2.2(3)	1.7(2)	2.1(2)	∞	∞*50*	0/15
$\mathbf{f_{15}}$	*1.6e+2*:3.0	*1.0e+2*:13	*6.3e+1*:24	*4.0e+1*:55	*1.6e+1*:289	5/5
	1.4(1)	1.7(2)	4.4(4)	∞	∞*50*	0/15
$\mathbf{f_{16}}$	*4.0e+1*:4.8	*2.5e+1*:16	*1.6e+1*:46	*1.0e+1*:120	*4.0e+0*:334	15/15
	1.5(0.9)	2.4(2)	3.5(4)	3.0(3)	∞*50*	0/15
$\mathbf{f_{17}}$	*1.0e+1*:5.2	*6.3e+0*:26	*4.0e+0*:57	*2.5e+0*:110	*6.3e-1*:412	15/15
	3.0(5)	1.8(2)	3.9(4)	6.4(7)	∞*50*	0/15
$\mathbf{f_{18}}$	*6.3e+1*:3.4	*4.0e+1*:7.2	*2.5e+1*:20	*1.6e+1*:58	*1.6e+0*:318	15/15
	1.3(1)	1.3(2)	1.5(2)	3.8(4)	∞*50*	0/15
$\mathbf{f_{19}}$	*1.6e-1*:172	*1.0e-1*:242	*6.3e-2*:675	*4.0e-2*:3078	*2.5e-2*:4946	15/15
	∞	∞	∞	∞	∞*50*	0/15
$\mathbf{f_{20}}$	*6.3e+3*:5.1	*4.0e+3*:8.4	*4.0e+1*:15	*2.5e+0*:69	*1.0e+0*:851	15/15
	1.4(2)	0.83(1)	∞	∞	∞*50*	0/15
$\mathbf{f_{21}}$	*4.0e+1*:3.9	*2.5e+1*:11	*1.6e+1*:31	*6.3e+0*:73	*1.6e+0*:347	5/5
	1.5(2)	1.5(2)	2.1(2)	∞	∞*50*	0/15
$\mathbf{f_{22}}$	*6.3e+1*:3.6	*4.0e+1*:15	*2.5e+1*:32	*1.0e+1*:71	*1.6e+0*:341	5/5
	1.7(3)	1.5(2)	1.1(1)	4.9(6)	∞*50*	0/15
$\mathbf{f_{23}}$	*1.0e+1*:3.0	*6.3e+0*:9.0	*4.0e+0*:33	*2.5e+0*:84	*1.0e+0*:518	15/15
	1.2(1)	2.1(2)	3.3(3)	8.9(9)	∞*50*	0/15
$\mathbf{f_{24}}$	*6.3e+1*:15	*4.0e+1*:37	*4.0e+1*:37	*2.5e+1*:118	*1.6e+1*:692	15/15
	1.9(3)	19(21)	19(23)	∞	∞*50*	0/15

20-D

#FEs/D	0.5	1.2	3.0	10	50	#succ
$\mathbf{f_1}$	*6.3e+1*:24	*4.0e+1*:42	*1.0e-8*:43	*1.0e-8*:43	*1.0e-8*:43	15/15
	58(62)	∞	∞	∞	∞*200*	0/15
$\mathbf{f_2}$	*4.0e+6*:29	*2.5e+6*:42	*1.0e+5*:65	*1.0e+4*:207	*1.0e-8*:412	15/15
