Comparison Tables: BBOB 2013 Testbed in 20-D (Expensive Setting)

The BBOBies

May 15, 2014

Abstract

This document provides tabular results of the workshop for Black-Box Optimization Benchmarking at GECCO 2013 with a focus on benchmarking black-box algorithms for small function evaluation budgets ("expensive setting"), see `http://coco.gforge.inria.fr/doku.php?id=bbob-2013`. About 30 algorithms have been tested on 24 benchmark functions in dimensions between 2 and 40. A description of the used objective functions can be found in [6, 4]. The experimental set-up is described in [5].

The performance measure provided in the following tables is the expected number of objective function evaluations to reach a given target function value (ERT, expected running time), divided by the respective value for the best algorithm in BBOB-2009 (see [2]) if an algorithm from BBOB-2009 reached the given target function value. The ERT value is given otherwise ($\mathrm{ERT}_{\mathrm{best}}$ is noted as infinite). See [5] for details on how ERT is obtained. Bold entries in the table correspond to values below 3 or the top-three best values. Table 1 gives an overview on all algorithms submitted to the noise-free testbed in 2013.

Table 1: Names and references of all algorithms submitted for the noise-free testbed

algorithm short name	paper	reference
BIPOP-aCMA-STEP los	BI-Population CMA-ES Algorithms with Surrogate Models and Line Searches (Page 1177)	[11]
BIPOP-saACM-k los	BI-Population CMA-ES Algorithms with Surrogate Models and Line Searches (Page 1177)	[11]
CMAES hut	An Evaluation of Sequential Model-Based Optimization for Expensive Blackbox Functions (Page 1209)	[8]
DE pal	Benchmarking a Hybrid Multi Level Single Linkage Algorithm on the BBOB Noiseless Testbed	[12]
HCMA los	BI-Population CMA-ES Algorithms with Surrogate Models and Line Searches (Page 1177)	[11]
HMLSL pal	Benchmarking a Hybrid Multi Level Single Linkage Algorithm on the BBOB Noiseless Testbed	[12]
IPOP-10DDr lia	Bounding the Population Size of IPOP-CMA-ES on the Noiseless BBOB Testbed (Page 1161)	[9]
IPOP-500 lia	Bounding the Population Size of IPOP-CMA-ES on the Noiseless BBOB Testbed (Page 1161)	[9]
IPOP-tany lia	Testing the Impact of Parameter Tuning on a Variant of IPOP-CMA-ES with a Bounded Maximum Population Size on the Noiseless BBOB Testbed (Page 1169)	[10]
IPOP-texp lia	Testing the Impact of Parameter Tuning on a Variant of IPOP-CMA-ES with a Bounded Maximum Population Size on the Noiseless BBOB Testbed (Page 1169)	[10]
IPOP lia	Bounding the Population Size of IPOP-CMA-ES on the Noiseless BBOB Testbed (Page 1161)	[9]
	Testing the Impact of Parameter Tuning on a Variant of IPOP-CMA-ES with a Bounded Maximum Population Size on the Noiseless BBOB Testbed (Page 1169)	[10]
MLSL pal	Benchmarking a Hybrid Multi Level Single Linkage Algorithm on the BBOB Noiseless Testbed	[12]
OQNLP pal	Comparison of Multistart Global Optimization Algorithms on the BBOB Noiseless Testbed (Page 1153)	[13]
P-DCN tra	Multiobjectivization with NSGA-II on the Noiseless BBOB Testbed (Page 1217)	[15]
P-zero tra	Multiobjectivization with NSGA-II on the Noiseless BBOB Testbed (Page 1217)	[15]
SMAC hut	An Evaluation of Sequential Model-Based Optimization for Expensive Blackbox Functions (Page 1209)	[8]
U-DCN tra	Multiobjectivization with NSGA-II on the Noiseless BBOB Testbed (Page 1217)	[15]
U-zero tra	Multiobjectivization with NSGA-II on the Noiseless BBOB Testbed (Page 1217)	[15]
fmincon pal	Comparison of Multistart Global Optimization Algorithms on the BBOB Noiseless Testbed (Page 1153)	[13]
fminunc pal	Comparison of Multistart Global Optimization Algorithms on the BBOB Noiseless Testbed (Page 1153)	[13]
ga100 hol	Benchmarking Cellular Genetic Algorithms on the BBOB Noiseless Testbed (Page 1201)	[7]
grid100 hol	Benchmarking Cellular Genetic Algorithms on the BBOB Noiseless Testbed (Page 1201)	[7]
grid16 hol	Benchmarking Cellular Genetic Algorithms on the BBOB Noiseless Testbed (Page 1201)	[7]
hill hol	Benchmarking Cellular Genetic Algorithms on the BBOB Noiseless Testbed (Page 1201)	[7]
lmmCMA aug	Benchmarking the Local Metamodel CMA-ES on the Noiseless BBOB'2013 Test Bed (Page 1225)	[1]
memPSODE vog	Adapt-MEMPSODE: A Memetic Algorithm with Adaptive Selection of Local Searches (Page 1137)	[16]
prcga saw	Benchmarking Projection-Based Real Coded Genetic Algorithm on BBOB-2013 Noiseless Function Testbed (Page 1193)	[14]
ring100 hol	Benchmarking Cellular Genetic Algorithms on the BBOB Noiseless Testbed (Page 1201)	[7]
ring16 hol	Benchmarking Cellular Genetic Algorithms on the BBOB Noiseless Testbed (Page 1201)	[7]
simplex pal	Comparison of Multistart Global Optimization Algorithms on the BBOB Noiseless Testbed (Page 1153)	[13]

Table 2: 20-D, running time excess ERT/ERT$_{\text{best 2009}}$ on f_1 for given run-length based budgets (0.5D, 1.2D, 3D, 10D, and 50D function evaluations). 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 ERT$_{\text{best 2009}}$ (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. Entries with succeeding star are statistically significantly better (according to the rank-sum test) compared to all other algorithms in the table, with $p = 0.05$ or $p = 10^{-k}$ when the number k following the star is larger than 1, with Bonferroni correction by the number of instances.

#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
BIPOP-aCMA	4.5(0)	3.2(0.4)	18(0.5)	18(0.5)	18(0.5)	15/15
BIPOP-saAC	4.0(2)	3.4(0.2)	16(0.7)	16(0.7)	16(0.7)	15/15
CMAES hut	4.3(2)	3.6(2)	∞	∞	∞ *2006*	0/15
DE pal	18(8)	22(5)	768(18)	768(18)	768(18)	15/15
HCMA los	**1.7**(0)	**1.0**(0)	**1.0**(0.0)	**1.0**(0.0)	**1.0**(0.0)	15/15
HMLSL pal	**0.91**(0)	**0.53**(0)	**5.1**(0.5)	**5.1**(0.5)	**5.1**(0.5)	15/15
IPOP-10DDr	4.2(2)	3.8(0.7)	63(5)	63(5)	63(5)	15/15
IPOP-500 l	4.2(2)	3.8(0.7)	63(5)	63(5)	63(5)	15/15
IPOP-tany	3.8(1)	3.3(1)	68(4)	68(4)	68(4)	15/15
IPOP-texp	**2.0**(1)	**2.1**(0.8)	66(4)	66(4)	66(4)	15/15
IPOP lia	4.2(2)	3.8(0.7)	63(5)	63(5)	63(5)	15/15
MLSL pal	**0.91**(0)	**0.53**(0)	**5.1**(0.5)	**5.1**(0.5)	**5.1**(0.5)	15/15
OQNLP pal	**2.0**(0.0)	**1.2**(0.0)	**1.8**(0)	**1.8**(0)	**1.8**(0)	15/15
P-DCN tra	17(20)	21(13)	4134(1370)	4134(1370)	4134(1370)	15/15
P-zero tra	29(24)	26(14)	7717(2217)	7717(2217)	7717(2217)	15/15
SMAC hut	**0.80**(0.4)	**0.67**(0.2)	∞	∞	∞ *2000*	0/15
U-DCN tra	5.6(2)	5.7(2)	3.2e4(3e4)	3.2e4(3e4)	3.2e4(3e4)	15/15
U-zero tra	4.0(2)	3.7(2)	4.0e5(2e5)	4.0e5(3e5)	4.0e5(3e5)	13/15
fmincon pa	**0.91**(0)	**0.53**(0)	**5.1**(0.5)	**5.1**(0.5)	**5.1**(0.5)	15/15
fminunc pa	**1.1**(0.4)	**1.00**(0)	**1**(0)	**1**(0)	**1**(0)	15/15
ga100 hol	25(7)	23(6)	∞	∞	∞ *1e6*	0/15
grid100 ho	75(65)	90(37)	∞	∞	∞ *1e6*	0/15
grid16 hol	20(9)	19(8)	∞	∞	∞ *1e6*	0/15
hill hol	5.7(2)	4.4(1)	∞	∞	∞ *1e6*	0/15
lmmCMA aug	**2.5**(1)	**2.5**(1)	10(0.2)	10(0.2)	10(0.2)	15/15
memPSODE v	7.5(0.9)	5.5(2)	25(25)	25(25)	25(25)	15/15
prcga saw	13(9)	15(5)	9668(1e4)	9668(1e4)	9668(1e4)	15/15
ring100 ho	51(24)	55(13)	∞	∞	∞ *1e6*	0/15
ring16 hol	13(5)	12(4)	∞	∞	∞ *1e6*	0/15
simplex pa	62(42)	60(4)	∞	∞	∞ *4e5*	0/15

Table 3: 20-D, running time excess ERT/ERT$_{\text{best 2009}}$ on f_2 for given run-length based budgets (0.5D, 1.2D, 3D, 10D, and 50D function evaluations). 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 ERT$_{\text{best 2009}}$ (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. Entries with succeeding star are statistically significantly better (according to the rank-sum test) compared to all other algorithms in the table, with $p = 0.05$ or $p = 10^{-k}$ when the number k following the star is larger than 1, with Bonferroni correction by the number of instances.

#FEs/D	0.5	1.2	3	10	50	#succ
f2	*4.0e+6*:29	*2.5e+6*:42	*1.0e+5*:65	*1.0e+4*:207	*1.0e-8*:412	15/15
BIPOP-aCMA	**2.3**(2)	**2.1**(2)	**3.6**(0.3)	**1.5**(0.1)	**28**(19)	15/15
BIPOP-saAC	**1.2**(0.8)	**1.4**(0.7)	10(2)	**4.0**(0.7)	**5.9**(0.6)	15/15
CMAES hut	**0.97**(0.9)	**0.94**(0.7)	14(5)	35(35)	∞ *2006*	0/15
DE pal	**1.7**(2)	**2.4**(2)	29(7)	20(2)	106(3)	15/15
HCMA los	**1.3**(0.7)	**0.93**(0)	**1.0**(0.2)$^{\star 4}$	**1.4**(0.6)	**7.7**(4)	15/15
HMLSL pal	**2.4**(4)	**2.5**(5)	10(7)	5.4(3)	38(31)	15/15
IPOP-10DDr	**1.3**(1)	**2.0**(1)	14(3)	12(3)	52(2)	15/15
IPOP-500 l	**1.3**(1)	**2.0**(1)	14(3)	12(3)	52(2)	15/15
IPOP-tany	**1.00**(1)	**1.1**(1)	14(5)	12(3)	52(2)	15/15
IPOP-texp	**0.72**(0.6)	**0.96**(0.5)	10(5)	10(2)	50(2)	15/15
IPOP lia	**1.3**(1)	**2.0**(1)	14(3)	12(3)	52(2)	15/15
MLSL pal	**2.4**(4)	**2.5**(5)	10(7)	5.4(3)	58(89)	15/15
OQNLP pal	**1.6**(0.0)	**1.3**(0.3)	**5.3**(3)	**2.6**(0.8)	∞ *3e5*	0/15
P-DCN tra	**3.0**(2)	5.3(7)	33(10)	17(5)	2.2e4(3e4)	13/15
P-zero tra	7.6(8)	11(10)	34(16)	17(5)	3.6e5(4e5)	2/15
SMAC hut	**0.54**(0.4)	**0.70**(0.6)	23(21)	143(145)	∞ *2000*	0/15
U-DCN tra	**1.8**(1.0)	**1.9**(2)	10(5)	14(5)	2.1e5(2e5)	3/15
U-zero tra	**1.4**(1)	**1.7**(1)	7.4(5)	9.2(5)	∞ *2e7*	0/15
fmincon pa	**2.6**(4)	**2.3**(4)	10(8)	6.1(4)	**22**(9)	15/15
fminunc pa	**1.6**(1)	**1.4**(0.5)	**5.7**(2)	5.8(2)	113(111)	15/15
ga100 hol	**1.5**(2)	**2.8**(4)	37(12)	25(7)	∞ *1e6*	0/15
grid100 ho	**0.89**(0.8)	3.2(5)	128(40)	117(26)	∞ *1e6*	0/15
grid16 hol	5.1(9)	6.4(8)	28(7)	19(7)	∞ *1e6*	0/15
hill hol	4.5(3)	3.7(2)	7.5(7)	6.4(3)	∞ *1e6*	0/15
lmmCMA aug	**0.53**(0.5)	**0.68**(0.7)	**7.2**(2)	**3.8**(0.8)	**14**(1)	15/15
memPSODE v	4.1(4)	4.8(3)	12(19)	12(14)	53(44)	15/15
prcga saw	**0.50**(0.6)	**1.3**(1)	17(6)	11(2)	1.7e4(2e4)	4/15
ring100 ho	**2.2**(1)	4.9(9)	77(14)	58(8)	∞ *1e6*	0/15
ring16 hol	3.3(3)	4.6(2)	16(4)	12(3)	∞ *1e6*	0/15
simplex pa	27(15)	22(10)	52(13)	1532(1738)	∞ *4e5*	0/15

Table 4: 20-D, running time excess ERT/ERT$_{\text{best 2009}}$ on f_3 for given run-length based budgets (0.5D, 1.2D, 3D, 10D, and 50D function evaluations). 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 ERT$_{\text{best 2009}}$ (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. Entries with succeeding star are statistically significantly better (according to the rank-sum test) compared to all other algorithms in the table, with $p = 0.05$ or $p = 10^{-k}$ when the number k following the star is larger than 1, with Bonferroni correction by the number of instances.

