

Comparison tables: BBOB 2012 testbed in 20-D

The BBOBies

August 16, 2012

Abstract

This document provides tabular results of the workshop for Black-Box Optimization Benchmarking at GECCO 2012, see <http://coco.gforge.inria.fr/doku.php?id=bbob-2012>. More than 27 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 [4, 2]. The experimental set-up is described in [3].

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 [1]) if an algorithm from BBOB-2009 reached the given target function value. The ERT value is given otherwise (ERT_{best} is noted as infinite). See [3] 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 2012.

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

testbed algorithm name	short	paper	reference
ACOR		An ACO Algorithm Benchmarked on the BBOB Noiseless Function Testbed (Page 159)	[5]
BIPOPacCMA		Black-Box Optimization Benchmarking of IPOP-SaACM-ES and BIPOP-SaACM-ES on the BBOB-2012 Noiseless Testbed (Page 175)	[12]
BIPOPsaACM		Black-box Optimization Benchmarking of IPOP-SaACM-ES and BIPOP-SaACM-ES on the BBOB-2012 Noiseless Testbed (Page 175)	[12]
CMA		Comparing Mirrored Mutations and Active Covariance Matrix Adaptation in the IPOP-CMA-ES on the Noiseless BBOB Testbed (Page 297)	[14]
CMAES		Benchmarking the Differential Evolution with Adaptive Encoding on Noiseless Functions (Page 189)	[9]
CMAa		Comparing Mirrored Mutations and Active Covariance Matrix Adaptation in the IPOP-CMA-ES on the Noiseless BBOB Testbed (Page 297)	[14]
CMAm		Comparing Mirrored Mutations and Active Covariance Matrix Adaptation in the IPOP-CMA-ES on the Noiseless BBOB Testbed (Page 297)	[14]
CMama		On the Impact of a Small Initial Population Size in the IPOP Active CMA-ES with Mirrored Mutations on the Noiseless BBOB Testbed (Page 285)	[19]
CMamah		On the Impact of a Small Initial Population Size in the IPOP Active CMA-ES with Mirrored Mutations on the Noiseless BBOB Testbed (Page 285)	[19]
CMAmh		On the Impact of Active Covariance Matrix Adaptation in the CMA-ES With Mirrored Mutations and Small Initial Population Size on the Noiseless BBOB Testbed (Page 291)	[20]
DBRCGA		Black-Box Optimization Benchmarking for Noiseless Function Testbed Using A Direction-Based RCGA (Page 167)	[11]
DE		Benchmarking the Differential Evolution with Adaptive Encoding on Noiseless Functions (Page 189)	[9]
DE-AUTO		MEMPSODE: An Empirical Assessment of Local Search Algorithm Impact on a Memetic Algorithm Using Noiseless Testbed (Page 245)	[17]
DE-BFGS		MEMPSODE: Comparing Particle Swarm Optimization and Differential Evolution Within a Hybrid Memetic Global Optimization Framework (Page 253)	[18]
DE-ROLL		MEMPSODE: An Empirical Assessment of Local Search Algorithm Impact on a Memetic Algorithm Using Noiseless Testbed (Page 245)	[17]
DE-SIMPLEX		MEMPSODE: An Empirical Assessment of Local Search Algorithm Impact on a Memetic Algorithm Using Noiseless Testbed (Page 245)	[17]
DEctpb		JADE, an Adaptive Differential Evolution Algorithm, Benchmarked on the BBOB Noiseless Testbed (Page 197)	[16]
IPOPsaACM		Black-box Optimization Benchmarking of NIPOP-aCMA-ES and NBIPOP-aCMA-ES on the BBOB-2012 Noiseless Testbed (Page 269)	[14]
JADEctpb		JADE, an Adaptive Differential Evolution Algorithm, Benchmarked on the BBOB Noiseless Testbed (Page 197)	[16]
MVDE		Benchmarking the Multi-View Differential Evolution on the Noiseless BBOB-2012 Function Testbed (Page 183)	[10]
NBIPOPacCMA		Black-box Optimization Benchmarking of NIPOP-aCMA-ES and NBIPOP-aCMA-ES on the BBOB-2012 Noiseless Testbed (Page 269)	[13]
NIPOPacCMA		Black-box Optimization Benchmarking of NIPOP-aCMA-ES and NBIPOP-aCMA-ES on the BBOB-2012 Noiseless Testbed (Page 269)	[13]
PSO-BFGS		MEMPSODE: Comparing Particle Swarm Optimization and Differential Evolution Within a Hybrid Memetic Global Optimization Framework (Page 253)	[18]
SNES		Benchmarking Separable Natural Evolution Strategies on the Noiseless and Noisy Black-box Optimization Testbeds (Page 205)	[8]
xNES		Benchmarking Exponential Natural Evolution Strategies on the Noiseless and Noisy Black-Box Optimization Testbeds (Page 213)	[6]
xNESas		Benchmarking Natural Evolution Strategies with Adaptation Sampling on the Noiseless and Noisy Black-Box Optimization Testbeds (Page 229)	[7]
xNESas		Investigating the Impact of Adaptation Sampling in Natural Evolution Strategies on Black-Box Optimization Testbeds (Page 221)	[15]

Table 2: 20-D, running time excess $\text{ERT}/\text{ERT}_{\text{best 2009}}$ on f_1 , in italics is given the median final function value and the median number of function evaluations to reach this value divided by dimension.

Δf_{opt}	1e1	1e0	1e-1	1e-3	1e-5	1e-7	#succ
<i>f1</i>	43	43	43	43	43	43	15/15
ACOR	24(5)	43(8)	60(8)	95(9)	129(10)	164(8)	15/15
BIPOPacCMA	7.5(2)	14(2)	20(2)	33(2)	46(4)	59(4)	15/15
BIPOPsaACM	4.0(0.2)	5.1(0.4)	6.6(0.7)	10(0.7)	13(0.8)	16(1)	15/15
CMA	7.3(1)	13(1)	19(1)	32(2)	43(2)	56(2)	15/15
CMAES	7.5(2)	13(2)	20(2)	33(2)	45(3)	58(4)	15/15
CMAa	7.8(1)	14(2)	20(2)	32(2)	45(3)	58(3)	15/15
CMAm	6.1(1)	10(1)	14(2)	23(1)	32(1)	41(2)	15/15
CMAMA	5.8(0.8)	10(1.0)	14(1)	23(1)	32(1)	41(2)	15/15
CMAmah	3.8(0.8)	6.6(0.9)	10(1)	15(1)	21(1)	27(1)	15/15
CMAmh	3.8 (0.6)	6.7(0.7)	10(1)	15(1)	22(2)	28(2)	15/15
DBRCGA	142(31)	304(46)	485(63)	799(93)	1119(109)	1449(135)	15/15
DE	89(17)	162(31)	241(28)	400(27)	558(30)	717(39)	15/15
DE-AUTO	3.1 (0.1)	3.1 (0.1)	3.1 (0.1)	3.1 (0.1)	3.1 (0.1)	3.1 (0.1)	15/15
DE-BFGS	2.0 (0.2)	2.2 (0)	2.2 (0)	2.2 (0)	2.2 (0)	2.2 (0)	15/15
DE-ROLL	6.4(7)	36(35)	37(36)	38(36)	38(36)	38(36)	15/15
DE-SIMPLEX	71(41)	181(83)	237(92)	389(99)	461(117)	840(800)	15/15
DEctpb	91(14)	181(15)	269(21)	440(21)	615(20)	803(34)	15/15
IPOPsaACM	3.9(0.2)	5.0 (0.4)	6.5 (0.5)	9.5 (0.7)	13 (0.7)	16 (0.8)	15/15
JADEb	35(3)	67(4)	102(5)	179(13)	260(14)	346(17)	15/15
JADEctpb	47(7)	94(8)	143(8)	240(8)	340(10)	437(13)	15/15
MVDE	144(16)	299(10)	445(13)	743(10)	1048(21)	1355(25)	15/15
NBIPOPacCMA	7.9(1)	14(1)	20(1)	33(2)	46(2)	59(3)	15/15
NIPOPacCMA	7.7(2)	14(1)	20(2)	33(2)	45(2)	58(3)	15/15
PSO-BFGS	1.9 (0.2)	2.2 (0)	2.2 (0)	2.2 (0)	2.2 (0)	2.2 (0)	15/15
SNES	5.4(0.8)	14(1)	25(3)	45(2)	66(2)	86(2)	15/15
xNES	5.8(3)	70(5)	137(6)	274(5)	410(7)	546(9)	15/15
xNESas	7.3(2)	41(9)	61(16)	88(23)	110(25)	128(32)	15/15

Table 3: 20-D, running time excess $\text{ERT}/\text{ERT}_{\text{best 2009}}$ on f_2 , in italics is given the median final function value and the median number of function evaluations to reach this value divided by dimension.