	0.99(0.8)	1.6(2)	∞	∞	∞*200*	0/15
$\mathbf{f_3}$	*6.3e+2*:33	*4.0e+2*:44	*1.6e+2*:109	*1.0e+2*:255	*2.5e+1*:3277	15/15
	2.6(4)	68(75)	∞	∞	∞*200*	0/15
$\mathbf{f_4}$	*6.3e+2*:22	*4.0e+2*:91	*2.5e+2*:250	*1.6e+2*:332	*6.3e+1*:1927	15/15
	5.3(8)	∞	∞	∞	∞*200*	0/15
$\mathbf{f_5}$	*2.5e+2*:19	*1.6e+2*:34	*1.0e-8*:41	*1.0e-8*:41	*1.0e-8*:41	15/15
	1.3(1.0)	3.6(1)	∞	∞	∞*200*	0/15
$\mathbf{f_6}$	*2.5e+5*:16	*6.3e+4*:43	*1.6e+4*:62	*1.6e+2*:353	*1.6e+1*:1078	15/15
	4.7(5)	12(12)	47(53)	∞	∞*200*	0/15
$\mathbf{f_7}$	*1.0e+3*:11	*4.0e+2*:39	*2.5e+2*:74	*6.3e+1*:319	*1.0e+1*:1351	15/15
	1.3(2)	10(11)	20(20)	∞	∞*200*	0/15
$\mathbf{f_8}$	*4.0e+4*:19	*2.5e+4*:35	*4.0e+3*:67	*2.5e+2*:231	*1.6e+1*:1470	15/15
	21(27)	84(88)	∞	∞	∞*200*	0/15
$\mathbf{f_9}$	*1.0e+2*:357	*6.3e+1*:560	*4.0e+1*:684	*2.5e+1*:756	*1.0e+1*:1716	15/15
	∞	∞	∞	∞	∞*200*	0/15
$\mathbf{f_{10}}$	*1.6e+6*:15	*1.0e+6*:27	*4.0e+5*:70	*6.3e+4*:231	*4.0e+3*:1015	15/15
	15(12)	34(36)	∞	∞	∞*200*	0/15
$\mathbf{f_{11}}$	*4.0e+4*:11	*2.5e+3*:27	*1.6e+2*:313	*1.0e+2*:481	*1.0e+1*:1002	15/15
	0.98(1.0)	2.8(4)	∞	∞	∞*200*	0/15
$\mathbf{f_{12}}$	*1.0e+8*:23	*6.3e+7*:39	*2.5e+7*:76	*4.0e+6*:209	*1.0e+1*:1042	15/15
	8.7(9)	36(39)	∞	∞	∞*200*	0/15
$\mathbf{f_{13}}$	*1.6e+3*:28	*1.0e+3*:64	*6.3e+2*:79	*4.0e+1*:211	*2.5e+0*:1724	15/15
	26(25)	∞	∞	∞	∞*200*	0/15
$\mathbf{f_{14}}$	*2.5e+1*:15	*1.6e+1*:42	*1.0e+1*:75	*1.6e+0*:219	*6.3e-4*:1106	15/15
	32(40)	33(38)	∞	∞	∞*200*	0/15
$\mathbf{f_{15}}$	*6.3e+2*:15	*4.0e+2*:67	*2.5e+2*:292	*1.6e+2*:846	*1.0e+2*:1671	15/15