#FEs/D	0.5	1.2	3	10	50	#succ
f3	*6.3e+2*:33	*4.0e+2*:44	*1.6e+2*:109	*1.0e+2*:255	*2.5e+1*:3277	15/15
BIPOP-aCMA	**2.8**(0.7)	3.0(0.4)	**1.8**(0.2)$^{\star 2}$	**1.0**(0.2)$^{\star 3}$	**0.29**(0.0)	15/15
BIPOP-saAC	**1.9**(1)	3.1(1.0)	7.1(3)	6.3(2)	**2.7**(2)	15/15
CMAES hut	**2.2**(1)	3.9(2)	7.5(3)	8.1(4)	4.5(5)	2/15
DE pal	5.0(4)	14(5)	35(10)	59(23)	1828(1953)	1/15
HCMA los	**1.6**(0.6)	3.3(2)	**2.8**(0.1)	**1.4**(0.1)	**0.29**(0.0)	15/15
HMLSL pal	6.6(6)	33(32)	60(13)	41(0.7)	17(11)	15/15
IPOP-10DDr	**2.3**(1)	3.7(0.8)	6.5(3)	6.6(2)	3.1(2)	15/15
IPOP-500 l	**2.3**(1)	3.7(0.8)	6.5(3)	6.6(2)	3.1(2)	15/15
IPOP-tany	**1.1**(0.5)	**2.9**(1)	6.2(2)	6.9(2)	**2.2**(2)	15/15
IPOP-texp	**0.57**(0.5)	**1.5**(0.8)	6.7(4)	5.9(1)	3.2(2)	15/15
IPOP lia	**2.3**(1)	3.7(0.8)	6.5(3)	6.6(2)	3.1(2)	15/15
MLSL pal	6.5(6)	41(29)	3849(4480)	7279(7179)	∞ *4e5*	0/15
OQNLP pal	13(18)	36(30)	780(803)	1324(1298)	∞ *3e5*	0/15
P-DCN tra	8.2(10)	25(33)	89(104)	113(153)	76(51)	15/15
P-zero tra	6.0(10)	27(45)	131(101)	105(68)	126(130)	15/15
SMAC hut	**0.49**(0.5)$_{\downarrow 2}$	**2.1**(3)	124(147)	114(122)	∞ *2000*	0/15
U-DCN tra	**1.9**(1)	3.4(2)	**5.3**(2)	**4.3**(2)	**1.9**(0.4)	15/15
U-zero tra	**1.5**(1)	**2.6**(1)	**3.6**(0.9)	**2.6**(0.6)	**0.78**(0.1)	15/15
fmincon pa	6.6(6)	32(29)	6179(6457)	2.3e4(3e4)	∞ *4e5*	0/15
fminunc pa	19(23)	36(31)	3868(3633)	2.3e4(3e4)	∞ *4e5*	0/15
ga100 hol	6.8(7)	17(5)	23(3)	14(1)	**2.8**(0.5)	15/15
grid100 ho	12(11)	54(25)	78(17)	52(16)	13(2)	15/15
grid16 hol	7.9(5)	16(4)	16(4)	10(2)	**2.4**(0.3)	15/15
hill hol	4.0(2)	4.1(1)	**3.0**(1)	**1.8**(0.6)	**0.54**(0.2)	15/15
lmmCMA aug	**1.0**(1)	**2.3**(1)	5.9(2)	4.8(0.9)	**2.1**(1.0)	14/15
memPSODE v	5.7(3)	5.9(1)	18(35)	21(16)	6.5(5)	15/15
prcga saw	**2.6**(3)	10(3)	20(5)	15(4)	**2.3**(0.4)	15/15
ring100 ho	8.5(8)	33(12)	52(8)	32(3)	6.4(0.5)	15/15
ring16 hol	5.7(4)	11(3)	10(2)	6.3(1.0)	**1.3**(0.1)	15/15
simplex pa	39(34)	782(1292)	∞	∞	∞ *4e5*	0/15

Table 5: 20-D, running time excess ERT/ERT$_{\text{best 2009}}$ on f_4 for given run-length based budgets (0.5D, 1.2D, 3D, 10D, and 50D function evaluations). 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 ERT$_{\text{best 2009}}$ (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. Entries with succeeding star are statistically significantly better (according to the rank-sum test) compared to all other algorithms in the table, with $p = 0.05$ or $p = 10^{-k}$ when the number k following the star is larger than 1, with Bonferroni correction by the number of instances.

#FEs/D	0.5	1.2	3	10	50	#succ
f4	*6.3e+2*:22	*4.0e+2*:91	*2.5e+2*:250	*1.6e+2*:332	*6.3e+1*:1927	15/15
BIPOP-aCMA	5.1(0)	**2.1**(0.7)	**1.1**(0.1)	**1.2**(0.2)	**0.34**(0.0)	15/15
BIPOP-saAC	6.7(4)	3.0(1)	**2.3**(0.5)	3.6(1)	**2.2**(2)	15/15
CMAES hut	5.8(3)	**2.8**(1)	**2.1**(0.7)	3.9(1)	**2.5**(2)	6/15
DE pal	21(9)	14(3)	12(3)	21(4)	54(27)	15/15
HCMA los	4.9(2)	**2.7**(1)	**1.4**(0.0)	**1.2**(0.1)	**0.34**(0.0)	15/15
HMLSL pal	**1.4**(2)	18(22)	19(12)	27(3)	7.7(5)	15/15
IPOP-10DDr	4.6(6)	3.8(0.9)	**2.3**(0.5)	3.7(1)	**1.4**(0.3)	15/15
IPOP-500 l	4.6(6)	3.8(0.9)	**2.3**(0.5)	3.7(1)	**1.4**(0.3)	15/15
IPOP-tany	3.4(4)	**2.9**(1)	**2.4**(0.9)	4.1(2)	**1.4**(0.3)	15/15
IPOP-texp	**0.59**(0.7)	**0.92**(0.5)*	**1.4**(0.4)	3.2(1)	**2.5**(2)	15/15
IPOP lia	4.6(6)	3.8(0.9)	**2.3**(0.5)	3.7(1)	**1.4**(0.3)	15/15
MLSL pal	**1.4**(2)	25(35)	656(810)	8305(9213)	∞ *4e5*	0/15
OQNLP pal	**1.6**(2)	45(82)	133(155)	874(899)	∞ *3e5*	0/15
P-DCN tra	41(55)	37(41)	31(32)	49(30)	54(35)	15/15
P-zero tra	48(44)	63(46)	56(29)	82(41)	74(61)	15/15
SMAC hut	6.9(10)	102(121)	∞	∞	∞ *2000*	0/15
U-DCN tra	6.2(3)	**3.0**(1)	**1.9**(0.8)	**2.6**(0.8)	**1.4**(0.4)	15/15
U-zero tra	4.1(2)	**1.9**(0.7)	**1.3**(0.4)	**1.6**(0.4)	**0.80**(0.2)	15/15
fmincon pa	**1.4**(2)	42(49)	524(762)	5111(6004)	∞ *4e5*	0/15
fminunc pa	**2.0**(2)	62(59)	3766(4717)	1.7e4(2e4)	∞ *4e5*	0/15
ga100 hol	27(10)	14(3)	8.8(2)	10(1)	3.3(0.6)	15/15
grid100 ho	71(52)	53(24)	35(8)	41(10)	14(4)	15/15
grid16 hol	23(12)	10(3)	6.1(2)	7.2(2)	**2.5**(0.5)	15/15
hill hol	7.0(4)	**2.3**(0.6)	**1.2**(0.3)	**1.3**(0.3)	**0.55**(0.1)	15/15
lmmCMA aug	**1.3**(2)	**2.2**(0.9)	**2.0**(0.6)	**3.0**(0.8)	**2.0**(2)	13/15
memPSODE v	22(37)	19(41)	11(16)	13(13)	4.7(4)	15/15
prcga saw	6.8(4)	7.0(3)	6.8(2)	9.0(2)	**2.8**(0.4)	15/15
ring100 ho	46(31)	29(7)	19(2)	22(2)	7.5(1)	15/15
ring16 hol	14(8)	7.2(2)	4.0(0.7)	4.3(0.5)	**1.5**(0.2)	15/15
simplex pa	18(22)	2835(3439)	∞	∞	∞ *4e5*	0/15

Table 6: 20-D, running time excess ERT/ERT$_{\text{best 2009}}$ on f_5 for given run-length based budgets (0.5D, 1.2D, 3D, 10D, and 50D function evaluations). 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 ERT$_{\text{best 2009}}$ (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. Entries with succeeding star are statistically significantly better (according to the rank-sum test) compared to all other algorithms in the table, with $p = 0.05$ or $p = 10^{-k}$ when the number k following the star is larger than 1, with Bonferroni correction by the number of instances.

#FEs/D	0.5	1.2	3	10	50	#succ
f5	*2.5e+2*:19	*1.6e+2*:34	*1.0e-8*:41	*1.0e-8*:41	*1.0e-8*:41	15/15
BIPOP-aCMA	**1.9**(0.6)	**1.2**(0)	**1.0**(0)	**1.0**(0)	**1.0**(0)	15/15
BIPOP-saAC	**1.9**(1)	**2.1**(0.9)	5.4(0.6)	5.4(0.6)	5.4(0.6)	15/15
CMAES hut	**1.9**(1)	**2.2**(0.7)	6.7(1)	6.7(1)	6.7(1)	15/15
DE pal	4.7(4)	26(7)	8276(216)	8276(216)	8276(216)	15/15
HCMA los	**2.2**(0)	**1.2**(0.0)	**1.4**(0.3)	**1.4**(0.3)	**1.4**(0.3)	15/15
HMLSL pal	**1.2**(0)	**1.3**(0)	1.0e4(284)	1.0e4(284)	1.0e4(284)	14/15
IPOP-10DDr	**1.1**(0.7)	**1.7**(1.0)	418(295)	418(295)	418(295)	15/15
IPOP-500 l	**1.1**(0.7)	**1.7**(1.0)	418(295)	418(295)	418(295)	15/15
IPOP-tany	**1.5**(0.7)	**2.3**(0.6)	285(214)	285(214)	285(196)	15/15
IPOP-texp	3.8(0.6)	3.6(0.9)	471(320)	471(320)	471(320)	15/15
IPOP lia	**1.1**(0.7)	**1.7**(1.0)	418(295)	418(295)	418(295)	15/15
MLSL pal	**1.2**(0)	**1.3**(0)	1.4e5(2e5)	1.4e5(2e5)	1.4e5(2e5)	1/15
OQNLP pal	**2.7**(0)	**1.5**(0)	**1.3**(0)	**1.3**(0)	**1.3**(0)	15/15
P-DCN tra	6.0(2)	27(19)	461(36)	461(36)	461(36)	15/15
P-zero tra	5.0(5)	27(18)	226(29)	226(29)	226(29)	15/15
SMAC hut	**0.46**(0.2)$_{\downarrow 2}$	**0.33**(0.1)$^{\star 4}$	**0.66**(0.2)$^{\star 2}$	**0.66**(0.2)$^{\star 2}$	**0.66**(0.2)$^{\star 2}$	15/15
U-DCN tra	**2.5**(1)	4.3(2)	∞	∞	∞ *2e7*	0/15
U-zero tra	**1.9**(0.9)	3.3(1)	∞	∞	∞ *2e7*	0/15
fmincon pa	**1.2**(0)	**1.3**(0)	3.0e4(3e4)	3.0e4(4e4)	3.0e4(4e4)	4/15
fminunc pa	**2.3**(0)	**1.3**(0)	**2.6**(0)	**2.6**(0)	**2.6**(0)	15/15
ga100 hol	8.5(8)	19(9)	133(18)	133(18)	133(18)	15/15
grid100 ho	6.8(11)	79(41)	486(90)	486(90)	486(90)	15/15
grid16 hol	7.8(5)	15(9)	81(17)	81(17)	81(17)	15/15
hill hol	3.9(3)	3.9(2)	15(5)	15(5)	15(5)	15/15
lmmCMA aug	**1.8**(0.5)	**2.1**(0.6)	6.1(1)	6.1(1)	6.1(1)	15/15
memPSODE v	**1.4**(1)	**2.7**(1)	3.1(0.3)	3.1(0.3)	3.1(0.3)	15/15
prcga saw	11(8)	16(10)	∞	∞	∞ *1e6*	0/15
ring100 ho	5.2(12)	44(9)	265(28)	265(28)	265(28)	15/15
ring16 hol	5.4(4)	11(3)	52(7)	52(7)	52(7)	15/15
simplex pa	40(15)	63(30)	227(93)	227(93)	227(93)	15/15

Table 7: 20-D, running time excess ERT/$\mathrm{ERT}_{\mathrm{best\ 2009}}$ on f_6 for given run-length based budgets (0.5D, 1.2D, 3D, 10D, and 50D function evaluations). 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 $\mathrm{ERT}_{\mathrm{best\ 2009}}$ (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. Entries with succeeding star are statistically significantly better (according to the rank-sum test) compared to all other algorithms in the table, with $p = 0.05$ or $p = 10^{-k}$ when the number k following the star is larger than 1, with Bonferroni correction by the number of instances.