Δf_{opt}	1e1	1e0	1e-1	1e-3	1e-5	1e-7	#succ
f_2	385	386	387	390	391	393	15/15
ACOR	10(0.9)	12(0.7)	14(0.5)	17(1)	21(0.9)	25(0.9)	15/15
BIPOPaCMA	23(4)	27(3)	29(3)	31(2)	33(1)	34(1)	15/15
BIPOPsaACM	6.8(1)	8.0(1)	8.9(1)	10(1)	10(1)	10 (1)	15/15
CMA	34(5)	40(6)	43(3)	45(3)	47(1)	48(1)	15/15
CMAES	37(4)	43(3)	45(2)	47(1)	48(1)	50(1)	15/15
CMAa	23(3)	27(3)	29(3)	31(2)	32(2)	34(2)	15/15
CMAm	34(6)	39(6)	42(5)	45(2)	47(2)	48(2)	15/15
CMAma	22(4)	25(3)	27(2)	29(2)	31(1)	32(1)	15/15
CMAmah	23(5)	26(4)	28(2)	30(1)	31(1)	32(1)	15/15
CMAmh	32(5)	36(4)	38(2)	40(2)	41(2)	41(2)	15/15
DBRCGA	75(6)	93(7)	113(8)	147(10)	183(9)	220(9)	15/15
DE	41(3)	50(3)	59(3)	76(5)	93(5)	110(5)	15/15
DE-AUTO	3.5 (2)	3.9 (2)	4.3 (2)	4.7 (2)	5.1 (2)	5.7 (3)	15/15
DE-BFGS	5.7 (4)	6.1 (4)	6.2 (4)	6.5 (4)	7.1 (5)	10 (5)	15/15
DE-ROLL	15(12)	16(12)	16(12)	16(12)	17(12)	17(12)	15/15
DE-SIMPLEX	90(20)	104(16)	120(23)	135(24)	149(23)	287(246)	15/15
DEctpb	47(2)	56(3)	66(3)	86(4)	105(4)	125(5)	15/15
IPOPsaACM	7.3(1)	8.3(2)	8.9(2)	10(2)	10 (1)	10 (1)	15/15
JADEb	20(2)	25(2)	30(2)	39(2)	48(3)	57(4)	15/15
JADEctpb	28(1)	34(1)	39(2)	50(2)	61(3)	71(4)	15/15
MVDE	76(2)	92(2)	109(3)	141(2)	173(3)	206(4)	15/15
NBIPOPaCMA	23(4)	27(3)	29(2)	32(2)	33(2)	34(2)	15/15
NIPOPaCMA	23(3)	26(3)	29(2)	31(2)	33(2)	34(2)	15/15
PSO-BFGS	5.2 (3)	5.4 (3)	5.6 (3)	6.7 (5)	7.6 (5)	12(12)	15/15
SNES	4.8 (0.3)	5.9 (0.2)	7.0 (0.3)	9.2 (0.3)	11(0.3)	14(0.4)	15/15
xNES	29(0.7)	36(0.7)	43(0.9)	58(1)	72(0.8)	87(1)	15/15
xNESas	26(1)	31(2)	34(3)	38(4)	41(6)	43(6)	15/15

Table 4: 20-D, running time excess $\text{ERT}/\text{ERT}_{\text{best}} 2009$ on f_3 , in italics is given the median final function value and the median number of function evaluations to reach this value divided by dimension.

Δf_{opt}	1e1	1e0	1e-1	1e-3	1e-5	1e-7	#succ
f3	5066	7626	7635	7643	7646	7651	15/15
ACOR	1018(1197)	∞	∞	∞	∞	∞ <i>1e7</i>	0/15
BIPOPaCMA	9.0(5)	1.7e4(2e4)	∞	∞	∞	∞ <i>2e7</i>	0/15
BIPOPsaACM	10(7)	∞	∞	∞	∞	∞ <i>2e7</i>	0/5
CMA	13(9)	∞	∞	∞	∞	∞ <i>3e6</i>	0/15
CMAES	638(691)	∞	∞	∞	∞	∞ <i>1e6</i>	0/15
CMAa	8.7(7)	∞	∞	∞	∞	∞ <i>3e6</i>	0/15
CMAm	8.5 (6)	∞	∞	∞	∞	∞ <i>3e6</i>	0/15
CMAMA	7.1 (3)	∞	∞	∞	∞	∞ <i>3e6</i>	0/15
CMAmah	13(7)	4956(5374)	4950(5811)	4945(5275)	4944(5839)	4941(5786)	1/15
CMAmh	13(16)	∞	∞	∞	∞	∞ <i>3e6</i>	0/15
DBRCGA	144(64)	450(415)	1181(1278)	1180(1178)	1181(1326)	1182(1365)	3/15
DE	39(10)	67(49)	167(170)	168(170)	168(162)	169(162)	9/15
DE-AUTO	47(49)	224(179)	401(309)	401(353)	401(353)	401(309)	8/15
DE-BFGS	56(24)	132(68)	181(131)	181(151)	181(149)	191(159)	13/15
DE-ROLL	15(11)	55 (30)	82 (65)	82 (65)	82 (65)	82 (65)	15/15
DE-SIMPLEX	119(44)	212(139)	355(283)	355(297)	355(283)	484(409)	4/15
DEctpb	114(10)	94(8)	95(7)	96(7)	97(7)	98(7)	15/15
IPOPsaACM	11(15)	∞	∞	∞	∞	∞ <i>2e7</i>	0/5
JADEb	6.3 (0.3)	13 (13)	17 (20)	18 (20)	19 (20)	20 (20)	15/15
JADEctpb	6.4 (0.3)	6.0 (0.2)	6.8 (0.2)	8.3 (0.2)	10 (0.2)	11 (0.2)	15/15
MVDE	28(2)	23 (3)	33 (3)	35 (3)	36 (3)	38 (3)	14/15
NBIPOPaCMA	12(8)	∞	∞	∞	∞	∞ <i>2e7</i>	0/15
NIPOPaCMA	9.4(6)	∞	∞	∞	∞	∞ <i>2e7</i>	0/15
PSO-BFGS	∞	∞	∞	∞	∞	∞ <i>2e6</i>	0/15
SNES	550(526)	∞	∞	∞	∞	∞ <i>7e6</i>	0/15
xNES	629(781)	∞	∞	∞	∞	∞ <i>7e6</i>	0/15
xNESas	1055(1471)	∞	∞	∞	∞	∞ <i>1e7</i>	0/15

Table 5: 20-D, running time excess $\text{ERT}/\text{ERT}_{\text{best 2009}}$ on f_4 , in italics is given the median final function value and the median number of function evaluations to reach this value divided by dimension.

Δf_{opt}	1e1	1e0	1e-1	1e-3	1e-5	1e-7	#succ
f_4	4722	7628	7666	7700	7758	1.4e5	9/15
ACOR	1.5e4(2e4)	∞	∞	∞	∞	∞ 1e7	0/15
BIPOPacCMA	3.0e4(3e4)	∞	∞	∞	∞	∞ 2e7	0/15
BIPOPsaACM	∞	∞	∞	∞	∞	∞ 2e7	0/5
CMA	∞	∞	∞	∞	∞	∞ 3e6	0/15
CMAES	∞	∞	∞	∞	∞	∞ 1e6	0/15
CMAa	∞	∞	∞	∞	∞	∞ 3e6	0/15
CMAm	∞	∞	∞	∞	∞	∞ 3e6	0/15
CMAma	∞	∞	∞	∞	∞	∞ 3e6	0/15
CMAmah	∞	∞	∞	∞	∞	∞ 2e6	0/15
CMAmh	∞	∞	∞	∞	∞	∞ 2e6	0/15
DBRCGA	236(100)	∞	∞	∞	∞	∞ 2e6	0/15
DE	30(9)	∞	∞	∞	∞	∞ 1e6	0/15
DE-AUTO	67(50)	1265(1305)	3887(4114)	3870(4290)	3841(4000)	211(227)	1/15
DE-BFGS	143(83)	589(526)	3893(4440)	3876(4551)	3847(3872)	212(227)	1/15
DE-ROLL	26 (19)	165(86)	407 (392)	406 (325)	403 (385)	22 (21)	8/15
DE-SIMPLEX	172(76)	388(277)	3910(4178)	3893(4225)	3866(4000)	∞ 2e6	0/15
DEctpb	144(19)	119 (14)	311 (265)	311 (264)	310 (259)	17 (14)	6/15
IPOPsaACM	1.9e4(2e4)	∞	∞	∞	∞	∞ 2e7	0/5
JADEb	17 (11)	102 (122)	265 (268)	265 (264)	264 (267)	15 (16)	6/15
JADEctpb	8.0 (0.4)	7.0 (0.3)	8.0 (0.2)*	10 (0.2)*	11 (0.3)*	0.71 (0.0)*	15/15
MVDE	28 (4)	71 (68)	869(1042)	867(1039)	862(967)	48(50)	2/15
NBIPOPacCMA	6.1e4(7e4)	∞	∞	∞	∞	∞ 2e7	0/15
NIPOPacCMA	∞	∞	∞	∞	∞	∞ 2e7	0/15
PSO-BFGS	∞	∞	∞	∞	∞	∞ 2e6	0/15
SNES	4050(3765)	∞	∞	∞	∞	∞ 7e6	0/15
xNES	6323(7716)	∞	∞	∞	∞	∞ 7e6	0/15
xNESas	4193(4743)	∞	∞	∞	∞	∞ 1e7	0/15

Table 6: 20-D, running time excess $\text{ERT}/\text{ERT}_{\text{best 2009}}$ on f_5 , in italics is given the median final function value and the median number of function evaluations to reach this value divided by dimension.