	5.6(7)	44(50)	∞	∞	∞*200*	0/15
$\mathbf{f_{16}}$	*4.0e+1*:26	*2.5e+1*:127	*1.6e+1*:540	*1.6e+1*:540	*1.0e+1*:1384	15/15
	3.3(3)	24(23)	∞	∞	∞*200*	0/15
$\mathbf{f_{17}}$	*1.6e+1*:11	*1.0e+1*:63	*6.3e+0*:305	*4.0e+0*:468	*1.0e+0*:1030	15/15
	2.3(5)	6.0(8)	∞	∞	∞*200*	0/15
$\mathbf{f_{18}}$	*4.0e+1*:116	*2.5e+1*:252	*1.6e+1*:430	*1.0e+1*:621	*4.0e+0*:1090	15/15
	2.8(3)	∞	∞	∞	∞*200*	0/15
$\mathbf{f_{19}}$	*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
	∞	∞	∞	∞	∞*200*	0/15
$\mathbf{f_{20}}$	*1.6e+4*:38	*1.0e+4*:42	*2.5e+2*:62	*2.5e+0*:250	*1.6e+0*:2536	15/15
	17(18)	∞	∞	∞	∞*200*	0/15
$\mathbf{f_{21}}$	*6.3e+1*:36	*4.0e+1*:77	*4.0e+1*:77	*1.6e+1*:456	*4.0e+0*:1094	15/15
	9.2(8)	39(41)	39(46)	∞	∞*200*	0/15
$\mathbf{f_{22}}$	*6.3e+1*:45	*4.0e+1*:68	*4.0e+1*:68	*1.6e+1*:231	*6.3e+0*:1219	15/15
	10(9)	21(23)	21(23)	∞	∞*200*	0/15
$\mathbf{f_{23}}$	*6.3e+0*:29	*4.0e+0*:118	*2.5e+0*:306	*2.5e+0*:306	*1.0e+0*:1614	15/15
	1.1(0.9)	12(13)	∞	∞	∞*200*	0/15
$\mathbf{f_{24}}$	*2.5e+2*:208	*1.6e+2*:918	*1.0e+2*:6628	*6.3e+1*:9885	*4.0e+1*:31629	15/15
	∞	∞	∞	∞	∞*200*	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 (preceded by the target Δf-value in *italics*) in the first. #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. 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.

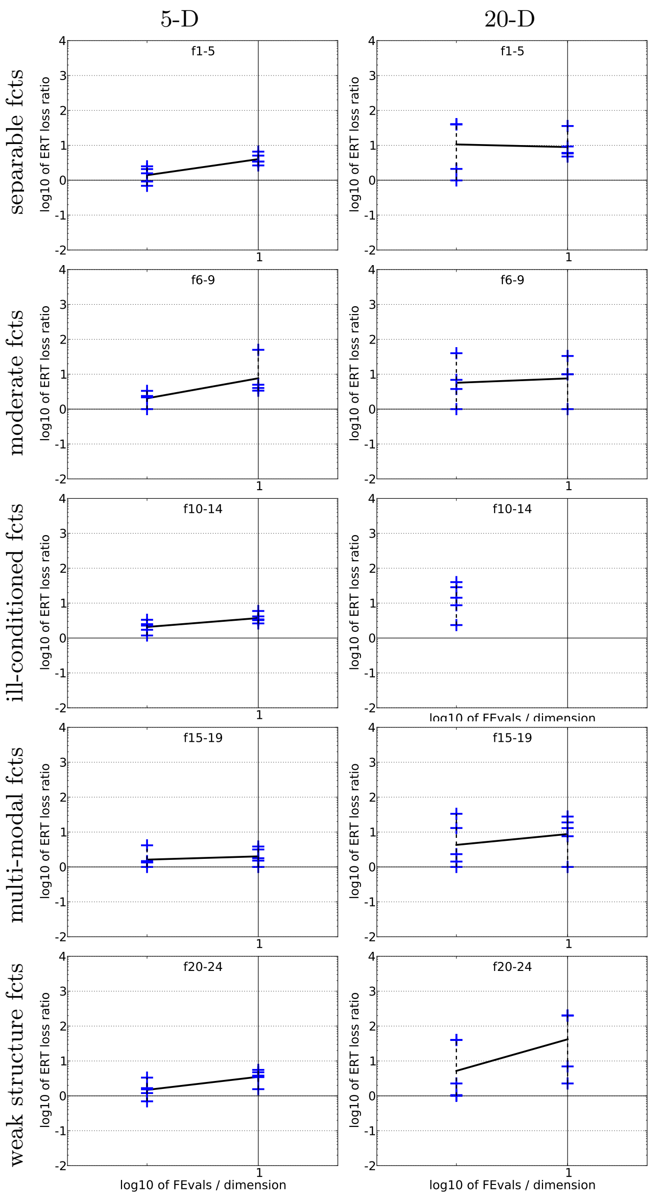


Figure 4: ERT loss ratios (see Figure 3 for details). Each cross (+) represents a single function, the line is the geometric mean.