#FEs/D	0.5	1.2	3	10	50	#succ
f6	*2.5e+5*:16	*6.3e+4*:43	*1.6e+4*:62	*1.6e+2*:353	*1.6e+1*:1078	15/15
BIPOP-aCMA	3.8(4)	3.5(1)	3.4(1)	**3.0**(0.7)	**1.8**(0.2)	15/15
BIPOP-saAC	3.0(3)	**2.3**(1)	**2.1**(0.6)	**2.4**(1)	**1.6**(0.6)	15/15
CMAES hut	3.1(2)	**2.1**(0.9)	**2.0**(0.9)	**2.6**(1)	**1.9**(1.0)	13/15
DE pal	9.1(11)	17(12)	23(18)	16(9)	45(24)	15/15
HCMA los	**2.6**(0.0)	**1.1**(0.1)	**0.90**(0.2)	**1.6**(2)	**1.8**(0.3)	15/15
HMLSL pal	5.3(12)	6.5(10)	6.9(9)	3.0(2)	**1.9**(1)	15/15
IPOP-10DDr	**3.0**(3)	**2.8**(1)	3.1(1)	**1.5**(0.6)	**1.3**(0.3)	15/15
IPOP-500 l	**3.0**(3)	**2.8**(1)	3.1(1)	**1.5**(0.6)	**1.3**(0.3)	15/15
IPOP-tany	**2.0**(2)	**2.6**(2)	**2.9**(1)	**1.6**(0.4)	**1.4**(0.4)	15/15
IPOP-texp	**2.1**(2)	**2.1**(2)	**2.4**(1)	**1.4**(0.5)	**1.4**(0.3)	15/15
IPOP lia	**3.0**(3)	**2.8**(1)	3.1(1)	**1.5**(0.6)	**1.3**(0.3)	15/15
MLSL pal	5.3(12)	6.5(10)	6.9(9)	3.0(2)	**1.9**(1)	15/15
OQNLP pal	**2.3**(2)	**1.3**(0.3)	**1.2**(0.5)	**0.58**(0.2)	**0.94**(0.7)*	15/15
P-DCN tra	5.7(8)	12(13)	15(14)	8.5(3)	8.3(3)	15/15
P-zero tra	17(22)	21(18)	22(15)	10(5)	9.3(5)	15/15
SMAC hut	**1.6**(1)	**1.2**(0.9)	**1.6**(1.0)	**2.8**(3)	∞ *2000*	0/15
U-DCN tra	3.2(3)	4.0(3)	4.9(4)	6.5(4)	324(433)	15/15
U-zero tra	3.2(3)	**2.9**(2)	4.2(3)	10(9)	698(1970)	15/15
fmincon pa	6.0(13)	5.3(7)	5.9(6)	**2.6**(1)	**1.6**(0.5)	15/15
fminunc pa	**2.0**(2)	**1.6**(1)	**1.6**(0.5)	**0.64**(0.3)	**2.2**(0.9)	15/15
ga100 hol	13(15)	16(9)	15(7)	10(2)	19(8)	15/15
grid100 ho	26(38)	52(55)	67(50)	68(51)	908(1032)	9/15
grid16 hol	8.6(12)	11(8)	13(8)	15(10)	240(466)	13/15
hill hol	6.1(5)	4.0(3)	3.6(2)	5.3(5)	235(468)	13/15
lmmCMA aug	**1.6**(1)	**1.6**(1)	**2.0**(0.9)	6.8(3)	9.0(6)	11/15
memPSODE v	5.8(5)	4.3(1)	3.6(2)	6.4(5)	6.9(2)	15/15
prcga saw	11(14)	13(10)	16(10)	7.1(4)	366(709)	14/15
ring100 ho	19(26)	32(28)	38(22)	24(7)	46(10)	15/15
ring16 hol	5.5(6)	7.4(4)	8.4(3)	7.2(4)	17(14)	15/15
simplex pa	65(73)	46(24)	40(4)	98(92)	∞ *4e5*	0/15

Table 8: 20-D, running time excess ERT/ERT$_{\text{best 2009}}$ on f_7 for given run-length based budgets (0.5D, 1.2D, 3D, 10D, and 50D function evaluations). 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 ERT$_{\text{best 2009}}$ (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. Entries with succeeding star are statistically significantly better (according to the rank-sum test) compared to all other algorithms in the table, with $p = 0.05$ or $p = 10^{-k}$ when the number k following the star is larger than 1, with Bonferroni correction by the number of instances.

#FEs/D	0.5	1.2	3	10	50	#succ
f7	*1.0e+3*:11	*4.0e+2*:39	*2.5e+2*:74	*6.3e+1*:319	*1.0e+1*:1351	15/15
BIPOP-aCMA	4.3(3)	4.2(2)	3.9(2)	**1.9**(0.6)	**1.5**(1)	15/15
BIPOP-saAC	3.2(3)	**2.8**(2)	**2.5**(1)	**1.1**(0.2)	**0.52**(0.2)	15/15
CMAES hut	**1.3**(1)	**2.0**(1)	**2.1**(0.8)	**1.4**(0.4)	**1.3**(0.9)	12/15
DE pal	3.4(4)	9.4(8)	12(5)	16(4)	21(5)	15/15
HCMA los	**2.1**(2)	**1.3**(0.3)	**0.87**(0.3)	**1.6**(1)	**0.98**(0.9)	15/15
HMLSL pal	**2.7**(4)	21(14)	23(6)	19(7)	21(5)	15/15
IPOP-10DDr	**1.7**(2)	3.2(0.7)	**2.5**(0.6)	**1.4**(0.3)	**1.7**(2)	15/15
IPOP-500 l	**1.7**(2)	3.2(0.7)	**2.5**(0.6)	**1.4**(0.3)	**1.7**(2)	15/15
IPOP-tany	**0.93**(2)	**2.1**(1)	**1.9**(0.7)	**1.5**(0.4)	**1.0**(0.3)	15/15
IPOP-texp	**1.1**(2)	**1.3**(0.9)	**1.1**(0.6)	**1.2**(0.3)	**1.6**(2)	15/15
IPOP lia	**1.7**(2)	3.2(0.7)	**2.5**(0.6)	**1.4**(0.3)	**1.7**(2)	15/15
MLSL pal	4.6(7)	185(247)	674(765)	∞	∞ *2e5*	0/15
OQNLP pal	6.7(4)	24(23)	36(30)	58(56)	∞ *2e4*	0/15
P-DCN tra	**1.4**(1)	10(19)	18(23)	181(295)	1.7e4(2e4)	8/15
P-zero tra	**1.6**(2)	27(32)	63(60)	282(323)	2528(2942)	15/15
SMAC hut	**0.58**(0.6)	**0.61**(0.6)	**0.49**(0.3)*	**0.39**(0.3)*	**0.57**(0.3)	15/15
U-DCN tra	**1.3**(1)	**2.3**(2)	**2.3**(1)	38(57)	1.8e4(2e4)	8/15
U-zero tra	**1.8**(2)	**2.3**(2)	**2.4**(1)	11(15)	2.1e4(2e4)	7/15
fmincon pa	**2.9**(5)	166(168)	469(328)	∞	∞ *2e5*	0/15
fminunc pa	4.9(7)	144(214)	933(1264)	∞	∞ *2e5*	0/15
ga100 hol	**2.2**(3)	10(6)	10(4)	8.4(2)	175(224)	14/15
grid100 ho	**1.3**(2)	30(23)	50(38)	105(101)	5054(5182)	2/15
grid16 hol	3.7(2)	9.4(6)	9.2(5)	23(30)	2371(2391)	4/15
hill hol	6.3(6)	3.9(2)	3.2(1)	7.7(9)	2235(2591)	4/15
lmmCMA aug	**0.49**(0.7)	**1.2**(0.9)	**1.7**(1)	**1.0**(0.2)	**0.48**(0.1)	15/15
memPSODE v	**2.6**(2)	15(9)	13(13)	17(12)	26(21)	15/15
prcga saw	**2.2**(3)	5.7(4)	6.7(3)	5.4(2)	513(788)	10/15
ring100 ho	**1.4**(1)	20(9)	24(9)	23(10)	93(121)	15/15
ring16 hol	3.3(4)	5.6(3)	6.1(2)	8.8(5)	842(1104)	8/15
simplex pa	4.3(7)	248(379)	1019(917)	∞	∞ *3e5*	0/15

Table 9: 20-D, running time excess ERT/$\mathrm{ERT}_{\mathrm{best\ 2009}}$ on f_8 for given run-length based budgets (0.5D, 1.2D, 3D, 10D, and 50D function evaluations). 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 $\mathrm{ERT}_{\mathrm{best\ 2009}}$ (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. Entries with succeeding star are statistically significantly better (according to the rank-sum test) compared to all other algorithms in the table, with $p = 0.05$ or $p = 10^{-k}$ when the number k following the star is larger than 1, with Bonferroni correction by the number of instances.

#FEs/D	0.5	1.2	3	10	50	#succ
f8	*4.0e+4*:19	*2.5e+4*:35	*4.0e+3*:67	*2.5e+2*:231	*1.6e+1*:1470	15/15
BIPOP-aCMA	8.0(2)	5.2(2)	5.9(1)	3.1(0.4)	**2.8**(2)	15/15
BIPOP-saAC	4.6(2)	3.5(1)	**2.7**(0.3)	**1.3**(0.3)	**0.76**(0.2)	15/15
CMAES hut	7.0(4)	4.3(2)	4.2(0.8)	3.4(2)	∞ *2006*	0/15
DE pal	28(11)	21(7)	32(7)	27(3)	12(1)	15/15
HCMA los	**2.2**(0)	**1.2**(0)	**0.91**(0.3)	**1.8**(1)	**1.1**(0.3)	15/15
HMLSL pal	**1.1**(1)	**0.99**(0.9)	**1.6**(1)	**1.4**(0.5)	**0.83**(0.2)	15/15
IPOP-10DDr	5.2(4)	4.9(0.6)	4.2(0.4)	**2.7**(0.6)	**2.6**(0.8)	15/15
IPOP-500 l	5.2(4)	4.9(0.6)	4.2(0.4)	**2.7**(0.6)	**2.6**(0.8)	15/15
IPOP-tany	3.8(3)	3.5(1.0)	4.3(0.6)	**2.9**(0.7)	3.1(1)	15/15
IPOP-texp	**1.6**(2)	**1.4**(1)	**2.5**(2)	**2.3**(0.3)	**2.9**(1.0)	15/15
IPOP lia	5.2(4)	4.9(0.6)	4.2(0.4)	**2.7**(0.6)	**2.6**(0.8)	15/15
MLSL pal	**1.1**(1)	**0.99**(0.9)	**1.6**(1)	**1.4**(0.5)	**0.83**(0.2)	15/15
OQNLP pal	**1.7**(1)	**1.2**(0.7)	**0.97**(0.2)	**0.72**(0.3)	**0.67**(0.2)	15/15
P-DCN tra	28(37)	22(18)	24(8)	12(3)	135(178)	15/15
P-zero tra	37(20)	27(12)	25(6)	12(3)	62(27)	15/15
SMAC hut	**1.4**(2)	**1.5**(1)	**2.5**(0.8)	4.1(3)	∞ *2000*	0/15
U-DCN tra	7.9(3)	5.6(2)	8.8(3)	22(7)	461(684)	15/15
U-zero tra	5.7(2)	4.1(2)	5.5(1)	8.5(4)	1013(1581)	15/15
fmincon pa	**1.1**(1)	**0.99**(0.9)	**1.6**(1)	**1.4**(0.5)	**0.84**(0.2)	15/15
fminunc pa	**0.87**(0.6)	**0.86**(0.6)	**0.97**(0.3)	**0.94**(0.2)	**1.3**(0.7)	15/15
ga100 hol	31(10)	24(8)	31(9)	26(4)	1124(1691)	6/15
grid100 ho	122(71)	98(64)	128(24)	127(40)	2099(2403)	4/15
grid16 hol	30(16)	20(11)	23(6)	22(9)	526(701)	9/15
hill hol	10(5)	5.7(2)	4.9(1)	6.0(6)	309(473)	11/15
lmmCMA aug	**2.2**(2)	**2.5**(1)	3.3(1.0)	**2.6**(0.5)	**1.3**(0.5)	15/15
memPSODE v	40(53)	22(29)	14(16)	8.4(6)	4.6(2)	15/15
prcga saw	12(5)	10(7)	18(4)	16(5)	573(692)	13/15
ring100 ho	73(37)	60(18)	66(12)	58(7)	206(305)	14/15
ring16 hol	20(7)	14(4)	15(2)	12(3)	2033(2380)	4/15
simplex pa	46(62)	45(38)	65(28)	3286(2621)	∞ *4e5*	0/15

Table 10: 20-D, running time excess ERT/ERT$_{\text{best 2009}}$ on f_9 for given run-length based budgets (0.5D, 1.2D, 3D, 10D, and 50D function evaluations). 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 ERT$_{\text{best 2009}}$ (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. Entries with succeeding star are statistically significantly better (according to the rank-sum test) compared to all other algorithms in the table, with $p = 0.05$ or $p = 10^{-k}$ when the number k following the star is larger than 1, with Bonferroni correction by the number of instances.