Δf_{opt}	1e1	1e0	1e-1	1e-3	1e-5	1e-7	#succ
<i>f5</i>	41	41	41	41	41	41	15/15
ACOR	10(3)	12(4)	12(4)	12(4)	12(4)	12(4)	15/15
BIPOPacMA	5.5(0.9)	6.6(0.8)	6.7(0.9)	6.7(0.9)	6.7(0.9)	6.7(0.9)	15/15
BIPOPsaACM	4.7(0.7)	5.3(0.7)	5.4(0.7)	5.4(0.7)	5.4(0.7)	5.4(0.7)	15/15
CMA	4.9(1)	5.7(0.9)	5.9(1)	5.9(1)	5.9(1)	5.9(1)	15/15
CMAES	5.1(1.0)	6.2(0.9)	6.2(0.9)	6.2(0.9)	6.2(0.9)	6.2(0.9)	15/15
CMAa	5.5(1)	6.5(2)	6.6(2)	6.6(2)	6.6(2)	6.6(2)	15/15
CMAm	4.4(1)	5.4(1)	5.5(1)	5.5(1)	5.5(1)	5.5(1)	15/15
CMAMA	4.6(1)	5.2(2)	5.3(1)	5.3(1)	5.3(1)	5.3(1)	15/15
CMAmah	3.1 (0.6)	4.0 (1)	4.1 (1)	4.1 (1)	4.1 (1)	4.1 (1)	15/15
CMAmh	3.2 (1)	3.7 (1)	3.8 (1)	3.8 (1)	3.8 (1)	3.8 (1)	15/15
DBRCGA	151(38)	213(84)	228(106)	233(112)	234(112)	234(112)	15/15
DE	27(6)	35(4)	36(6)	36(6)	36(6)	36(6)	15/15
DE-AUTO	3.1 (0.1)	3.1 (0.1)	3.1 (0.1)	3.1 (0.1)	3.1 (0.1)	3.1 (0.1)	15/15
DE-BFGS	14(8)	22(14)	24(16)	24(16)	26(20)	26(20)	15/15
DE-ROLL	3.8 (0.7)	4.0 (0.9)	4.0 (0.9)	4.0 (0.9)	4.0 (0.9)	4.0 (0.9)	15/15
DE-SIMPLEX	578(126)	869(181)	1437(334)	2145(454)	2753(766)	2.9e4(3e4)	8/15
DEctpb	37(7)	43(4)	46(9)	46(10)	46(10)	46(10)	15/15
IPOPsaACM	4.5(0.7)	5.1(0.7)	5.2(0.8)	5.2(0.8)	5.2(0.8)	5.2(0.8)	15/15
JADEb	28(8)	35(7)	37(8)	37(8)	37(8)	37(8)	15/15
JADEctpb	43(9)	52(7)	54(8)	54(8)	54(8)	54(8)	15/15
MVDE	212(18)	307(31)	379(42)	449(86)	462(95)	463(95)	15/15
NBIPOPacMA	5.1(1)	6.1(1)	6.3(1)	6.3(1)	6.3(1)	6.3(1)	15/15
NIPOPacMA	5.6(1)	6.4(1)	6.6(1)	6.6(1)	6.6(1)	6.6(1)	15/15
PSO-BFGS	22(16)	31(32)	31(32)	33(36)	33(36)	33(36)	15/15
SNES	9.4(2)	12(3)	12(3)	12(3)	12(3)	12(3)	15/15
xNES	10(1)	12(1)	12(1)	12(1)	12(1)	12(1)	15/15
xNESas	8.6(1)	10(1)	11(2)	11(2)	11(2)	11(2)	15/15

Table 7: 20-D, running time excess ERT/ERT_{best} 2009 on f_6 , in italics is given the median final function value and the median number of function evaluations to reach this value divided by dimension.

Δf_{opt}	1e1	1e0	1e-1	1e-3	1e-5	1e-7	#succ
f_6	1296	2343	3413	5220	6728	8409	15/15
ACOR	6.5(2)	5.3(1)	4.8(0.9)	4.7(0.6)	4.8(0.6)	4.9(0.6)	15/15
BIPOPacCMA	1.5 (0.2)	1.2 (0.1)	1.1 (0.1)	1.1 (0.1)	1.1 (0.1)	1.1 (0.1)	15/15
BIPOPsaACM	1.4 (0.3)	1.2 (0.2)	1.1 (0.2)	1.1 (0.2)	1.3 (0.3)	1.4 (0.3)	15/15
CMA	1.7 (0.2)	1.3 (0.2)	1.2 (0.1)	1.2 (0.1)	1.2 (0.1)	1.2 (0.1)	15/15
CMAES	1.7 (0.5)	1.3 (0.3)	1.2 (0.3)	1.2 (0.1)	1.2 (0.2)	1.2 (0.1)	15/15
CMAa	1.6 (0.3)	1.3 (0.2)	1.1 (0.1)	1.1 (0.1)	1.1 (0.1)	1.1 (0.1)	15/15
CMAm	1.7 (0.3)	1.3 (0.2)	1.2 (0.1)	1.2 (0.2)	1.2 (0.2)	1.3 (0.1)	15/15
CMAMA	1.5 (0.3)	1.2 (0.1)	1.0 (0.1)	1.0 (0.1)	1.1 (0.1)	1.1 (0.1)	15/15
CMAmah	1.2 (0.3)	1.1 (0.2)	1.0 (0.2)	1.1 (0.3)	1.2 (0.3)	1.3 (0.3)	15/15
CMAmh	1.2 (0.4)	1.1 (0.3)	1.1 (0.3)	1.3 (0.5)	1.8 (0.5)	2.3 (1)	15/15
DBRCGA	26(11)	55(8)	46(9)	43(8)	43(10)	43(11)	15/15
DE	53(9)	46(7)	46(7)	50(9)	57(11)	61(12)	15/15
DE-AUTO	1.9 (0.7)	2.2 (2)	4.3(3)	12(3)	16(3)	71(126)	10/15
DE-BFGS	6.8(5)	8.5(6)	17(16)	32(36)	96(149)	295(334)	2/15
DE-ROLL	21(7)	23(35)	23(24)	69(35)	209(297)	1025(1176)	1/15
DE-SIMPLEX	34(13)	34(10)	42(23)	102(61)	329(184)	∞ 2e6	0/15
DEctpb	29(3)	23(2)	21(2)	21(1)	21(1)	21(1)	15/15
IPOPsaACM	1.5 (0.4)	1.2 (0.3)	1.1 (0.2)	1.1 (0.2)	1.2 (0.2)	1.3 (0.3)	15/15
JADEb	25(13)	72(53)	362(353)	∞	∞	∞ 1e6	0/15
JADEctpb	9.4(0.7)	7.8(0.8)	7.3(0.7)	7.2(0.9)	7.4(0.9)	7.4(0.9)	15/15
MVDE	37(7)	35(8)	35(7)	37(7)	40(9)	43(10)	15/15
NBIPOPacCMA	1.5 (0.3)	1.2 (0.2)	1.1 (0.1)	1.1 (0.1)	1.1 (0.1)	1.1 (0.1)	15/15
NIPOPacCMA	1.5 (0.2)	1.2 (0.1)	1.1 (0.1)	1.1 (0.1)	1.1 (0.1)	1.1 (0.1)	15/15
PSO-BFGS	9.4(8)	20(18)	40(52)	148(193)	198(267)	352(384)	0/15
SNES	1.3 (0.2)	1.2 (0.2)	1.2 (0.2)	35(57)	137(396)	445(523)	11/15
xNES	4.9(0.3)	4.8(0.2)	4.7(0.2)	5.0(0.1)	5.3(0.1)	5.4(0.1)	15/15
xNESas	4.8(0.2)	4.6(0.2)	4.5(0.1)	4.8(0.1)	5.2(0.1)	5.3(0.1)	15/15

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Table 8: 20-D, running time excess $\text{ERT}/\text{ERT}_{\text{best}} 2009$ on f_7 , in italics is given the median final function value and the median number of function evaluations to reach this value divided by dimension.

Δf_{opt}	1e1	1e0	1e-1	1e-3	1e-5	1e-7	#succ
<i>f7</i>	1351	4274	9503	16524	16524	16969	15/15
ACOR	76(36)	3.5e4(4e4)	∞	∞	∞	∞ <i>1e7</i>	0/15
BIPOPacMA	1.3 (1)	2.9 (2)	2.3 (1)	1.5 (0.6)	1.5 (0.6)	1.4 (0.6)	15/15
BIPOPsaACM	1.0 (0.9)	1.6 (0.6)	0.84 (0.3)	0.61 (0.1) \downarrow 3	0.61 (0.1) \downarrow 3	0.60 (0.1) \downarrow 3	15/15
CMA	1.7 (1)	3.9(1)	2.7 (2)	1.7 (1.0)	1.7 (1.0)	1.6 (0.9)	15/15
CMAES	1.5 (1)	191(214)	754(840)	∞	∞	∞ <i>1e6</i>	0/15
CMAa	1.0 (1.0)	2.3 (1.0)	1.7 (0.7)	1.1 (0.4)	1.1 (0.4)	1.0 (0.4)	15/15
CMAm	1.7 (1)	4.2(2)	2.7 (1.0)	1.7 (0.6)	1.7 (0.6)	1.6 (0.6)	15/15
CMAMA	1.6 (1)	2.7 (1)	1.8 (0.7)	1.1 (0.4)	1.1 (0.4)	1.1 (0.4)	15/15
CMAmah	1.7 (1)	2.4 (0.7)	1.5 (0.6)	0.95 (0.3)	0.95 (0.3)	0.93 (0.3)	15/15
CMAmh	2.9 (1)	4.4(1)	2.6 (1)	1.6 (0.6)	1.6 (0.6)	1.6 (0.6)	15/15
DBRCGA	80(75)	∞	∞	∞	∞	∞ <i>2e6</i>	0/15
DE	24(6)	94(122)	235(316)	256(274)	256(274)	249(295)	3/15
DE-AUTO	28(11)	577(588)	522(534)	439(424)	439(414)	427(415)	4/15
DE-BFGS	502(758)	∞	∞	∞	∞	∞ <i>2e6</i>	0/15
DE-ROLL	26(34)	259(265)	548(571)	∞	∞	∞ <i>2e6</i>	0/15
DE-SIMPLEX	125(107)	1278(1262)	∞	∞	∞	∞ <i>2e6</i>	0/15
DEctpb	29(5)	32(10)	28(5)	20(4)	20(4)	20(6)	14/15
IPOPsaACM	1.0 (1)	1.6 (0.6)	0.92 (0.6)	0.66 (0.3) \downarrow 2	0.66 (0.3) \downarrow 2	0.65 (0.3) \downarrow 2	15/15
JADEb	119(370)	3279(3685)	∞	∞	∞	∞ <i>1e6</i>	0/15
JADEctpb	4.8(0.9)	272(351)	686(789)	402(480)	402(510)	391(442)	2/15
MVDE	25(5)	106(124)	470(532)	882(938)	882(908)	860(914)	1/15
NBIPOPacMA	1.1 (1)	3.9(0.8)	2.6 (1)	1.6 (0.6)	1.6 (0.6)	1.6 (0.6)	15/15
NIPOPacMA	0.99 (0.4)	2.8 (2)	1.7 (0.9)	1.2 (0.3)	1.2 (0.3)	1.2 (0.3)	15/15
PSO-BFGS	∞	∞	∞	∞	∞	∞ <i>2e6</i>	0/15
SNES	32(59)	2715(2771)	∞	∞	∞	∞ <i>7e6</i>	0/15
xNES	1.8 (0.4)	1.6 (0.1)	1.1 (0.0)	0.94 (0.1)	0.94 (0.1)	0.96 (0.1)	15/15
xNESas	1.9 (0.2)	1.5 (0.1)	1.0 (0.1)	0.89 (0.1)	0.89 (0.1)	0.91 (0.1)	15/15

Table 9: 20-D, running time excess $ERT/ERT_{\text{best}} 2009$ on f_8 , in italics is given the median final function value and the median number of function evaluations to reach this value divided by dimension.

Δf_{opt}	1e1	1e0	1e-1	1e-3	1e-5	1e-7	#succ
<i>f8</i>	2039	3871	4040	4219	4371	4484	15/15
ACOR	24(8)	66(114)	72(101)	89(86)	107(84)	125(83)	15/15
BIPOPacCMA	3.3(0.9)	4.0(3)	4.3(3)	4.4(3)	4.4(3)	4.5(3)	15/15
BIPOPsaACM	1.3 (0.2)	1.5 (0.9)	1.5 (0.9)	1.6 (0.8)	1.6 (0.8)	1.6 (0.8)	15/15
CMA	3.7(0.6)	4.4(0.3)	4.7(0.3)	4.9(0.3)	4.9(0.3)	5.0(0.3)	15/15
CMAES	3.9(0.8)	4.3(0.7)	4.7(0.7)	4.8(0.7)	4.9(0.7)	4.9(0.7)	15/15
CMAa	3.6(0.7)	3.5(0.6)	3.8(0.6)	4.0(0.6)	4.0(0.6)	4.0(0.6)	15/15
CMAm	3.9(0.7)	5.0(4)	5.3(4)	5.4(3)	5.4(3)	5.4(3)	15/15
CMAma	3.1(0.6)	4.2(3)	4.4(3)	4.5(3)	4.5(2)	4.5(2)	15/15
CMAmah	2.6 (0.5)	3.4(2)	3.6 (2)	3.7 (2)	3.6 (2)	3.6 (2)	15/15
CMAmh	3.2(1)	4.5(3)	4.7(3)	4.8(3)	4.8(3)	4.8(3)	15/15
DBRCGA	50(40)	150(262)	159(250)	184(239)	213(233)	257(242)	12/15
DE	53(4)	95(6)	106(9)	120(11)	130(11)	138(12)	14/15
DE-AUTO	1.5 (0.4)	4.2(3)	5.2(5)	8.2(5)	9.3(4)	12(5)	15/15
DE-BFGS	1.5 (1)	2.8 (4)	2.8 (4)	3.2 (3)	3.2 (3)	3.2 (3)	15/15
DE-ROLL	6.4(8)	15(16)	20(19)	28(21)	33(20)	129(117)	13/15
DE-SIMPLEX	12(8)	13(8)	15(8)	19(8)	24(10)	81(56)	14/15
DEctpb	52(3)	66(2)	76(2)	89(4)	100(4)	111(4)	15/15
IPOPsaACM	1.4 (0.2)	1.3 (0.1)	1.4 (0.1)	1.4 (0.1)	1.4 (0.1)	1.4 (0.1)	15/15
JADEb	12(4)	14(12)	14(11)	15(11)	16(10)	17(10)	15/15
JADEctpb	18(1)	16(0.6)	16(0.6)	17(0.6)	17(0.7)	18(0.7)	15/15
MVDE	∞	∞	∞	∞	∞	∞ <i>1e6</i>	0/15
NBIPOPacCMA	3.2(0.7)	3.4 (1)	3.6(1)	3.8(1)	3.8(1.0)	3.8(1.0)	15/15
NIPOPacCMA	3.3(0.4)	3.9(2)	4.1(2)	4.2(2)	4.3(2)	4.3(2)	15/15
PSO-BFGS	1.6 (1)	4.1(4)	4.7(5)	6.0(4)	6.3(4)	9.0(12)	15/15
SNES	37(10)	145(138)	299(251)	1107(1152)	1.3e4(1e4)	2.6e4(3e4)	0/15
xNES	7.5(0.8)	6.9(1)	7.5(1)	7.7(1)	8.4(1.0)	10(0.9)	15/15
xNESas	7.2(0.6)	7.9(2)	9.1(3)	9.4(4)	10(4)	10(4)	15/15

Table 10: 20-D, running time excess $ERT/ERT_{\text{best 2009}}$ on f_9 , in italics is given the median final function value and the median number of function evaluations to reach this value divided by dimension.

Δf_{opt}	1e1	1e0	1e-1	1e-3	1e-5	1e-7	#succ
<i>f9</i>	1716	3102	3277	3455	3594	3727	15/15
ACOR	45(7)	78(8)	119(11)	286(31)	473(52)	651(74)	15/15
BIPOPacCMA	3.8(1.0)	4.4(0.6)	4.7(0.6)	4.8(0.5)	4.8(0.5)	4.8(0.5)	15/15
BIPOPsaACM	1.5(0.3)	1.7(0.2)	1.7(0.2)	1.8(0.2)	1.8(0.2)	1.7(0.2)	15/15
CMA	4.7(0.9)	5.1(0.6)	5.4(0.6)	5.6(0.5)	5.6(0.5)	5.6(0.5)	15/15
CMAES	4.5(1)	5.0(0.7)	5.4(0.6)	5.5(0.6)	5.5(0.6)	5.5(0.6)	15/15
CMAa	3.9(0.7)	4.1(0.4)	4.4(0.4)	4.5(0.4)	4.5(0.4)	4.5(0.4)	15/15
CMAm	4.1(1)	5.4(0.7)	5.7(0.6)	5.8(0.6)	5.8(0.6)	5.8(0.6)	15/15
CMAMA	3.4(0.9)	4.1(0.6)	4.3(0.5)	4.4(0.5)	4.4(0.4)	4.4(0.4)	15/15
CMAmah	2.9(0.9)	4.8(3)	4.9(3)	5.0(3)	4.9(3)	4.9(2)	15/15
CMAmh	3.1(2)	4.2(0.9)	4.5(0.9)	4.6(0.9)	4.6(0.8)	4.6(0.8)	15/15
DBRCGA	353(124)	1855(1640)	∞	∞	∞	∞ <i>2e6</i>	0/15
DE	∞	∞	∞	∞	∞	∞ <i>1e6</i>	0/15
DE-AUTO	2.0(0.9)	6.9(5)	8.8(6)	11(5)	11(4)	20(30)	15/15
DE-BFGS	1.8(1)	2.6(2)	2.8(1)	2.7(1)	2.7(1)	2.7(1)	15/15
DE-ROLL	25(16)	44(18)	54(26)	63(23)	83(44)	1299(1470)	1/15
DE-SIMPLEX	24(8)	149(212)	144(198)	140(188)	142(179)	207(294)	13/15
DEctpb	417(90)	∞	∞	∞	∞	∞ <i>1e6</i>	0/15
IPOPsaACM	1.6(0.4)	1.8(1)	1.9(1)	1.9(1)	1.9(1.0)	1.9(1.0)	15/15
JADEb	24(6)	32(24)	33(23)	35(22)	35(21)	36(20)	15/15
JADEctpb	36(3)	30(3)	32(3)	33(2)	33(2)	33(2)	15/15
MVDE	∞	∞	∞	∞	∞	∞ <i>1e6</i>	0/15
NBIPOPacCMA	3.8(0.7)	4.0(0.3)	4.3(0.3)	4.5(0.2)	4.5(0.2)	4.5(0.2)	15/15
NIPOPacCMA	3.9(1)	4.5(0.5)	4.8(0.5)	4.9(0.5)	4.9(0.5)	4.9(0.5)	15/15
PSO-BFGS	1.7(0.7)	4.9(4)	5.7(4)	7.1(5)	6.9(5)	6.9(4)	15/15
SNES	520(442)	1.8e4(2e4)	3.5e4(4e4)	∞	∞	∞ <i>8e6</i>	0/15
xNES	8.9(1)	8.5(1)	9.3(2)	9.4(2)	10(1)	11(1)	15/15
xNESas	8.1(1)	8.9(2)	10(2)	10(2)	11(2)	11(2)	15/15