#FEs/D	0.5	1.2	3	10	50	#succ
f9	*1.0e+2*:357	*6.3e+1*:560	*4.0e+1*:684	*2.5e+1*:756	*1.0e+1*:1716	15/15
BIPOP-aCMA	**2.5**(0.9)	**1.8**(0.8)	**1.6**(0.7)	**1.7**(0.6)	3.9(0.6)	15/15
BIPOP-saAC	**1.3**(0.4)	**0.89**(0.2)	**0.80**(0.2)	**0.78**(0.2)	**1.3**(0.2)	15/15
CMAES hut	**2.2**(0.5)	**1.5**(0.3)	**1.4**(0.2)	**1.5**(0.3)	∞ *2006*	0/15
DE pal	48(78)	129(357)	108(293)	101(265)	∞ *4e5*	0/15
HCMA los	**2.1**(0.6)	**1.5**(0.4)	**1.2**(0.4)	**1.2**(0.3)	**1.6**(0.3)	15/15
HMLSL pal	**0.30**(0.0)$_{\downarrow 4}$	**0.31**(3e-3)$_{\downarrow 4}$	**0.32**(0.0)	**0.34**(0.0)	**0.17**(0.0)	15/15
IPOP-10DDr	**2.8**(0.7)	3.4(5)	**2.9**(5)	**2.8**(4)	5.0(1)	15/15
IPOP-500 l	**2.8**(0.7)	3.4(5)	**2.9**(5)	**2.8**(4)	5.0(1)	15/15
IPOP-tany	**2.1**(0.6)	**2.2**(0.8)	**2.0**(0.7)	**2.0**(0.7)	5.0(1)	15/15
IPOP-texp	**1.3**(0.2)	**0.96**(0.1)	**0.92**(0.1)	**1.0**(0.1)	4.8(1)	15/15
IPOP lia	**2.8**(0.7)	3.4(5)	**2.9**(5)	**2.8**(4)	5.0(1)	15/15
MLSL pal	**0.30**(0.0)$_{\downarrow 4}$	**0.31**(3e-3)$_{\downarrow 4}$	**0.32**(0.0)	**0.34**(0.0)	**0.17**(0.0)	15/15
OQNLP pal	**0.20**(4e-3)$^{\star 4}_{\downarrow 4}$	**0.74**(0.0)	**0.73**(2e-3)	**0.66**(4e-3)	**0.32**(1e-3)	15/15
P-DCN tra	145(7)	131(98)	108(80)	98(73)	1600(1101)	15/15
P-zero tra	42(92)	33(86)	27(70)	25(64)	412(296)	15/15
SMAC hut	5.0(3)	26(28)	∞	∞	∞ *2000*	0/15
U-DCN tra	58(47)	1040(773)	891(716)	828(667)	1.7e4(1e4)	9/15
U-zero tra	2351(309)	2082(4003)	1714(3302)	1554(2990)	4.0e4(4e4)	4/15
fmincon pa	**0.30**(0.0)$_{\downarrow 4}$	**0.31**(3e-3)$_{\downarrow 4}$	**0.32**(0.0)	**0.34**(0.0)	**0.17**(0.0)	15/15
fminunc pa	**0.25**(0.0)$_{\downarrow 4}$	**0.33**(0.0)$_{\downarrow 4}$	**0.34**(0.0)	**0.33**(0.0)	**0.16**(0.0)	15/15
ga100 hol	233(30)	195(277)	169(237)	163(218)	∞ *1e6*	0/15
grid100 ho	1812(2803)	2834(3593)	2357(2937)	2194(2660)	∞ *1e6*	0/15
grid16 hol	70(91)	210(216)	183(200)	176(188)	∞ *1e6*	0/15
hill hol	241(171)	728(1004)	601(823)	547(744)	∞ *1e6*	0/15
lmmCMA aug	**1.6**(0.4)	**1.3**(0.2)	**1.1**(0.2)	**1.2**(0.2)	**2.1**(0.5)	15/15
memPSODE v	7.0(6)	7.1(8)	6.3(6)	5.8(6)	8.8(3)	15/15
prcga saw	8.4(3)	181(606)	167(517)	160(470)	688(1166)	10/15
ring100 ho	61(15)	51(8)	53(12)	68(10)	∞ *1e6*	0/15
ring16 hol	215(16)	186(327)	156(272)	145(246)	∞ *1e6*	0/15
simplex pa	∞	∞	∞	∞	∞ *4e5*	0/15

Table 11: 20-D, running time excess ERT/ERT$_{\text{best 2009}}$ on f_{10} for given run-length based budgets (0.5D, 1.2D, 3D, 10D, and 50D function evaluations). 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 ERT$_{\text{best 2009}}$ (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. Entries with succeeding star are statistically significantly better (according to the rank-sum test) compared to all other algorithms in the table, with $p = 0.05$ or $p = 10^{-k}$ when the number k following the star is larger than 1, with Bonferroni correction by the number of instances.

#FEs/D	0.5	1.2	3	10	50	#succ
f10	*1.6e+6*:15	*1.0e+6*:27	*4.0e+5*:70	*6.3e+4*:231	*4.0e+3*:1015	15/15
BIPOP-aCMA	7.3(6)	7.1(5)	8.2(4)	5.2(1)	3.1(0.9)	15/15
BIPOP-saAC	4.6(4)	4.9(4)	4.7(4)	**2.9**(0.6)	**0.90**(0.2)	15/15
CMAES hut	5.2(4)	5.3(3)	5.8(4)	4.6(1)	30(32)	1/15
DE pal	17(10)	12(9)	29(18)	330(203)	∞ *4e5*	0/15
HCMA los	**3.1**(1)	**2.0**(0.6)	**1.0**(0.4)	**1.6**(2)	**1.2**(0.2)	15/15
HMLSL pal	5.2(3)	3.8(2)	**2.6**(1)	**1.5**(0.6)	**0.57**(0.1)	15/15
IPOP-10DDr	7.5(4)	6.9(2)	5.6(1)	5.0(2)	3.4(0.9)	15/15
IPOP-500 l	7.5(4)	6.9(2)	5.6(1)	5.0(2)	3.4(0.9)	15/15
IPOP-tany	5.3(5)	5.5(4)	4.8(2)	4.9(2)	3.3(1)	15/15
IPOP-texp	**2.5**(2)	**2.1**(2)	3.1(2)	4.0(1)	3.1(0.7)	15/15
IPOP lia	7.5(4)	6.9(2)	5.6(1)	5.0(2)	3.4(0.9)	15/15
MLSL pal	5.2(3)	3.8(2)	**2.6**(1)	**1.5**(0.6)	**0.57**(0.1)	15/15
OQNLP pal	**3.7**(0.9)	**2.3**(0.5)	**1.4**(0.4)	**1.6**(0.9)	**0.83**(0.3)	15/15
P-DCN tra	13(15)	11(13)	12(10)	17(6)	396(333)	15/15
P-zero tra	18(23)	17(19)	13(11)	14(8)	160(119)	15/15
SMAC hut	**3.7**(3)	5.5(5)	6.2(5)	18(19)	∞ *2000*	0/15
U-DCN tra	6.0(6)	5.7(4)	16(13)	353(405)	3303(2513)	15/15
U-zero tra	5.5(3)	4.9(3)	8.6(13)	108(100)	1.1e4(1e4)	12/15
fmincon pa	5.2(3)	3.8(2)	**2.7**(1)	**1.7**(0.8)	**0.67**(0.2)	15/15
fminunc pa	**2.7**(1)	**2.2**(2)	**1.6**(1)	**1.7**(0.6)	**1.5**(0.7)	15/15
ga100 hol	15(13)	20(9)	20(7)	42(53)	4567(5015)	3/15
grid100 ho	48(54)	59(47)	82(57)	1317(2279)	∞ *1e6*	0/15
grid16 hol	15(14)	14(16)	17(9)	145(145)	1.4e4(1e4)	1/15
hill hol	8.0(5)	5.7(3)	4.8(3)	41(61)	∞ *1e6*	0/15
lmmCMA aug	3.7(3)	**3.5**(3)	4.2(1)	**2.3**(0.5)	**1.0**(0.2)	15/15
memPSODE v	14(9)	11(9)	7.7(5)	18(8)	10(4)	15/15
prcga saw	10(11)	11(9)	14(8)	22(12)	1278(1113)	13/15
ring100 ho	23(29)	24(16)	30(11)	63(31)	6727(7828)	2/15
ring16 hol	12(6)	10(5)	13(6)	37(27)	1.4e4(2e4)	1/15
simplex pa	60(28)	54(33)	33(1)	14(1)	1070(1006)	5/15

Table 12: 20-D, running time excess ERT/ERT$_{\text{best 2009}}$ on f_{11} for given run-length based budgets (0.5D, 1.2D, 3D, 10D, and 50D function evaluations). 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 ERT$_{\text{best 2009}}$ (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. Entries with succeeding star are statistically significantly better (according to the rank-sum test) compared to all other algorithms in the table, with $p = 0.05$ or $p = 10^{-k}$ when the number k following the star is larger than 1, with Bonferroni correction by the number of instances.

#FEs/D	0.5	1.2	3	10	50	#succ
f11	*4.0e+4*:11	*2.5e+3*:27	*1.6e+2*:313	*1.0e+2*:481	*1.0e+1*:1002	15/15
BIPOP-aCMA	**2.6**(3)	**2.1**(3)	12(2)	7.9(1)	4.8(0.4)	15/15
BIPOP-saAC	**2.4**(2)	**1.9**(2)	4.7(1)	3.2(0.7)	**1.6**(0.4)	15/15
CMAES hut	**1.9**(1)	**2.5**(2)	∞	∞	∞ *2006*	0/15
DE pal	**2.6**(3)	**2.8**(2)	10(11)	50(32)	∞ *4e5*	0/15
HCMA los	**2.4**(2)	**1.6**(0.7)	4.2(3)	3.4(0.4)	**1.7**(0.2)	15/15
HMLSL pal	4.4(2)	**2.7**(1)	**0.33**(0.1)	**0.22**(0.1)	**0.17**(0.0)	15/15
IPOP-10DDr	**2.2**(3)	**2.5**(3)	14(9)	14(3)	10(0.6)	15/15
IPOP-500 l	**2.2**(3)	**2.5**(3)	14(9)	14(3)	10(0.6)	15/15
IPOP-tany	**1.0**(1.0)	**1.6**(1)	12(10)	14(2)	9.4(0.4)	15/15
IPOP-texp	**1.9**(2)	**1.8**(1)	11(9)	13(1)	8.4(0.6)	15/15
IPOP lia	**2.2**(3)	**2.5**(3)	14(9)	14(3)	10(0.6)	15/15
MLSL pal	4.4(2)	**2.7**(1)	**0.33**(0.1)	**0.22**(0.1)	**0.17**(0.0)	15/15
OQNLP pal	4.5(0.3)	**2.2**(0.8)	**0.27**(0.2)	**0.21**(0.1)	**0.16**(0.0)	15/15
P-DCN tra	**1.8**(2)	**1.9**(1)	102(129)	155(136)	457(265)	15/15
P-zero tra	**1.9**(2)	**1.7**(1)	170(185)	250(196)	676(222)	15/15
SMAC hut	**0.59**(0.5)	**0.68**(0.6)	**2.5**(3)	7.3(8)	∞ *2000*	0/15
U-DCN tra	**1.7**(1)	**1.6**(2)	30(33)	55(48)	786(641)	15/15
U-zero tra	**1.2**(1)	**1.0**(0.8)	44(49)	84(51)	1213(560)	15/15
fmincon pa	4.4(2)	**2.7**(1)	**0.33**(0.1)	**0.22**(0.1)	**0.16**(0.0)	15/15
fminunc pa	5.2(2)	**2.6**(1)	**0.35**(0.2)	**0.60**(0.4)	**0.51**(0.1)	15/15
ga100 hol	**2.4**(3)	4.1(6)	18(18)	43(27)	333(121)	15/15
grid100 ho	**1.3**(2)	5.1(6)	901(852)	3491(3481)	∞ *1e6*	0/15
grid16 hol	**2.0**(3)	**1.9**(2)	164(206)	315(222)	2753(2555)	5/15
hill hol	**2.7**(2)	**1.7**(1.0)	118(136)	168(135)	577(255)	15/15
lmmCMA aug	**1.3**(1)	**1.4**(1)	4.5(3)	3.7(0.6)	**2.1**(0.2)	15/15
memPSODE v	**2.4**(3)	**2.1**(1)	12(6)	8.9(2)	4.5(1.0)	15/15
prcga saw	**2.7**(4)	**2.7**(2)	3.5(4)	96(205)	1.3e4(1e4)	2/15
ring100 ho	**1.3**(1.0)	3.1(4)	29(43)	154(71)	808(199)	14/15
ring16 hol	**1.8**(2)	**2.2**(2)	27(48)	61(56)	470(240)	14/15
simplex pa	40(7)	18(2)	**2.9**(4)	34(47)	∞ *4e5*	0/15

Table 13: 20-D, running time excess ERT/ERT$_{\text{best 2009}}$ on f_{12} for given run-length based budgets (0.5D, 1.2D, 3D, 10D, and 50D function evaluations). 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 ERT$_{\text{best 2009}}$ (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. Entries with succeeding star are statistically significantly better (according to the rank-sum test) compared to all other algorithms in the table, with $p = 0.05$ or $p = 10^{-k}$ when the number k following the star is larger than 1, with Bonferroni correction by the number of instances.

#FEs/D	0.5	1.2	3	10	50	#succ
f12	*1.0e+8*:23	*6.3e+7*:39	*2.5e+7*:76	*4.0e+6*:209	*1.0e+1*:1042	15/15
BIPOP-aCMA	8.0(4)	6.2(2)	4.7(1)	**2.8**(0.5)	3.1(3)	15/15
BIPOP-saAC	3.5(2)	3.3(1)	**2.4**(0.5)	**1.3**(0.2)	**0.83**(0.1)	15/15
CMAES hut	5.2(3)	4.6(2)	3.8(1)	**2.4**(0.4)	4.8(4)	6/15
DE pal	13(9)	17(10)	22(6)	22(2)	102(112)	14/15
HCMA los	**2.8**(0.9)	**2.1**(0.4)	**1.8**(0.5)	**1.8**(1)	**1.7**(1)	15/15
HMLSL pal	**1.9**(2)	**1.8**(1)	**1.6**(0.7)	**1.4**(0.7)	**0.81**(0.6)	15/15
IPOP-10DDr	4.2(3)	4.1(1)	3.5(0.4)	**2.3**(0.2)	**2.6**(2)	15/15
IPOP-500 l	4.2(3)	4.1(1)	3.5(0.4)	**2.3**(0.2)	**2.6**(2)	15/15
IPOP-tany	3.6(2)	3.5(1)	3.4(0.7)	**2.3**(0.3)	**2.4**(0.2)	15/15
IPOP-texp	**2.3**(3)	**2.0**(2)	**2.4**(0.8)	**2.1**(0.4)	**2.3**(0.2)	15/15
IPOP lia	4.2(3)	4.1(1)	3.5(0.4)	**2.3**(0.2)	**2.6**(2)	15/15
MLSL pal	**1.9**(2)	**1.8**(1)	**1.6**(0.7)	**1.4**(0.7)	**0.81**(0.6)	15/15
OQNLP pal	**2.1**(2)	**1.7**(0.4)	**1.0**(0.2)	**0.80**(0.6)	**1.1**(0.5)	15/15
P-DCN tra	25(29)	29(15)	27(8)	15(4)	7018(9607)	11/15
P-zero tra	38(38)	35(23)	28(12)	14(4)	6998(9606)	11/15
SMAC hut	**2.8**(4)	38(52)	∞	∞	∞ *2000*	0/15
U-DCN tra	5.5(3)	5.1(2)	5.3(2)	8.4(4)	3164(9601)	13/15
U-zero tra	3.9(2)	3.9(2)	3.8(1)	3.8(1)	7490(9691)	11/15
fmincon pa	**1.9**(2)	**1.8**(1)	**1.6**(0.7)	**1.4**(0.7)	**0.81**(0.5)	15/15
fminunc pa	**1.9**(2)	**1.7**(1)	**1.5**(1)	**0.88**(0.6)	**0.61**(0.2)	15/15
ga100 hol	21(13)	22(7)	24(6)	19(3)	721(648)	11/15
grid100 ho	71(46)	91(43)	100(31)	71(20)	∞ *1e6*	0/15
grid16 hol	24(16)	22(12)	19(6)	14(3)	2612(2511)	5/15
hill hol	6.9(2)	5.0(1)	3.9(1)	**2.5**(0.5)	685(630)	11/15
lmmCMA aug	**2.0**(2)	**2.4**(1)	**2.6**(0.7)	**1.9**(0.3)	**1.1**(0.1)	15/15
memPSODE v	16(5)	25(26)	17(14)	9.1(6)	5.7(4)	15/15
prcga saw	8.5(6)	11(7)	13(5)	11(2)	214(226)	14/15
ring100 ho	34(29)	40(21)	55(11)	43(5)	605(147)	15/15
ring16 hol	14(6)	13(4)	12(3)	8.9(1)	571(547)	12/15
simplex pa	66(51)	55(26)	37(2)	560(730)	∞ *4e5*	0/15

Table 14: 20-D, running time excess ERT/$\mathrm{ERT}_{\text{best 2009}}$ on f_{13} for given run-length based budgets (0.5D, 1.2D, 3D, 10D, and 50D function evaluations). 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 $\mathrm{ERT}_{\text{best 2009}}$ (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. Entries with succeeding star are statistically significantly better (according to the rank-sum test) compared to all other algorithms in the table, with $p = 0.05$ or $p = 10^{-k}$ when the number k following the star is larger than 1, with Bonferroni correction by the number of instances.

#FEs/D	0.5	1.2	3	10	50	#succ
f13	*1.6e+3*:28	*1.0e+3*:64	*6.3e+2*:79	*4.0e+1*:211	*2.5e+0*:1724	15/15
BIPOP-aCMA	6.4(2)	5.2(1)	6.2(1)	6.0(0.8)	**2.4**(2)	15/15
BIPOP-saAC	**3.0**(1)	**2.4**(0.3)	**2.3**(0.2)	**1.8**(0.2)	**0.67**(0.5)	15/15
CMAES hut	3.2(2)	3.4(1)	4.5(0.9)	5.5(0.5)	3.4(3)	5/15
DE pal	14(8)	20(7)	38(9)	89(13)	63(99)	14/15
HCMA los	**1.5**(0.1)	**0.85**(0.2)	**0.89**(0.2)	**2.3**(1)	**0.78**(0.5)	15/15
HMLSL pal	**1.1**(0.4)	**1.2**(0.8)	**1.8**(1.0)	**2.8**(0.6)	**0.51**(0.1)	15/15
IPOP-10DDr	4.0(1)	3.3(0.6)	4.6(0.8)	5.4(0.3)	**2.8**(3)	15/15
IPOP-500 l	4.0(1)	3.3(0.6)	4.6(0.8)	5.4(0.3)	**2.8**(3)	15/15
IPOP-tany	**2.9**(2)	3.3(1.0)	4.3(0.2)	6.0(0.6)	4.5(4)	15/15
IPOP-texp	**1.6**(0.8)	**1.9**(0.4)	3.6(0.4)	5.3(0.6)	3.6(3)	15/15
IPOP lia	4.0(1)	3.3(0.6)	4.6(0.8)	5.4(0.3)	**2.8**(3)	15/15
MLSL pal	**1.1**(0.4)	**1.2**(0.8)	**1.8**(1.0)	**2.8**(0.6)	**0.51**(0.1)	15/15
OQNLP pal	**1.8**(0.0)	**0.84**(0.2)	**1.0**(0.2)	**2.9**(0.1)	**0.51**(0.0)	15/15
P-DCN tra	7.9(10)	15(9)	23(8)	1.5e4(5e4)	1.7e4(2e4)	6/15
P-zero tra	18(20)	19(10)	24(9)	2.4e4(5e4)	3.2e4(4e4)	4/15
SMAC hut	**0.81**(0.5)	**0.66**(0.2)	**0.84**(0.1)	**1.4**(0.4)	∞ *2000*	0/15
U-DCN tra	3.2(2)	4.1(2)	10(6)	1.5e4(5e4)	2.3e4(3e4)	5/15
U-zero tra	**2.5**(1)	3.3(0.9)	5.9(3)	69(22)	1.0e4(2e4)	8/15
fmincon pa	**1.1**(0.4)	**1.2**(0.8)	**1.8**(1.0)	**2.8**(0.6)	**0.51**(0.1)	15/15
fminunc pa	**1.3**(0.8)	**0.97**(0)	**1.0**(0.3)	**1.9**(0.4)	**0.94**(0.1)	15/15
ga100 hol	18(7)	21(4)	30(5)	148(37)	817(934)	7/15
grid100 ho	47(46)	79(28)	124(32)	1526(1175)	∞ *1e6*	0/15
grid16 hol	13(9)	17(7)	26(6)	176(51)	1929(2210)	4/15
hill hol	5.5(3)	3.9(2)	4.7(1)	39(18)	3919(4349)	2/15
lmmCMA aug	**1.6**(0.7)	**2.6**(1)	3.3(0.9)	4.2(0.4)	**1.1**(0.2)	15/15
memPSODE v	9.3(3)	18(17)	22(16)	19(8)	3.9(1)	15/15
prcga saw	7.9(6)	14(7)	21(6)	67(14)	1825(2343)	6/15
ring100 ho	30(16)	46(13)	70(14)	298(43)	522(562)	10/15
ring16 hol	9.1(4)	10(2)	15(3)	1255(2385)	1252(1456)	5/15
simplex pa	53(35)	42(5)	79(74)	∞	∞ *4e5*	0/15

Table 15: 20-D, running time excess ERT/ERT$_{\text{best 2009}}$ on f_{14} for given run-length based budgets (0.5D, 1.2D, 3D, 10D, and 50D function evaluations). 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 ERT$_{\text{best 2009}}$ (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. Entries with succeeding star are statistically significantly better (according to the rank-sum test) compared to all other algorithms in the table, with $p = 0.05$ or $p = 10^{-k}$ when the number k following the star is larger than 1, with Bonferroni correction by the number of instances.

#FEs/D	0.5	1.2	3	10	50	#succ
f14	*2.5e+1*:15	*1.6e+1*:42	*1.0e+1*:75	*1.6e+0*:219	*6.3e-4*:1106	15/15
BIPOP-aCMA	13(9)	7.1(3)	5.4(1)	3.3(0.8)	3.1(0.4)	15/15
BIPOP-saAC	7.2(3)	4.0(1)	3.1(0.7)	**1.9**(0.3)	**1.3**(0.1)	15/15
CMAES hut	6.6(4)	4.6(3)	3.8(1)	**2.8**(0.6)	∞ *2006*	0/15
DE pal	28(11)	20(9)	22(7)	28(3)	∞ *4e5*	0/15
HCMA los	3.9(1)	**1.7**(0.4)	**1.3**(0.3)	**2.0**(1)	**1.5**(0.1)	15/15
HMLSL pal	**1.9**(0.8)	**1.1**(0.5)	**0.74**(0.3)	**0.49**(0.1)	**0.60**(0.1)	15/15
IPOP-10DDr	8.5(3)	4.7(2)	3.8(0.7)	**2.7**(0.4)	4.0(0.5)	15/15
IPOP-500 l	8.5(3)	4.7(2)	3.8(0.7)	**2.7**(0.4)	4.0(0.5)	15/15
IPOP-tany	5.7(4)	4.1(1)	3.6(1)	**2.9**(0.5)	4.3(0.4)	15/15
IPOP-texp	**2.5**(2)	**1.5**(0.8)	**1.6**(0.8)	**2.2**(0.3)	3.9(0.4)	15/15
IPOP lia	8.5(3)	4.7(2)	3.8(0.7)	**2.7**(0.4)	4.0(0.5)	15/15
MLSL pal	**1.9**(0.8)	**1.1**(0.5)	**0.74**(0.3)	**0.49**(0.1)	**0.60**(0.1)	15/15
OQNLP pal	3.1(0.1)	**1.6**(0.3)	**1.1**(0.0)	**0.64**(0.1)	**0.51**(0.1)$^{\star 2}$	15/15
P-DCN tra	25(26)	23(13)	22(8)	15(3)	1804(494)	15/15
P-zero tra	41(42)	29(18)	25(9)	16(5)	1.1e4(1e4)	13/15
SMAC hut	**2.0**(2)	3.3(7)	19(19)	∞	∞ *2000*	0/15
U-DCN tra	8.5(5)	6.0(4)	6.6(3)	12(3)	3944(1429)	15/15
U-zero tra	7.0(4)	4.2(2)	4.0(2)	5.0(1)	∞ *2e7*	0/15
fmincon pa	**1.9**(0.8)	**1.1**(0.5)	**0.74**(0.3)	**0.49**(0.1)	**0.60**(0.1)	15/15
fminunc pa	**2.1**(0.7)	**1.2**(0.2)	**1.0**(0.3)	**0.94**(0.3)	**0.78**(0.1)	15/15
ga100 hol	29(19)	21(11)	19(8)	22(6)	∞ *1e6*	0/15
grid100 ho	95(102)	115(61)	100(46)	105(21)	∞ *1e6*	0/15
grid16 hol	45(27)	26(15)	22(10)	19(4)	∞ *1e6*	0/15
hill hol	8.0(4)	4.1(2)	3.5(1)	3.4(0.7)	∞ *1e6*	0/15
lmmCMA aug	3.8(5)	**2.9**(2)	3.0(1)	**2.2**(0.5)	**1.9**(0.1)	15/15
memPSODE v	17(5)	11(2)	10(14)	10(6)	5.3(1)	15/15
prcga saw	12(10)	12(4)	12(5)	15(4)	4543(4521)	5/15
ring100 ho	50(56)	45(17)	50(11)	57(6)	∞ *1e6*	0/15
ring16 hol	19(10)	13(5)	11(5)	11(2)	∞ *1e6*	0/15
simplex pa	93(67)	53(21)	37(6)	2598(2622)	∞ *4e5*	0/15

Table 16: 20-D, running time excess ERT/ERT$_{\text{best 2009}}$ on f_{15} for given run-length based budgets (0.5D, 1.2D, 3D, 10D, and 50D function evaluations). 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 ERT$_{\text{best 2009}}$ (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. Entries with succeeding star are statistically significantly better (according to the rank-sum test) compared to all other algorithms in the table, with $p = 0.05$ or $p = 10^{-k}$ when the number k following the star is larger than 1, with Bonferroni correction by the number of instances.