Table 11: 20-D, running time excess $ERT/ERT_{\text{best 2009}}$ on f_{10} , in italics is given the median final function value and the median number of function evaluations to reach this value divided by dimension.

Δf_{opt}	1e1	1e0	1e-1	1e-3	1e-5	1e-7	#succ
f10	7413	8661	10735	14920	17073	17476	15/15
ACOR	2.0e4(2e4)	∞	∞	∞	∞	∞	0/15
BIPOPacMA	1.2 (0.2)	1.2 (0.2)	1.1 (0.1)	0.83 (0.0) \downarrow_4	0.76 (0.0) \downarrow_4	0.77 (0.0) \downarrow_4	15/15
BIPOPsaACM	0.36 (0.1) \downarrow_4	0.35 (0.0) \downarrow_4	0.31 (0.0) \downarrow_4	0.24 (0.0) \downarrow_4	0.23 (0.0) \downarrow_4	0.23 (0.0) \downarrow_4	15/15
CMA	1.8 (0.3)	1.8 (0.2)	1.6 (0.1)	1.2 (0.1)	1.1 (0.0)	1.1 (0.0)	15/15
CMAES	1.7 (0.1)	1.7 (0.2)	1.6 (0.1)	1.2 (0.0)	1.1 (0.0)	1.1 (0.0)	15/15
CMAa	1.2 (0.2)	1.2 (0.2)	1.0 (0.1)	0.82 (0.0) \downarrow_4	0.75 (0.0) \downarrow_4	0.76 (0.0) \downarrow_4	15/15
CMAm	1.8 (0.2)	1.8 (0.2)	1.6 (0.1)	1.2 (0.0)	1.1 (0.0)	1.1 (0.0)	15/15
CMAma	1.1 (0.2)	1.1 (0.1)	0.98 (0.1)	0.76 (0.0) \downarrow_4	0.70 (0.0) \downarrow_4	0.71 (0.0) \downarrow_4	15/15
CMAmah	1.2 (0.2)	1.2 (0.2)	1.0 (0.1)	0.79 (0.1) \downarrow_4	0.71 (0.0) \downarrow_4	0.71 (0.0) \downarrow_4	15/15
CMAmh	1.6 (0.2)	1.6 (0.2)	1.4 (0.1)	1.1 (0.0)	0.95 (0.0)	0.94 (0.0) \downarrow	15/15
DBRCGA	∞	∞	∞	∞	∞	∞	0/15
DE	∞	∞	∞	∞	∞	∞	0/15
DE-AUTO	1.5 (1)	1.5 (1)	1.8 (2)	2.5 (2)	4.6(2)	17(11)	9/15
DE-BFGS	6.1(6)	5.3(5)	4.3(4)	3.1(3)	2.7 (3)	2.6 (3)	15/15
DE-ROLL	∞	∞	∞	∞	∞	∞	0/15
DE-SIMPLEX	138(105)	817(821)	∞	∞	∞	∞	0/15
DEctpb	∞	∞	∞	∞	∞	∞	0/15
IPOPsaACM	0.35 (0.1) \downarrow_4	0.36 (0.1) \downarrow_4	0.31 (0.0) \downarrow_4	0.24 (0.0) \downarrow_4	0.22 (0.0) \downarrow_4	0.23 (0.0) \downarrow_4	15/15
JADEb	39(17)	54(24)	64(16)	116(73)	862(923)	∞	0/15
JADEctpb	12(5)	15(4)	15(4)	15(4)	15(3)	18(4)	15/15
MVDE	∞	∞	∞	∞	∞	∞	0/15
NBIPOPacMA	1.1 (0.1)	1.1 (0.2)	1.0 (0.1)	0.80 (0.0) \downarrow_4	0.73 (0.0) \downarrow_4	0.75 (0.0) \downarrow_4	15/15
NIPOPacMA	1.2 (0.2)	1.2 (0.1)	1.0 (0.1)	0.81 (0.0) \downarrow_4	0.74 (0.0) \downarrow_4	0.76 (0.0) \downarrow_4	15/15
PSO-BFGS	29(15)	24(12)	20(10)	14(7)	12(6)	12(6)	14/15
SNES	∞	∞	∞	∞	∞	∞	0/15
xNES	1.5 (0.0)	1.6 (0.0)	1.6 (0.0)	1.5 (0.0)	1.7 (0.0)	2.0 (0.0)	15/15
xNESas	1.3 (0.1)	1.4 (0.1)	1.3 (0.1)	1.0 (0.1)	0.99 (0.1)	1.0 (0.1)	15/15

Table 12: 20-D, running time excess $ERT/ERT_{\text{best}} 2009$ on f_{11} , in italics is given the median final function value and the median number of function evaluations to reach this value divided by dimension.

Δf_{opt}	1e1	1e0	1e-1	1e-3	1e-5	1e-7	#succ
f11	1002	2228	6278	9762	12285	14831	15/15
ACOR	1002(53)	1328(2262)	679(810)	995(1040)	1037(1227)	1462(1687)	2/15
BIPOPacMA	4.5(0.3)	2.3 (0.1)	0.87 (0.0)	0.64 (0.0) \downarrow_4	0.56 (0.0) \downarrow_4	0.51 (0.0) \downarrow_4	15/15
BIPOPsaACM	2.5 (0.4)	1.2 (0.2)	0.44 (0.1)	0.30 (0.0) \downarrow_4	0.26 (0.0) \downarrow_4	0.23 (0.0) \downarrow_4	15/15
CMA	10(1.0)	5.1(0.3)	1.9 (0.1)	1.4 (0.0)	1.2 (0.0)	1.0 (0.0)	15/15
CMAES	11(0.8)	5.3(0.2)	2.0 (0.1)	1.4 (0.0)	1.2 (0.0)	1.0 (0.0)	15/15
CMAa	4.5(0.2)	2.2 (0.1)	0.86 (0.0)	0.63 (0.0) \downarrow_4	0.55 (0.0) \downarrow_4	0.50 (0.0) \downarrow_4	15/15
CMAm	11(0.7)	5.4(0.4)	2.0 (0.1)	1.4 (0.1)	1.2 (0.1)	1.1 (0.0)	15/15
CMAma	4.3(0.5)	2.1 (0.2)	0.82 (0.1)	0.59 (0.0) \downarrow_4	0.51 (0.0) \downarrow_4	0.45 (0.0) \downarrow_4	15/15
CMAmah	4.8(0.5)	2.4 (0.2)	0.92 (0.1)	0.66 (0.0) \downarrow_4	0.56 (0.0) \downarrow_4	0.49 (0.0) \downarrow_4	15/15
CMAmh	11(0.9)	5.6(0.3)	2.1 (0.1)	1.5 (0.1)	1.3 (0.0)	1.1 (0.0)	15/15
DBRCGA	431(168)	396(54)	189(21)	165(8)	154(5)	∞ <i>2e6</i>	0/15
DE	7377(8476)	∞	∞	∞	∞	∞ <i>1e6</i>	0/15
DE-AUTO	0.38 (0.5)	0.19 (0.2) \downarrow_3	0.07 (0.1) \downarrow_4	0.06 (0.1) \downarrow_4	0.05 (0.0) \downarrow_4	0.10 (0.0) \downarrow_4	15/15
DE-BFGS	0.20 (0.1) \downarrow_4	0.11 (0.1) \downarrow_4	0.05 (0.0) \downarrow_4	0.04 (0.0) \downarrow_4	0.04 (9e-3) \downarrow_4	0.05 (0.0) \downarrow_4	15/15
DE-ROLL	510(225)	6543(7136)	∞	∞	∞	∞ <i>2e6</i>	0/15
DE-SIMPLEX	90(38)	162(67)	142(53)	1512(1538)	∞	∞ <i>2e6</i>	0/15
DEctpb	∞	∞	∞	∞	∞	∞ <i>1e6</i>	0/15
IPOPsaACM	2.5 (0.5)	1.2 (0.2)	0.45 (0.1)	0.31 (0.1) \downarrow_4	0.26 (0.1) \downarrow_4	0.23 (0.0) \downarrow_4	15/15
JADEb	281(507)	140(229)	54(81)	41(52)	37(42)	35(34)	12/15
JADEctpb	92(19)	46(8)	18(4)	15(3)	15(3)	15(3)	14/15
MVDE	∞	∞	∞	∞	∞	∞ <i>1e6</i>	0/15
NBIPOPacMA	4.6(0.4)	2.3 (0.2)	0.89 (0.1)	0.64 (0.0) \downarrow_4	0.56 (0.0) \downarrow_4	0.51 (0.0) \downarrow_4	15/15
NIPOPacMA	4.5(0.3)	2.3 (0.1)	0.87 (0.0)	0.64 (0.0) \downarrow_4	0.56 (0.0) \downarrow_4	0.50 (0.0) \downarrow_4	15/15
PSO-BFGS	0.25 (0.2) \downarrow_4	0.14 (0.1) \downarrow_4	0.05 (0.0) \downarrow_4	0.04 (0.0) \downarrow_4	0.04 (0.0) \downarrow_4	0.05 (0.0) \downarrow_4	15/15
SNES	1.2e5(1e5)	∞	∞	∞	∞	∞ <i>8e6</i>	0/15
xNES	4.9(0.3)	3.3(0.2)	1.6 (0.1)	1.6 (0.0)	1.8 (0.0)	1.9 (0.0)	15/15
xNESas	4.8(0.3)	3.1(0.2)	1.4 (0.1)	1.1 (0.2)	1.00 (0.2)	0.91 (0.2)	15/15