#FEs/D	0.5	1.2	3	10	50	#succ
f15	*6.3e+2*:15	*4.0e+2*:67	*2.5e+2*:292	*1.6e+2*:846	*1.0e+2*:1671	15/15
BIPOP-aCMA	7.9(4)	3.8(1)	**1.5**(0.3)	**1.1**(0.3)	**1.5**(0.5)	15/15
BIPOP-saAC	4.0(2)	**2.1**(0.6)	**0.83**(0.3)	**0.93**(0.6)	**1.2**(0.4)	15/15
CMAES hut	4.2(4)	**2.3**(1)	**1.1**(0.2)	**0.90**(0.3)	**2.1**(1)	8/15
DE pal	13(8)	11(6)	7.2(2)	12(5)	142(122)	13/15
HCMA los	**3.3**(0.9)	**2.4**(3)	**1.5**(0.8)	**1.3**(0.9)	**1.3**(0.4)	15/15
HMLSL pal	26(61)	24(21)	10(7)	11(2)	6.2(0.1)	15/15
IPOP-10DDr	6.1(2)	**2.4**(0.5)	**1.0**(0.2)	**0.95**(0.5)	**1.3**(0.2)	15/15
IPOP-500 l	6.1(2)	**2.4**(0.5)	**1.0**(0.2)	**0.95**(0.5)	**1.3**(0.2)	15/15
IPOP-tany	**3.5**(2)	**1.9**(0.6)	**1.0**(0.2)	**0.88**(0.3)	**1.4**(0.3)	15/15
IPOP-texp	**1.9**(1)	**1.1**(0.5)	**0.80**(0.3)	**0.80**(0.3)	**1.3**(0.3)	15/15
IPOP lia	6.1(2)	**2.4**(0.5)	**1.0**(0.2)	**0.95**(0.5)	**1.3**(0.2)	15/15
MLSL pal	26(59)	22(18)	13(15)	253(185)	∞ *4e5*	0/15
OQNLP pal	61(54)	135(119)	189(198)	199(164)	358(380)	6/15
P-DCN tra	9.3e4(166)	2.6e5(4e5)	4.5e5(5e5)	∞	∞ *2e7*	0/15
P-zero tra	8.7e5(1e6)	∞	∞	∞	∞ *2e7*	0/15
SMAC hut	**1.1**(0.8)	**2.9**(1)	**2.8**(4)	∞	∞ *2000*	0/15
U-DCN tra	5.2(3)	3.4(2)	3.7(3)	31(55)	1.4e4(2e4)	7/15
U-zero tra	4.5(4)	**2.4**(1)	4.8(5)	3990(1e4)	2.4e4(3e4)	5/15
fmincon pa	29(59)	20(20)	41(88)	323(356)	1681(1799)	2/15
fminunc pa	20(50)	30(18)	144(286)	644(692)	3548(3660)	1/15
ga100 hol	16(12)	12(5)	5.5(1)	5.1(2)	11(3)	15/15
grid100 ho	24(23)	51(29)	65(49)	802(828)	3979(4490)	2/15
grid16 hol	13(12)	14(9)	261(43)	344(621)	1762(2094)	4/15
hill hol	7.8(6)	6.0(6)	636(1712)	2371(2958)	8394(9129)	1/15
lmmCMA aug	**1.4**(2)	**1.3**(0.9)	**0.77**(0.4)	**0.72**(0.3)	**0.86**(0.3)⋆	15/15
memPSODE v	83(65)	31(17)	21(20)	16(11)	20(10)	15/15
prcga saw	4.7(5)	6.6(3)	4.1(1)	3.9(1)	5.5(2)	15/15
ring100 ho	15(24)	27(12)	17(5)	18(7)	31(12)	15/15
ring16 hol	12(7)	6.8(4)	4.6(2)	5.9(3)	66(75)	14/15
simplex pa	66(52)	250(734)	1119(1189)	∞	∞ *4e5*	0/15

Table 17: 20-D, running time excess ERT/ERT$_{\text{best 2009}}$ on f_{16} for given run-length based budgets (0.5D, 1.2D, 3D, 10D, and 50D function evaluations). 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 ERT$_{\text{best 2009}}$ (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. Entries with succeeding star are statistically significantly better (according to the rank-sum test) compared to all other algorithms in the table, with $p = 0.05$ or $p = 10^{-k}$ when the number k following the star is larger than 1, with Bonferroni correction by the number of instances.

#FEs/D	0.5	1.2	3	10	50	#succ
f16	*4.0e+1*:26	*2.5e+1*:127	*1.6e+1*:540	*1.6e+1*:540	*1.0e+1*:1384	15/15
BIPOP-aCMA	5.1(6)	13(10)	4.0(2)	4.0(2)	**2.3**(0.9)	15/15
BIPOP-saAC	3.1(4)	10(4)	**2.9**(1.0)	**2.9**(1.0)	**1.3**(0.3)	15/15
CMAES hut	10(9)	12(8)	3.7(2)	3.7(3)	**2.1**(2)	9/15
DE pal	3.4(4)	30(35)	879(996)	879(937)	∞ *4e5*	0/15
HCMA los	**2.2**(0.9)	**3.5**(6)	3.2(3)	3.2(3)	**1.8**(0.8)	15/15
HMLSL pal	17(16)	44(44)	68(56)	68(56)	478(486)	7/15
IPOP-10DDr	**2.9**(3)	8.3(3)	**2.6**(0.7)	**2.6**(0.7)	**1.2**(0.3)	15/15
IPOP-500 l	**2.9**(3)	8.3(3)	**2.6**(0.7)	**2.6**(0.7)	**1.2**(0.3)	15/15
IPOP-tany	3.7(3)	9.2(6)	3.0(0.9)	3.0(0.9)	**1.3**(0.4)	15/15
IPOP-texp	3.1(4)	5.7(3)	**1.8**(0.7)	**1.8**(0.7)	**0.86**(0.3)	15/15
IPOP lia	**2.9**(3)	8.3(3)	**2.6**(0.7)	**2.6**(0.7)	**1.2**(0.3)	15/15
MLSL pal	17(16)	29(23)	78(83)	78(83)	1274(1415)	3/15
OQNLP pal	52(28)	183(326)	233(263)	233(236)	642(648)	3/15
P-DCN tra	**2.9**(2)	7.6(2)	8.0(18)	8.0(18)	2687(7227)	13/15
P-zero tra	**2.2**(1)	272(843)	9631(2e4)	9631(2e4)	2.3e4(3e4)	6/15
SMAC hut	**2.4**(3)	**1.5**(1)	**0.78**(0.4)	**0.78**(0.4)	**0.76**(0.5)	14/15
U-DCN tra	3.5(3)	**4.8**(3)	74(8)	74(8)	2759(7235)	13/15
U-zero tra	3.1(4)	**4.4**(5)	969(26)	969(26)	7416(7415)	12/15
fmincon pa	22(13)	29(21)	51(45)	51(45)	675(765)	5/15
fminunc pa	130(65)	938(1594)	1.0e4(1e4)	1.0e4(1e4)	∞ *4e5*	0/15
ga100 hol	**2.3**(3)	21(18)	14(6)	14(6)	59(2)	14/15
grid100 ho	3.7(4)	17(16)	37(30)	37(30)	294(387)	12/15
grid16 hol	**2.8**(4)	5.9(4)	98(73)	98(73)	276(365)	13/15
hill hol	**2.0**(2)	**4.4**(7)	26(44)	26(44)	322(382)	11/15
lmmCMA aug	4.8(7)	8.1(6)	**2.7**(0.9)	**2.7**(0.9)	**1.2**(0.4)	15/15
memPSODE v	3.7(5)	5.1(4)	10(8)	10(8)	8.5(9)	15/15
prcga saw	3.0(2)	16(15)	10(5)	10(5)	4.8(2)	15/15
ring100 ho	3.8(5)	13(6)	12(6)	12(6)	16(6)	15/15
ring16 hol	3.6(6)	5.5(5)	5.6(3)	5.6(3)	106(298)	14/15
simplex pa	56(4)	19(0.6)	34(14)	34(14)	130(121)	15/15

Table 18: 20-D, running time excess ERT/ERT$_{\text{best 2009}}$ on f_{17} for given run-length based budgets (0.5D, 1.2D, 3D, 10D, and 50D function evaluations). 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 ERT$_{\text{best 2009}}$ (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. Entries with succeeding star are statistically significantly better (according to the rank-sum test) compared to all other algorithms in the table, with $p = 0.05$ or $p = 10^{-k}$ when the number k following the star is larger than 1, with Bonferroni correction by the number of instances.

#FEs/D	0.5	1.2	3	10	50	#succ
f17	*1.6e+1*:11	*1.0e+1*:63	*6.3e+0*:305	*4.0e+0*:468	*1.0e+0*:1030	15/15
BIPOP-aCMA	7.7(7)	4.2(2)	**1.4**(0.4)	**1.3**(0.3)	**2.0**(0.3)	15/15
BIPOP-saAC	5.9(4)	**2.8**(1)	**1.0**(0.3)	**1.0**(0.3)	3.3(4)	15/15
CMAES hut	4.2(4)	**1.8**(1)	**0.89**(0.3)	**0.96**(0.3)	**1.0**(0.5)	15/15
DE pal	8.6(14)	8.2(4)	4.4(2)	8.4(2)	17(3)	15/15
HCMA los	5.6(3)	**2.7**(4)	**1.5**(1.0)	**1.6**(0.2)	**2.8**(1)	15/15
HMLSL pal	28(10)	24(41)	14(15)	17(5)	21(7)	15/15
IPOP-10DDr	4.3(4)	**1.9**(0.8)	**0.82**(0.2)	**0.81**(0.1)	**0.78**(0.1)	15/15
IPOP-500 l	4.3(4)	**1.9**(0.8)	**0.82**(0.2)	**0.81**(0.1)	**0.78**(0.1)	15/15
IPOP-tany	**2.7**(2)	**1.7**(0.8)	**0.88**(0.3)	**0.91**(0.2)	**0.96**(0.2)	15/15
IPOP-texp	**2.4**(4)	**1.2**(0.9)	**0.65**(0.2)	**0.78**(0.4)	**0.96**(0.2)	15/15
IPOP lia	4.3(4)	**1.9**(0.8)	**0.82**(0.2)	**0.81**(0.1)	**0.78**(0.1)	15/15
MLSL pal	28(10)	22(30)	22(23)	1162(1366)	∞ *4e5*	0/15
OQNLP pal	43(83)	100(33)	126(197)	696(697)	∞ *3e5*	0/15
P-DCN tra	3.2(3)	**2.6**(2)	2.4e4(3e4)	∞	∞ *2e7*	0/15
P-zero tra	3.9(2)	2.3e4(7)	4.3e5(5e5)	∞	∞ *2e7*	0/15
SMAC hut	**0.52**(1)	**0.92**(1)	15(19)	61(69)	∞ *2000*	0/15
U-DCN tra	3.8(3)	**1.9**(1)	10(3)	8233(2e4)	∞ *2e7*	0/15
U-zero tra	**2.6**(2)	**1.7**(0.7)	222(48)	2.0e4(4e4)	∞ *2e7*	0/15
fmincon pa	20(10)	21(28)	14(14)	728(834)	∞ *4e5*	0/15
fminunc pa	87(218)	19(38)	106(103)	1499(1794)	∞ *4e5*	0/15
ga100 hol	**3.0**(5)	7.4(3)	4.1(1)	5.1(1)	8.9(3)	15/15
grid100 ho	9.2(16)	25(28)	276(349)	2605(3479)	∞ *1e6*	0/15
grid16 hol	11(21)	21(21)	2350(3274)	8681(9625)	∞ *1e6*	0/15
hill hol	26(27)	6895(7988)	1.3e4(2e4)	∞	∞ *1e6*	0/15
lmmCMA aug	**0.62**(0.8)	**1**(1)	**0.65**(0.4)	**0.79**(0.3)	**1.4**(0.6)	14/15
memPSODE v	136(103)	39(22)	28(18)	55(36)	194(137)	15/15
prcga saw	3.5(6)	**2.6**(2)	**2.5**(1)	3.9(1.0)	490(971)	12/15
ring100 ho	3.7(5)	12(10)	11(6)	20(9)	1587(2000)	6/15
ring16 hol	4.9(7)	4.6(2)	6.2(5)	787(1072)	∞ *1e6*	0/15
simplex pa	49(62)	25(15)	220(485)	5764(6415)	∞ *4e5*	0/15

Table 19: 20-D, running time excess ERT/ERT$_{\text{best 2009}}$ on f_{18} for given run-length based budgets (0.5D, 1.2D, 3D, 10D, and 50D function evaluations). 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 ERT$_{\text{best 2009}}$ (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. Entries with succeeding star are statistically significantly better (according to the rank-sum test) compared to all other algorithms in the table, with $p = 0.05$ or $p = 10^{-k}$ when the number k following the star is larger than 1, with Bonferroni correction by the number of instances.

#FEs/D	0.5	1.2	3	10	50	#succ
f18	*4.0e+1*:116	*2.5e+1*:252	*1.6e+1*:430	*1.0e+1*:621	*4.0e+0*:1090	15/15
BIPOP-aCMA	**1.7**(0.7)	**1.3**(0.4)	**1.2**(0.4)	**1.2**(0.2)	**1.1**(0.3)	15/15
BIPOP-saAC	**1.4**(0.7)	**1.2**(0.4)	**1.1**(0.5)	**1.1**(0.5)	**1.1**(0.4)	15/15
CMAES hut	**0.82**(0.8)	**0.95**(0.4)	**0.96**(0.3)	**0.94**(0.3)	**1.0**(0.3)	15/15
DE pal	3.6(3)	5.7(2)	7.7(3)	13(5)	20(5)	15/15
HCMA los	**0.93**(0.6)	**1.5**(1)	**1.6**(0.4)	**1.4**(0.4)	**1.3**(0.4)	15/15
HMLSL pal	6.8(15)	13(12)	16(3)	18(4)	25(12)	15/15
IPOP-10DDr	**0.97**(0.3)	**0.87**(0.4)	**0.84**(0.2)	**0.87**(0.2)	**0.87**(0.2)	15/15
IPOP-500 l	**0.97**(0.3)	**0.87**(0.4)	**0.84**(0.2)	**0.87**(0.2)	**0.87**(0.2)	15/15
IPOP-tany	**0.78**(0.4)	**0.82**(0.2)	**0.83**(0.2)	**0.85**(0.2)	**0.88**(0.2)	15/15
IPOP-texp	**0.53**(0.3)	**0.67**(0.4)	**0.83**(0.3)	**0.97**(0.2)	**1.1**(0.5)	15/15
IPOP lia	**0.97**(0.3)	**0.87**(0.4)	**0.84**(0.2)	**0.87**(0.2)	**0.87**(0.2)	15/15
MLSL pal	6.5(15)	11(9)	1501(1405)	∞	∞ *4e5*	0/15
OQNLP pal	19(47)	87(89)	776(953)	1715(1692)	∞ *3e5*	0/15
P-DCN tra	252(153)	2.9e4(4e4)	3.0e5(4e5)	∞	∞ *2e7*	0/15
P-zero tra	1.3e4(4229)	1.2e5(2e5)	6.5e5(8e5)	∞	∞ *2e7*	0/15
SMAC hut	**0.31**(0.2)$_{\downarrow 2}$	8.3(10)	20(23)	22(26)	∞ *2000*	0/15
U-DCN tra	**0.98**(0.7)	**2.1**(2)	3422(423)	1.7e4(3e4)	7.8e4(9e4)	3/15
U-zero tra	11(0.6)	23(45)	5058(8837)	7.5e4(9e4)	∞ *2e7*	0/15
fmincon pa	7.0(14)	18(21)	823(1085)	∞	∞ *4e5*	0/15
fminunc pa	9.2(21)	37(75)	1943(2813)	∞	∞ *4e5*	0/15
ga100 hol	3.5(3)	4.8(1)	5.6(1)	80(2)	239(461)	12/15
grid100 ho	8.5(8)	138(185)	4123(4764)	1.1e4(1e4)	∞ *1e6*	0/15
grid16 hol	14(12)	1476(2014)	4200(4794)	2.4e4(3e4)	∞ *1e6*	0/15
hill hol	685(152)	3963(5947)	1.5e4(2e4)	∞	∞ *1e6*	0/15
lmmCMA aug	**0.41**(0.6)$_{\downarrow}$	**0.57**(0.3)	**0.77**(0.3)	**0.76**(0.3)	**0.85**(0.3)	15/15
memPSODE v	26(6)	43(20)	51(30)	81(61)	171(124)	15/15
prcga saw	**1.3**(1)	**2.5**(1)	3.3(1)	3.9(1)	16(2)	15/15
ring100 ho	7.3(5)	11(6)	21(8)	54(49)	1176(1407)	7/15
ring16 hol	**2.2**(1)	3.8(2)	258(597)	815(1610)	∞ *1e6*	0/15
simplex pa	15(7)	196(236)	4364(4197)	∞	∞ *4e5*	0/15

Table 20: 20-D, running time excess ERT/ERT$_{\text{best 2009}}$ on f_{19} for given run-length based budgets (0.5D, 1.2D, 3D, 10D, and 50D function evaluations). 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 ERT$_{\text{best 2009}}$ (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. Entries with succeeding star are statistically significantly better (according to the rank-sum test) compared to all other algorithms in the table, with $p = 0.05$ or $p = 10^{-k}$ when the number k following the star is larger than 1, with Bonferroni correction by the number of instances.