Table 13: 20-D, running time excess $ERT/ERT_{\text{best}} 2009$ on f_{12} , in italics is given the median final function value and the median number of function evaluations to reach this value divided by dimension.

Δf_{opt}	1e1	1e0	1e-1	1e-3	1e-5	1e-7	#succ
<i>f12</i>	1042	1938	2740	4140	12407	13827	15/15
ACOR	3665(4801)	1.0e4(1e4)	2.4e4(3e4)	∞	∞	∞ <i>1e7</i>	0/15
BIPOPacCMA	3.3(3)	3.6(3)	4.0(2)	3.7(1)	1.5 (0.4)	1.5 (0.4)	15/15
BIPOPsaACM	0.99 (0.9)	1.1 (1)	1.2 (0.9)	1.2 (0.9)	0.55 (0.3) \downarrow	0.59 (0.3) \downarrow ₂	15/15
CMA	3.4(5)	5.4(4)	5.6(3)	5.1(2)	2.1 (0.9)	2.2 (0.9)	15/15
CMAES	2.2 (0.2)	3.2(3)	4.0(3)	4.0(2)	1.8 (0.8)	1.9 (0.7)	15/15
CMAa	2.4 (0.2)	3.4(2)	3.4(2)	3.4(1)	1.4 (0.5)	1.5 (0.5)	15/15
CMAm	3.2(4)	4.1(5)	4.8(5)	4.6(3)	2.0 (1)	2.1 (1.0)	15/15
CMAMA	2.3 (2)	3.1(3)	3.2(2)	3.1(1)	1.3 (0.5)	1.4 (0.5)	15/15
CMAmah	1.2 (1)	2.1 (2)	2.6 (2)	2.5 (1)	1.1 (0.4)	1.1 (0.3)	15/15
CMAmh	4.5(5)	6.1(6)	6.4(5)	5.6(3)	2.4 (1)	2.4 (1)	15/15
DBRCGA	185(16)	1209(1550)	1.0e4(1e4)	∞	∞	∞ <i>2e6</i>	0/15
DE	99(6)	478(538)	1497(1825)	∞	∞	∞ <i>1e6</i>	0/15
DE-AUTO	2.2 (2)	2.3 (3)	2.9 (3)	4.4(4)	4.5(2)	39(49)	7/15
DE-BFGS	1.4 (0.8)	1.4 (1)	1.6 (1)	1.7 (1)	1.1 (0.6)	4.6(4)	15/15
DE-ROLL	21(35)	18(24)	18(17)	27(20)	25(20)	100(100)	6/15
DE-SIMPLEX	34(31)	30(23)	28(17)	31(17)	21(17)	621(724)	0/15
Dectpb	194(208)	406(392)	1276(1306)	∞	∞	∞ <i>1e6</i>	0/15
IPOPsaACM	0.67 (0.1)	0.88 (0.7)	1.1 (0.7)	1.2 (0.5)	0.56 (0.2) \downarrow ₂	0.60 (0.2) \downarrow ₂	15/15
JADEb	23(24)	34(30)	40(29)	39(17)	17(6)	18(5)	15/15
JADEctpb	19(4)	20(15)	28(15)	28(10)	13(3)	14(3)	15/15
MVDE	108(31)	272(275)	528(582)	∞	∞	∞ <i>1e6</i>	0/15
NBIPOPacCMA	2.3 (0.2)	2.7 (2)	3.2(2)	3.2(1)	1.3 (0.5)	1.4 (0.5)	15/15
NIPOPacCMA	3.5(3)	3.6(3)	3.5(2)	3.4(1)	1.4 (0.4)	1.4 (0.4)	15/15
PSO-BFGS	2.2 (2)	2.3 (2)	2.3 (2)	3.7(3)	5.0(4)	21(24)	13/15
SNES	23(38)	37(41)	122(57)	3134(3400)	∞	∞ <i>8e6</i>	0/15
xNES	16(0.5)	11(0.4)	9.3(1)	8.3(0.8)	3.5(0.2)	3.6(0.2)	15/15
xNESas	6.6(4)	16(8)	18(18)	35(38)	21(21)	22(21)	15/15

Table 14: 20-D, running time excess $ERT/ERT_{\text{best } 2009}$ on f_{13} , in italics is given the median final function value and the median number of function evaluations to reach this value divided by dimension.

Δf_{opt}	1e1	1e0	1e-1	1e-3	1e-5	1e-7	#succ
f13	652	2021	2751	18749	24455	30201	15/15
ACOR	1.8e4(2e4)	3.2e4(4e4)	5.1e4(6e4)	∞	∞	∞ 1e7	0/15
BIPOPacCMA	4.1(3)	3.3(3)	3.7(3)	0.85 (0.4)	1.1 (0.8)	1.4 (0.6)	15/15
BIPOPsaACM	1.1 (0.9)	0.89 (0.7)	1.4 (1.0)	0.38 (0.1) \downarrow_4	0.42 (0.2) \downarrow_4	0.40 (0.1) \downarrow_4	15/15
CMA	2.5 (0.4)	5.1(4)	7.5(6)	1.7 (1)	1.9 (0.9)	2.0 (1)	15/15
CMAES	6.3(5)	5.1(3)	4.5(3)	1.9 (2)	4.6(5)	8.4(9)	12/15
CMAa	2.4 (0.3)	3.5(3)	4.5(3)	1.1 (0.8)	1.2 (0.7)	1.5 (1.0)	15/15
CMAm	3.1(4)	3.2(4)	6.2(4)	1.7 (1)	2.4 (0.9)	2.4 (0.7)	15/15
CMAMA	2.9 (3)	3.5(3)	4.4(2)	0.94 (0.4)	1.1 (0.5)	1.5 (1)	15/15
CMAmah	3.6(3)	3.3(4)	4.2(3)	1.3 (0.4)	1.4 (0.6)	1.8 (0.9)	15/15
CMAmh	3.7(3)	5.1(5)	6.4(6)	1.8 (0.7)	2.4 (1.0)	2.7 (0.7)	15/15
DBRCGA	183(295)	398(495)	2064(2545)	∞	∞	∞ 2e6	0/15
DE	41(7)	214(306)	702(845)	∞	∞	∞ 1e6	0/15
DE-AUTO	1.8 (0.5)	0.91 (0.4)	0.95 (0.3)	0.70 (0.6)	4.5(3)	32(35)	7/15
DE-BFGS	1.3 (0.1)	0.59 (0.1) \downarrow_4	0.53 (0.0) \downarrow_4	0.18 (0.2) \downarrow_4	92(123)	∞ 2e6	0/15
DE-ROLL	24(15)	18(20)	17(15)	5.8(4)	24(16)	289(321)	1/15
DE-SIMPLEX	28(17)	15(7)	16(6)	9.0(6)	195(227)	∞ 2e6	0/15
Dectpb	50(8)	103(76)	607(559)	∞	∞	∞ 1e6	0/15
IPOPsaACM	1.7 (2)	1.7 (0.8)	1.5 (0.7)	0.34 (0.2) \downarrow_4	0.37 (0.1) \downarrow_4	0.41 (0.2) \downarrow_4	15/15
JADEb	61(53)	91(112)	175(194)	795(827)	∞	∞ 1e6	0/15
JADEctpb	17(2)	14(5)	15(4)	3.6(0.6)	4.8(0.8)	9.0(2)	15/15
MVDE	68(5)	297(495)	2523(3019)	∞	∞	∞ 1e6	0/15
NBIPOPacCMA	3.3(3)	2.6 (2)	3.7(3)	1.1 (1.0)	1.2 (0.6)	1.3 (0.8)	15/15
NIPOPacCMA	3.3(3)	3.7(3)	4.1(2)	0.95 (0.3)	1.1 (0.4)	1.5 (0.5)	15/15
PSO-BFGS	1.2 (0.1)	0.56 (0.0) \downarrow_4	0.51 (0.0) \downarrow_4	0.21 (0.1) \downarrow_4	133(167)	∞ 2e6	0/15
SNES	11(0.5)	54(59)	153(139)	140(126)	796(784)	∞ 7e6	0/15
xNES	16(0.5)	7.8(0.2)	7.9(0.2)	1.8 (0.0)	1.8 (0.0)	1.9 (0.0)	15/15
xNESas	7.0(3)	4.6(3)	19(28)	17(21)	40(33)	81(83)	0/15

Table 15: 20-D, running time excess $ERT/ERT_{\text{best } 2009}$ on f_{14} , in italics is given the median final function value and the median number of function evaluations to reach this value divided by dimension.

Δf_{opt}	1e1	1e0	1e-1	1e-3	1e-5	1e-7	#succ
f14	75	239	304	932	1648	15661	15/15
ACOR	15(4)	9.5(2)	11(2)	30(8)	∞	∞ <i>1e7</i>	0/15
BIPOPacMA	3.2(1)	2.6 (0.5)	3.3(0.4)	3.2(0.3)	3.8(0.2)	0.68 (0.0) \downarrow_4	15/15
BIPOPsaACM	3.2(1)	1.8 (0.6)	1.9 (0.4)	1.5 (0.2)	1.4 (0.2)	0.23 (0.0) \downarrow_4	15/15
CMA	4.5(2)	2.9 (0.6)	3.7(0.5)	4.1(0.4)	6.1(0.5)	1.2 (0.1)	15/15
CMAES	4.2(1)	3.0 (0.5)	3.7(0.4)	4.2(0.3)	6.2(0.5)	1.2 (0.1)	15/15
CMAa	3.8(1)	2.7 (0.3)	3.5(0.5)	3.1(0.2)	3.9(0.2)	0.69 (0.0) \downarrow_4	15/15
CMAm	2.9 (1)	2.3 (0.4)	2.8 (0.3)	3.7(0.4)	6.3(0.6)	1.2 (0.1)	15/15
CMAma	3.3(1)	2.3 (0.4)	2.8 (0.4)	2.9 (0.3)	3.7(0.3)	0.65 (0.0) \downarrow_4	15/15
CMAmah	2.0 (0.6)	1.5 (0.3)	1.9 (0.3)	2.3 (0.3)	3.4(0.4)	0.66 (0.0) \downarrow_4	15/15
CMAmh	2.3 (1)	1.6 (0.4)	1.9 (0.3)	2.8 (0.3)	5.7(0.7)	1.2 (0.1)	15/15
DBRCGA	32(9)	45(10)	67(12)	92(18)	1640(1210)	∞ <i>2e6</i>	0/15
DE	55(19)	46(6)	53(6)	502(176)	∞	∞ <i>1e6</i>	0/15
DE-AUTO	2.0 (0.3)	0.92 (0.1)	0.93 (0.1)	0.58 (0.0) \downarrow_4	0.91 (0.0) \downarrow_3	62(91)	0/15
DE-BFGS	1.7 (0.4)	0.84 (0.1)	0.90 (0.2)	0.62 (0.1) \downarrow_4	0.56 (0.1) \downarrow_4	125(150)	0/15
DE-ROLL	7.4(14)	18(21)	17(16)	33(7)	3481(3152)	∞ <i>2e6</i>	0/15
DE-SIMPLEX	12(10)	40(32)	53(17)	30(9)	122(52)	∞ <i>2e6</i>	0/15
DEctpb	57(23)	47(8)	57(10)	814(261)	∞	∞ <i>1e6</i>	0/15
IPOPsaACM	3.0(0.6)	1.8 (0.3)	1.9 (0.4)	1.4 (0.2)	1.4 (0.1)	0.23 (0.0) \downarrow_4	15/15
JADEb	14(4)	13(2)	18(2)	21(3)	77(30)	∞ <i>1e6</i>	0/15
JADEctpb	18(6)	18(1)	23(2)	20(1)	38(24)	62(77)	5/15
MVDE	57(10)	60(6)	78(4)	1465(1263)	∞	∞ <i>1e6</i>	0/15
NBIPOPacMA	4.3(1)	3.0 (0.5)	3.7(0.7)	3.2(0.5)	3.9(0.4)	0.67 (0.1) \downarrow_4	15/15
NIPOPacMA	4.3(1)	2.8 (0.6)	3.5(0.7)	3.3(0.3)	3.9(0.3)	0.69 (0.0) \downarrow_4	15/15
PSO-BFGS	1.7 (0.6)	0.85 (0.1)	0.98 (0.2)	0.63 (0.1) \downarrow_4	0.57 (0.1) \downarrow_4	892(978)	0/15
SNES	2.6 (0.9)	2.4 (0.4)	3.9(0.4)	8.5(4)	∞	∞ <i>8e6</i>	0/15
xNES	2.4 (1.0)	7.9(1)	19(0.7)	14(0.4)	12(0.3)	1.7 (0.0)	15/15
xNESas	2.6 (0.8)	7.6(1)	14(3)	12(1)	10(1)	1.5 (0.1)	15/15

Table 16: 20-D, running time excess $ERT/ERT_{\text{best 2009}}$ on f_{15} , in italics is given the median final function value and the median number of function evaluations to reach this value divided by dimension.

Δf_{opt}	1e1	1e0	1e-1	1e-3	1e-5	1e-7	#succ
f15	30378	1.5e5	3.1e5	3.2e5	4.5e5	4.6e5	15/15
ACOR	919(1153)	∞	∞	∞	∞	∞ <i>1e7</i>	0/15
BIPOPacMA	0.88 (0.4)	1.6 (0.6)	1.2 (0.6)	1.2 (0.6)	0.89 (0.5)	0.89 (0.4)	15/15
BIPOPsaACM	0.65 (0.6)	1.3 (0.6)	0.91 (0.7)	0.89 (0.6)	0.66 (0.5)	0.65 (0.5)	15/15
CMA	0.98 (0.7)	0.98 (0.4)	0.76 (0.2)	0.77 (0.2)	0.57 (0.2) \downarrow	0.58 (0.2) \downarrow	15/15
CMAES	37(36)	∞	∞	∞	∞	∞ <i>1e6</i>	0/15
CMAa	0.90 (0.5)	1.0 (0.3)	0.60 (0.3)	0.61 (0.3)	0.45 (0.2) \downarrow_3	0.46 (0.3) \downarrow_3	15/15
CMAm	0.81 (0.6)	1.1 (0.3)	0.69 (0.3)	0.70 (0.3)	0.52 (0.3) \downarrow_2	0.53 (0.3) \downarrow_2	15/15
CMAma	0.62 (0.2) \downarrow_3	0.98 (0.3)	0.65 (0.3)	0.67 (0.3)	0.49 (0.2) \downarrow_3	0.50 (0.2) \downarrow_3	15/15
CMAmah	0.92 (0.6)	1.2 (0.6)	0.64 (0.3)	0.65 (0.3)	0.48 (0.2) \downarrow_3	0.49 (0.2) \downarrow_3	15/15
CMAmh	0.98 (0.6)	1.1 (0.3)	0.66 (0.3)	0.67 (0.3)	0.50 (0.3) \downarrow_2	0.50 (0.3) \downarrow_2	15/15
DBRCGA	∞	∞	∞	∞	∞	∞ <i>2e6</i>	0/15
DE	∞	∞	∞	∞	∞	∞ <i>1e6</i>	0/15
DE-AUTO	59(46)	∞	∞	∞	∞	∞ <i>2e6</i>	0/15
DE-BFGS	28(15)	∞	∞	∞	∞	∞ <i>2e6</i>	0/15
DE-ROLL	32(19)	∞	∞	∞	∞	∞ <i>2e6</i>	0/15
DE-SIMPLEX	25(11)	∞	∞	∞	∞	∞ <i>2e6</i>	0/15
DEctpb	∞	∞	∞	∞	∞	∞ <i>1e6</i>	0/15
IPOPsaACM	0.60 (0.5)	0.92 (0.7)	0.53 (0.4)	0.52 (0.4)	0.37 (0.3) \downarrow_4	0.37 (0.3) \downarrow_4	15/15
JADEb	∞	∞	∞	∞	∞	∞ <i>1e6</i>	0/15
JADEctpb	39(35)	∞	∞	∞	∞	∞ <i>1e6</i>	0/15
MVDE	∞	∞	∞	∞	∞	∞ <i>1e6</i>	0/15
NBIPOPacMA	1.2 (0.9)	1.2 (0.5)	0.79 (0.5)	0.79 (0.5)	0.58 (0.4) \downarrow	0.59 (0.4) \downarrow	15/15
NIPOPacMA	0.81 (0.3)	0.99 (0.3)	0.67 (0.3)	0.68 (0.3)	0.50 (0.3) \downarrow_2	0.51 (0.3) \downarrow_2	15/15
PSO-BFGS	∞	∞	∞	∞	∞	∞ <i>2e6</i>	0/15
SNES	49(76)	∞	∞	∞	∞	∞ <i>8e6</i>	0/15
xNES	43(41)	∞	∞	∞	∞	∞ <i>7e6</i>	0/15
xNESas	44(52)	∞	∞	∞	∞	∞ <i>2e7</i>	0/15

Table 17: 20-D, running time excess $ERT/ERT_{\text{best 2009}}$ on f_{16} , in italics is given the median final function value and the median number of function evaluations to reach this value divided by dimension.