#FEs/D	0.5	1.2	3	10	50	#succ
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
BIPOP-aCMA	**0.88**(0.7)	**1.2**(1)	**2.6**(2)	5.2(5)	7.1(4)	15/15
BIPOP-saAC	**0.48**(0.4)	**0.72**(0.8)	**1.3**(0.9)	3.3(3)	5.5(3)	15/15
CMAES hut	∞	∞	∞	∞	∞ *2006*	0/15
DE pal	∞	∞	∞	∞	∞ *4e5*	0/15
HCMA los	**0.48**(0.3)	**0.72**(0.7)	**1.8**(1)	5.3(3)	10(6)	15/15
HMLSL pal	**6.2e-4**(0)$_{\downarrow 4}$	**7.3e-4**(0)$_{\downarrow 4}$	**8.8e-4**(4e-5)$_{\downarrow 4}$	**1.0e-3**(7e-5)$_{\downarrow 4}$	**1.2e-3**(7e-5)$_{\downarrow 4}$	15/15
IPOP-10DDr	5.1(5)	4.0(3)	5.0(6)	6.6(6)	7.5(5)	15/15
IPOP-500 l	5.1(5)	4.0(3)	5.1(5)	7.0(6)	16(19)	15/15
IPOP-tany	4.6(6)	3.7(4)	4.3(4)	5.5(5)	7.5(5)	15/15
IPOP-texp	**2.6**(2)	**2.0**(2)	**2.6**(2)	4.0(3)	5.5(2)	15/15
IPOP lia	5.1(5)	4.0(3)	5.0(6)	6.6(6)	7.5(5)	15/15
MLSL pal	**6.2e-4**(0)$_{\downarrow 4}$	**7.3e-4**(0)$_{\downarrow 4}$	**8.8e-4**(4e-5)$_{\downarrow 4}$	**1.0e-3**(7e-5)$_{\downarrow 4}$	**1.2e-3**(7e-5)$_{\downarrow 4}$	15/15
OQNLP pal	**4.6e-4**(2e-6)$^{\star 4}_{\downarrow 4}$	**5.4e-4**(1e-6)$^{\star 4}_{\downarrow 4}$	**6.0e-4**(1e-6)$^{\star 4}_{\downarrow 4}$	**6.7e-4**(1e-6)$^{\star 4}_{\downarrow 4}$	**7.4e-4**(1e-6)$^{\star 4}_{\downarrow 4}$	15/15
P-DCN tra	∞	∞	∞	∞	∞ *2e7*	0/15
P-zero tra	∞	∞	∞	∞	∞ *2e7*	0/15
SMAC hut	∞	∞	∞	∞	∞ *2000*	0/15
U-DCN tra	∞	∞	∞	∞	∞ *2e7*	0/15
U-zero tra	∞	∞	∞	∞	∞ *2e7*	0/15
fmincon pa	**6.2e-4**(0)$_{\downarrow 4}$	**7.3e-4**(0)$_{\downarrow 4}$	**8.8e-4**(4e-5)$_{\downarrow 4}$	**1.0e-3**(7e-5)$_{\downarrow 4}$	**1.2e-3**(7e-5)$_{\downarrow 4}$	15/15
fminunc pa	**7.1e-4**(4e-5)$_{\downarrow 4}$	**6.5e-4**(3e-5)$_{\downarrow 4}$	**7.6e-4**(3e-5)$_{\downarrow 4}$	**8.3e-4**(3e-5)$_{\downarrow 4}$	**8.9e-4**(3e-5)$_{\downarrow 4}$	15/15
ga100 hol	∞	∞	∞	∞	∞ *1e6*	0/15
grid100 ho	∞	∞	∞	∞	∞ *1e6*	0/15
grid16 hol	∞	∞	∞	∞	∞ *1e6*	0/15
hill hol	∞	∞	∞	∞	∞ *1e6*	0/15
lmmCMA aug	∞	∞	∞	∞	∞ *8805*	0/15
memPSODE v	30(28)	134(137)	∞	∞	∞ *1e7*	0/15
prcga saw	**0.19**(0.2)$_{\downarrow 2}$	**0.35**(0.2)	**0.70**(0.5)	**1.1**(0.7)	**1.4**(1)	15/15
ring100 ho	∞	∞	∞	∞	∞ *1e6*	0/15
ring16 hol	∞	∞	∞	∞	∞ *1e6*	0/15
simplex pa	**2.5e-3**(6e-4)$_{\downarrow 4}$	**0.18**(0.6)$_{\downarrow 3}$	**1.8**(2)	7.6(9)	∞ *4e5*	0/15

Table 21: 20-D, running time excess ERT/ERT$_{\text{best 2009}}$ on f_{20} for given run-length based budgets (0.5D, 1.2D, 3D, 10D, and 50D function evaluations). 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 ERT$_{\text{best 2009}}$ (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. Entries with succeeding star are statistically significantly better (according to the rank-sum test) compared to all other algorithms in the table, with $p = 0.05$ or $p = 10^{-k}$ when the number k following the star is larger than 1, with Bonferroni correction by the number of instances.

#FEs/D	0.5	1.2	3	10	50	#succ
f20	*1.6e+4*:38	*1.0e+4*:42	*2.5e+2*:62	*2.5e+0*:250	*1.6e+0*:2536	15/15
BIPOP-aCMA	4.9(3)	5.6(2)	7.0(1)	5.8(1)	23(25)	15/15
BIPOP-saAC	**2.8**(1)	3.1(0.7)	3.4(0.5)	4.4(1.0)	10(6)	15/15
CMAES hut	**2.7**(1)	**2.8**(2)	5.2(1)	5.1(1)	3.8(4)	3/15
DE pal	11(5)	15(3)	36(8)	68(21)	35(13)	15/15
HCMA los	**1.1**(0)	**1.00**(0)	**0.79**(0.2)	4.1(3)	10(7)	15/15
HMLSL pal	**0.60**(0)$\downarrow$	**0.55**(0)$\downarrow_4$	**1.5**(0)	**2.2**(0.5)	8.2(4)	15/15
IPOP-10DDr	4.0(1)	4.7(1)	6.0(1)	6.6(2)	31(30)	15/15
IPOP-500 l	4.0(1)	4.7(1)	6.0(1)	6.6(2)	31(30)	15/15
IPOP-tany	3.1(1)	3.8(0.8)	5.9(1)	9.1(1)	30(38)	15/15
IPOP-texp	**0.26**(0.2)$\downarrow$	**0.41**(0.2)$\downarrow_4$	**2.0**(0.8)	5.5(2)	41(58)	15/15
IPOP lia	4.0(1)	4.7(1)	6.0(1)	6.6(2)	31(30)	15/15
MLSL pal	**0.60**(0)$\downarrow$	**0.55**(0)$\downarrow_4$	**1.5**(0)	**2.2**(0.5)	5.2(4)	15/15
OQNLP pal	**1.2**(0)	**1.1**(0)	**0.79**(0)	**1.9**(2e-3)	51(54)	10/15
P-DCN tra	9.4(8)	13(8)	24(5)	8.3(1)	7.7(2)	15/15
P-zero tra	11(10)	15(9)	24(6)	8.1(2)	15(39)	15/15
SMAC hut	**0.25**(0.1)$\downarrow$	**0.46**(0.2)$\downarrow_4$	**0.90**(0.2)	∞	∞ *2000*	0/15
U-DCN tra	3.8(1)	5.0(2)	14(7)	10(4)	**2.2**(1)	15/15
U-zero tra	3.2(1)	3.8(2)	8.3(4)	4.7(1)	**1.1**(0.5)	15/15
fmincon pa	**0.60**(0)$\downarrow$	**0.55**(0)$\downarrow_4$	**1.5**(0)	**2.2**(0.5)	6.9(5)	15/15
fminunc pa	**0.57**(0)$\downarrow$	**0.52**(0)$\downarrow_4$	**0.69**(0)	8.5(0.3)	4.2(2)	15/15
ga100 hol	16(6)	21(5)	37(7)	23(3)	3.8(0.6)	15/15
grid100 ho	49(30)	59(40)	151(55)	82(26)	18(7)	15/15
grid16 hol	12(4)	17(8)	27(9)	14(5)	**2.6**(0.8)	15/15
hill hol	3.6(2)	3.9(2)	5.7(2)	**2.7**(1)	**0.73**(0.3)	15/15
lmmCMA aug	**0.91**(0.9)	**1.4**(2)	3.9(0.9)	6.6(1)	23(28)	2/15
memPSODE v	24(27)	27(26)	27(21)	9.5(5)	3.2(2)	15/15
prcga saw	**2.6**(2)	4.1(2)	10(4)	16(4)	5.3(3)	15/15
ring100 ho	28(19)	39(15)	79(13)	44(9)	7.2(1)	15/15
ring16 hol	8.9(4)	11(4)	18(4)	9.3(1)	**1.5**(0.3)	15/15
simplex pa	9.1(0.2)	10(0.2)	68(31)	264(345)	2326(2528)	1/15

Table 22: 20-D, running time excess ERT/ERT$_{\text{best 2009}}$ on f_{21} for given run-length based budgets (0.5D, 1.2D, 3D, 10D, and 50D function evaluations). 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 ERT$_{\text{best 2009}}$ (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. Entries with succeeding star are statistically significantly better (according to the rank-sum test) compared to all other algorithms in the table, with $p = 0.05$ or $p = 10^{-k}$ when the number k following the star is larger than 1, with Bonferroni correction by the number of instances.

#FEs/D	0.5	1.2	3	10	50	#succ
f21	*6.3e+1*:36	*4.0e+1*:77	*4.0e+1*:77	*1.6e+1*:456	*4.0e+0*:1094	15/15
BIPOP-aCMA	6.3(3)	3.9(1)	3.9(1)	**2.6**(6)	5.5(6)	15/15
BIPOP-saAC	4.6(1)	4.4(1)	4.4(1)	**1.4**(2)	**2.0**(2)	15/15
CMAES hut	4.5(2)	3.3(1)	3.3(1)	**3.0**(4)	4.1(5)	5/15
DE pal	32(20)	35(18)	35(18)	74(8)	64(183)	13/15
HCMA los	**1.7**(0.3)	**0.94**(0.1)	**0.94**(0.1)	**0.59**(0.5)	**0.96**(1)	15/15
HMLSL pal	**0.82**(0.3)	**0.64**(0.2)	**0.64**(0.2)	3.6(8)	4.4(5)	15/15
IPOP-10DDr	5.2(1)	3.6(0.6)	3.6(0.6)	3.0(6)	10(11)	15/15
IPOP-500 l	5.2(1)	3.6(0.6)	3.6(0.6)	3.0(6)	10(11)	15/15
IPOP-tany	4.3(2)	3.1(0.8)	3.1(0.8)	**2.2**(5)	**1.8**(2)	15/15
IPOP-texp	**2.0**(0.8)	**2.0**(1)	**2.0**(1)	**2.7**(0.7)	66(162)	15/15
IPOP lia	5.2(1)	3.6(0.6)	3.6(0.6)	3.0(6)	10(11)	15/15
MLSL pal	**0.82**(0.3)	**0.64**(0.2)	**0.64**(0.2)	**0.93**(2)	**1.2**(2)	15/15
OQNLP pal	**1.4**(0.0)	**0.88**(0.3)	**0.88**(0.3)	**0.51**(0.7)	**0.84**(0.9)	15/15
P-DCN tra	21(16)	18(9)	18(9)	1.1e4(2e4)	3.7e4(5e4)	5/15
P-zero tra	18(12)	15(7)	15(7)	3134(3)	2.1e4(3e4)	7/15
SMAC hut	7.5(6)	4.2(3)	4.2(3)	**2.7**(4)	5.2(6)	4/15
U-DCN tra	6.5(3)	5.9(3)	5.9(3)	6744(2e4)	2.7e4(4e4)	6/15
U-zero tra	6.4(2)	1.9e4(3)	1.9e4(3)	1.1e4(2e4)	2.7e4(4e4)	6/15
fmincon pa	**0.82**(0.3)	**0.64**(0.2)	**0.64**(0.2)	**0.96**(2)	**0.92**(0.9)	15/15
fminunc pa	**1.5**(0.6)	**1.2**(0.5)	**1.2**(0.5)	**1.1**(2)	**1.6**(2)	15/15
ga100 hol	29(11)	22(6)	22(6)	6.9(2)	806(918)	8/15
grid100 ho	115(57)	1027(54)	1027(54)	1133(2191)	3768(4518)	3/15
grid16 hol	17(7)	16(6)	16(6)	801(1098)	1841(2742)	5/15
hill hol	44(7)	956(139)	956(139)	1462(2191)	1829(2286)	5/15
lmmCMA aug	3.5(1)	**2.5**(1.0)	**2.5**(1.0)	**1.3**(2)	4.3(5)	11/15
memPSODE v	11(1)	8.7(10)	8.7(10)	5.4(8)	21(35)	15/15
prcga saw	20(12)	20(9)	20(9)	1099(2187)	6597(8455)	3/15
ring100 ho	47(21)	45(10)	45(10)	14(2)	12(3)	15/15
ring16 hol	13(5)	11(5)	11(5)	3.5(2)	460(914)	10/15
simplex pa	56(27)	32(3)	32(3)	10(6)	70(73)	15/15

Table 23: 20-D, running time excess ERT/ERT$_{\text{best 2009}}$ on f_{22} for given run-length based budgets (0.5D, 1.2D, 3D, 10D, and 50D function evaluations). 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 ERT$_{\text{best 2009}}$ (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. Entries with succeeding star are statistically significantly better (according to the rank-sum test) compared to all other algorithms in the table, with $p = 0.05$ or $p = 10^{-k}$ when the number k following the star is larger than 1, with Bonferroni correction by the number of instances.

#FEs/D	0.5	1.2	3	10	50	#succ
f22	*6.3e+1*:45	*4.0e+1*:68	*4.0e+1*:68	*1.6e+1*:231	*6.3e+0*:1219	15/15
BIPOP-aCMA	6.4(3)	15(35)	15(35)	88(29)	82(213)	15/15
BIPOP-saAC	3.8(2)	13(16)	13(16)	8.3(21)	43(29)	15/15
CMAES hut	3.9(2)	8.4(15)	8.4(15)	6.0(9)	**1.6**(2)	9/15
DE pal	35(11)	45(28)	45(28)	456(870)	498(657)	6/15
HCMA los	**2.3**(0.3)	6.9(3)	6.9(3)	8.2(12)	32(74)	15/15
HMLSL pal	**0.99**(0.0)	6.7(0.3)	6.7(0.3)	13(22)	124(168)	11/15
IPOP-10DDr	4.4(1)	4.0(1)	4.0(1)	10(26)	1610(1374)	14/15
IPOP-500 l	4.4(1)	4.0(1)	4.0(1)	10(26)	4374(8204)	12/15
IPOP-tany	4.4(2)	9.0(3)	9.0(3)	17(27)	1469(1146)	14/15
IPOP-texp	3.2(2)	**4.0**(3)	**4.0**(3)	20(27)	194(423)	15/15
IPOP lia	4.4(1)	4.0(1)	4.0(1)	10(26)	4178(8204)	12/15
MLSL pal	**0.99**(0.0)	**2.7**(0.3)	**2.7**(0.3)	**3.2**(4)	**2.4**(3)	15/15
OQNLP pal	**1.2**(0.0)	**1.8**(0.4)	**1.8**(0.4)	**1.2**(1)	9.1(16)	13/15
P-DCN tra	23(17)	25(13)	25(13)	3.2e4(4e4)	2.5e4(3e4)	6/15
P-zero tra	3.2e4(6)	2.1e4(13)	2.1e4(13)	3.2e4(4e4)	1.1e4(2e4)	9/15
SMAC hut	10(22)	7.3(15)	7.3(15)	**4.2**(5)	**2.0**(2)	7/15
U-DCN tra	6.3(4)	2.1e4(29)	2.1e4(29)	4.3e4(9e4)	1.9e4(2e4)	7/15
U-zero tra	4.1(2)	2.1e4(3)	2.1e4(3)	2.2e4(4e4)	1.4e4(2e4)	8/15
fmincon pa	**0.99**(0.0)	**2.5**(0.3)	**2.5**(0.3)	**2.9**(4)	**3.5**(2)	15/15
fminunc pa	**1.1**(0.2)	**3.1**(1)	**3.1**(1)	**2.9**(4)	**1.6**(2)	15/15
ga100 hol	24(12)	30(12)	30(12)	325(19)	414(820)	10/15
grid100 ho	90(42)	1164(73)	1164(73)	2953(4352)	1662(2058)	5/15
grid16 hol	25(14)	3724(7404)	3724(7404)	2914(4333)	2258(2871)	4/15
hill hol	3.7(2)	1060(3)	1060(3)	1084(2166)	718(1230)	8/15
lmmCMA aug	3.1(1)	5.8(2)	5.8(2)	5.9(6)	3.8(5)	11/15
memPSODE v	5.6(2)	6.9(3)	6.9(3)	18(9)	18(32)	15/15
prcga saw	19(11)	21(8)	21(8)	387(128)	496(821)	11/15
ring100 ho	44(23)	49(13)	49(13)	26(9)	68(12)	14/15
ring16 hol	12(5)	12(5)	12(5)	316(6)	207(411)	12/15
simplex pa	54(3)	41(6)	41(6)	30(32)	80(87)	15/15

Table 24: 20-D, running time excess ERT/ERT$_{\text{best 2009}}$ on f_{23} for given run-length based budgets (0.5D, 1.2D, 3D, 10D, and 50D function evaluations). 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 ERT$_{\text{best 2009}}$ (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. Entries with succeeding star are statistically significantly better (according to the rank-sum test) compared to all other algorithms in the table, with $p = 0.05$ or $p = 10^{-k}$ when the number k following the star is larger than 1, with Bonferroni correction by the number of instances.

#FEs/D	0.5	1.2	3	10	50	#succ
f23	*6.3e+0*:29	*4.0e+0*:118	*2.5e+0*:306	*2.5e+0*:306	*1.0e+0*:1614	15/15
BIPOP-aCMA	**2.9**(4)	19(20)	59(31)	59(31)	23(26)	15/15
BIPOP-saAC	4.7(5)	11(18)	75(69)	75(69)	29(36)	15/15
CMAES hut	7.5(8)	23(25)	97(98)	97(102)	∞ *2006*	0/15
DE pal	**1.4**(1)	7.8(6)	94(111)	94(111)	∞ *4e5*	0/15
HCMA los	3.6(2)	9.5(20)	31(40)	31(40)	23(15)	15/15
HMLSL pal	7.3(7)	**3.8**(2)	**2.8**(2)	**2.8**(2)	**6.4**(5)	15/15
IPOP-10DDr	**1.3**(1)	6.8(7)	50(36)	50(36)	35(39)	15/15
IPOP-500 l	**1.3**(1)	6.8(7)	50(36)	50(36)	35(39)	15/15
IPOP-tany	**1.6**(1)	7.7(10)	57(65)	57(65)	20(23)	15/15
IPOP-texp	**1.4**(1.0)	6.8(5)	46(61)	46(61)	28(36)	15/15
IPOP lia	**1.3**(1)	6.8(7)	50(36)	50(36)	35(39)	15/15
MLSL pal	7.3(7)	**3.8**(2)	**2.8**(2)	**2.8**(2)	**3.4**(3)	15/15
OQNLP pal	13(25)	5.3(6)	**3.7**(3)	**3.7**(3)	**3.5**(4)	15/15
P-DCN tra	**2.1**(2)	**3.1**(2)	4.1(4)	4.1(4)	1083(876)	14/15
P-zero tra	**1.4**(2)	**2.1**(1)	**3.3**(4)	**3.3**(4)	2304(5644)	14/15
SMAC hut	**1.6**(2)	5.0(8)	46(52)	46(49)	∞ *2000*	0/15
U-DCN tra	**1.3**(1)	**3.7**(4)	17(15)	17(15)	4711(6304)	12/15
U-zero tra	**1.1**(1)	5.9(7)	20(19)	20(19)	3936(6378)	12/15
fmincon pa	5.0(5)	4.8(5)	**3.2**(2)	**3.2**(2)	**4.4**(5)	15/15
fminunc pa	20(15)	10(7)	18(16)	18(16)	248(248)	10/15
ga100 hol	**1.1**(1)	7.3(8)	92(102)	92(102)	1486(1693)	5/15
grid100 ho	**1.9**(1)	8.7(13)	40(34)	40(34)	2274(2122)	4/15
grid16 hol	**2.8**(3)	5.4(7)	53(70)	53(70)	459(638)	10/15
hill hol	**1.7**(3)	6.3(8)	20(29)	20(29)	1120(1344)	6/15
lmmCMA aug	**1.9**(3)	8.2(9)	408(454)	408(447)	∞ *8823*	0/15
memPSODE v	12(14)	18(27)	13(13)	13(13)	25(20)	15/15
prcga saw	**1.8**(2)	12(8)	90(124)	90(124)	2615(2671)	4/15
ring100 ho	**2.1**(2)	7.9(11)	46(43)	46(43)	274(336)	12/15
ring16 hol	**2.1**(2)	5.5(5)	21(24)	21(24)	264(353)	12/15
simplex pa	38(25)	17(4)	8.4(0.3)	8.4(0.3)	**1.9**(0.2)	15/15

Table 25: 20-D, running time excess ERT/ERT$_{\text{best 2009}}$ on f_{24} for given run-length based budgets (0.5D, 1.2D, 3D, 10D, and 50D function evaluations). 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 ERT$_{\text{best 2009}}$ (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. Entries with succeeding star are statistically significantly better (according to the rank-sum test) compared to all other algorithms in the table, with $p = 0.05$ or $p = 10^{-k}$ when the number k following the star is larger than 1, with Bonferroni correction by the number of instances.

#FEs/D	0.5	1.2	3	10	50	#succ
f24	*2.5e+2*:208	*1.6e+2*:918	*1.0e+2*:6628	*6.3e+1*:9885	*4.0e+1*:31629	15/15
BIPOP-aCMA	**1.6**(0.3)	**1.5**(0.9)	3.4(4)	**2.8**(3)	**1.3**(1)	15/15
BIPOP-saAC	**1.1**(0.5)	**1.3**(0.9)	4.4(5)	6.0(10)	**2.2**(3)	15/15
CMAES hut	**1.1**(0.3)	**1.8**(1)	∞	∞	∞ *2006*	0/15
DE pal	9.3(4)	19(12)	277(288)	∞	∞ *4e5*	0/15
HCMA los	**0.44**(0.2)$_{\downarrow 4}$	**0.47**(0.5)	5.6(6)	5.5(4)	**2.0**(2)	15/15
HMLSL pal	**0.51**(0.3)$_{\downarrow 3}$	**1.9**(6)	**1.9**(0.8)	3.1(3)	12(14)	9/15
IPOP-10DDr	**1.3**(0.3)	**1.5**(1)	**1.6**(2)	**1.6**(1)	**1.4**(0.8)	15/15
IPOP-500 l	**1.3**(0.3)	**1.5**(1)	**1.6**(2)	**1.6**(1)	**1.4**(0.8)	15/15
IPOP-tany	**1.2**(0.3)	**1.7**(1)	**1.8**(1)	**1.4**(0.7)	**1.1**(0.9)	15/15
IPOP-texp	**0.33**(0.3)$_{\downarrow 3}$	**1.2**(1)	**1.8**(2)	**1.4**(1)	**1.2**(1)	15/15
IPOP lia	**1.3**(0.3)	**1.5**(1)	**1.6**(2)	**1.6**(1)	**1.4**(0.8)	15/15
MLSL pal	**0.51**(0.3)$_{\downarrow 3}$	31(108)	893(907)	∞	∞ *4e5*	0/15
OQNLP pal	**0.32**(0.1)$_{\downarrow 4}$	**0.54**(0.2)	3.9(4)	18(17)	37(42)	3/15
P-DCN tra	1.1e5(1e5)	3.0e5(3e5)	∞	∞	∞ *2e7*	0/15
P-zero tra	1.3e6(2e6)	∞	∞	∞	∞ *2e7*	0/15
SMAC hut	**0.65**(0.6)	10(11)	∞	∞	∞ *2000*	0/15
U-DCN tra	**2.6**(1)	39(20)	2680(4526)	∞	∞ *2e7*	0/15
U-zero tra	101(15)	5659(1e4)	4.2e4(4e4)	∞	∞ *2e7*	0/15
fmincon pa	**0.51**(0.3)$_{\downarrow 3}$	12(3)	886(997)	∞	∞ *4e5*	0/15
fminunc pa	**0.62**(0.5)	**0.35**(0.2)	∞	∞	∞ *4e5*	0/15
ga100 hol	7.1(2)	6.0(3)	11(6)	19(18)	43(42)	8/15
grid100 ho	56(35)	796(1015)	2249(2339)	∞	∞ *1e6*	0/15
grid16 hol	33(24)	802(825)	2151(2414)	∞	∞ *1e6*	0/15
hill hol	479(664)	626(1089)	650(761)	∞	∞ *1e6*	0/15
lmmCMA aug	**0.74**(0.2)$_{\downarrow}$	**1.1**(0.8)	**1.4**(1)	**1.2**(1.0)	**1.2**(1)	3/15
memPSODE v	50(25)	20(9)	6.4(4)	9.4(7)	13(8)	15/15
prcga saw	**1.7**(0.6)	7.6(8)	4.9(2)	5.0(5)	**2.7**(4)	15/15
ring100 ho	23(6)	31(14)	23(14)	116(109)	462(506)	1/15
ring16 hol	5.6(3)	13(9)	67(85)	673(799)	∞ *1e6*	0/15
simplex pa	**2.4**(1)	∞	∞	∞	∞ *4e5*	0/15

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