Δf_{opt}	1e1	1e0	1e-1	1e-3	1e-5	1e-7	#succ
f16	1384	27265	77015	1.9e5	2.0e5	2.2e5	15/15
ACOR	1.0e5(1e5)	∞	∞	∞	∞	∞ <i>1e7</i>	0/15
BIPOPacMA	1.7 (0.6)	0.87 (0.5)	0.78 (0.5)	0.92 (0.4)	1.2 (0.8)	1.1 (0.8)	15/15
BIPOPsaACM	1.9 (0.6)	0.74 (0.4)	0.51 (0.3)	0.60 (0.5)	0.84 (0.5)	0.83 (0.5)	15/15
CMA	1.8 (1)	1.1 (0.4)	0.82 (0.7)	1.1 (0.9)	1.2 (0.9)	1.1 (0.8)	15/15
CMAES	1.9 (0.8)	2.7 (2)	∞	∞	∞	∞ <i>1e6</i>	0/15
CMAa	1.9 (0.6)	0.76 (0.3)	0.83 (0.7)	0.81 (0.5)	1.00 (0.9)	0.95 (0.8)	15/15
CMAm	1.3 (0.6)	0.85 (0.5)	1.3 (1)	1.4 (1)	1.4 (1)	1.3 (1)	15/15
CMAma	2.2 (3)	0.63 (0.6)	0.84 (0.6)	0.76 (0.6)	0.85 (0.9)	0.79 (0.9)	15/15
CMAmah	2.3 (3)	0.91 (0.5)	0.90 (0.6)	0.92 (0.5)	1.3 (1)	1.2 (0.9)	15/15
CMAmh	3.0 (3)	1.1 (0.6)	1.1 (0.7)	1.0 (0.8)	1.1 (0.8)	1.0 (0.8)	15/15
DBRCGA	118(162)	∞	∞	∞	∞	∞ <i>2e6</i>	0/15
DE	∞	∞	∞	∞	∞	∞ <i>1e6</i>	0/15
DE-AUTO	40(46)	∞	∞	∞	∞	∞ <i>2e6</i>	0/15
DE-BFGS	595(508)	242(257)	∞	∞	∞	∞ <i>2e6</i>	0/15
DE-ROLL	20(18)	1093(1101)	∞	∞	∞	∞ <i>2e6</i>	0/15
DE-SIMPLEX	54(37)	∞	∞	∞	∞	∞ <i>2e6</i>	0/15
DEctpb	∞	∞	∞	∞	∞	∞ <i>1e6</i>	0/15
IPOPsaACM	1.8 (0.8)	0.55 (0.4)	0.77 (0.8)	0.52 (0.4)	0.55 (0.4)	0.50 (0.3) \downarrow	15/15
JADEb	60(42)	∞	∞	∞	∞	∞ <i>1e6</i>	0/15
JADEctpb	24(8)	∞	∞	∞	∞	∞ <i>1e6</i>	0/15
MVDE	1353(1596)	∞	∞	∞	∞	∞ <i>1e6</i>	0/15
NBIPOPacMA	2.6 (2)	0.80 (0.4)	0.51 (0.2) \downarrow	0.42 (0.2) \downarrow	0.43 (0.2) \downarrow	0.41 (0.2) \downarrow	15/15
NIPOPacMA	2.0 (0.9)	0.57 (0.3)	0.41 (0.3) \downarrow	0.38 (0.1) \downarrow ₃	0.39 (0.1) \downarrow ₂	0.37 (0.1) \downarrow ₂	15/15
PSO-BFGS	542(550)	∞	∞	∞	∞	∞ <i>2e6</i>	0/15
SNES	2.7 (1)	11(15)	157(133)	∞	∞	∞ <i>8e6</i>	0/15
xNES	17(8)	2.3 (2)	15(13)	48(54)	56(70)	50(52)	7/15
xNESas	20(10)	4.2(5)	9.2(7)	108(119)	133(158)	119(141)	6/15

Table 18: 20-D, running time excess $ERT/ERT_{\text{best 2009}}$ on f_{17} , in italics is given the median final function value and the median number of function evaluations to reach this value divided by dimension.

Δf_{opt}	1e1	1e0	1e-1	1e-3	1e-5	1e-7	#succ
<i>f17</i>	63	1030	4005	30677	56288	80472	15/15
ACOR	12(8)	4.5(1)	269(447)	4564(5379)	∞	∞ <i>1e7</i>	0/15
BIPOPacMA	3.0 (1)	1.1 (0.3)	1.7 (2)	1.0 (0.4)	0.90 (0.5)	1.1 (0.4)	15/15
BIPOPsaACM	3.2(2)	1.2 (0.4)	2.7 (3)	1.2 (0.7)	1.2 (0.5)	1.4 (0.8)	15/15
CMA	2.2 (1)	1.00 (0.3)	1.5 (2)	0.81 (0.3)	0.93 (0.4)	0.91 (0.3)	15/15
CMAES	2.8 (2)	0.96 (0.4)	1.5 (2)	8.1(8)	∞	∞ <i>1e6</i>	0/15
CMAa	2.3 (1)	0.87 (0.2)	0.52 (0.2)	0.70 (0.3)	0.80 (0.4)	0.92 (0.2)	15/15
CMAm	2.2 (0.5)	0.82 (0.3)	1.4 (1)	0.59 (0.3) \downarrow 2	0.82 (0.4)	0.92 (0.1)	15/15
CMAma	2.2 (2)	0.86 (0.2)	1.4 (2)	0.70 (0.3)	0.79 (0.3) \downarrow	0.82 (0.2) \downarrow	15/15
CMAmah	2.0 (1)	8.8(10)	4.0(2)	0.92 (0.4)	0.96 (0.4)	0.94 (0.3)	15/15
CMAmh	1.8 (0.8)	22(28)	7.7(6)	1.4 (0.8)	1.3 (0.7)	1.3 (0.6)	15/15
DBRCGA	18(9)	2347(2992)	∞	∞	∞	∞ <i>2e6</i>	0/15
DE	26(19)	16(4)	13(4)	8.8(9)	∞	∞ <i>1e6</i>	0/15
DE-AUTO	48(68)	335(185)	529(507)	∞	∞	∞ <i>2e6</i>	0/15
DE-BFGS	17(19)	117(48)	327(297)	952(1077)	∞	∞ <i>2e6</i>	0/15
DE-ROLL	15(17)	358(276)	535(572)	∞	∞	∞ <i>2e6</i>	0/15
DE-SIMPLEX	34(40)	381(238)	2127(2525)	∞	∞	∞ <i>2e6</i>	0/15
DEctpb	16(12)	17(3)	11(1)	4.3(0.6)	63(62)	183(193)	1/15
IPOPsaACM	2.5 (2)	0.91 (0.3)	0.98 (1)	1.2 (0.5)	1.2 (0.4)	1.1 (0.5)	15/15
JADEb	9.3(6)	14(12)	85(138)	466(570)	∞	∞ <i>1e6</i>	0/15
JADEctpb	7.8(5)	7.4(1)	4.4(0.7)	1.7 (0.5)	7.2(9)	23(25)	2/15
MVDE	19(14)	29(5)	24(5)	34(34)	∞	∞ <i>1e6</i>	0/15
NBIPOPacMA	2.6 (1)	1.00 (0.2)	0.77 (0.3)	1.2 (0.5)	1.4 (0.8)	1.2 (0.7)	15/15
NIPOPacMA	2.5 (1)	1.1 (0.3)	1.9 (2)	0.79 (0.4)	0.88 (0.3)	0.81 (0.2)	15/15
PSO-BFGS	19(15)	1652(1526)	∞	∞	∞	∞ <i>2e6</i>	0/15
SNES	2.0 (1)	1.0 (0.3)	5.9(10)	3.9(5)	239(237)	∞ <i>8e6</i>	0/15
xNES	1.9 (1)	3.6(0.6)	3.0 (0.1)	0.94 (0.0)	2.7 (3)	12(14)	15/15
xNESas	2.1 (1.0)	3.5(0.4)	2.9 (0.2)	0.92 (0.0)	1.4 (0.7)	12(9)	15/15

Table 19: 20-D, running time excess $ERT/ERT_{\text{best } 2009}$ on f_{18} , in italics is given the median final function value and the median number of function evaluations to reach this value divided by dimension.

Δf_{opt}	1e1	1e0	1e-1	1e-3	1e-5	1e-7	#succ
f18	621	3972	19561	67569	1.3e5	1.5e5	15/15
ACOR	4.7(2)	3.5(1)	493(767)	∞	∞	∞ <i>1e7</i>	0/15
BIPOPacMA	0.94 (0.2)	0.77 (0.1)	1.5 (0.7)	1.4 (0.5)	1.2 (0.7)	1.5 (0.7)	15/15
BIPOPsaACM	1.0 (0.3)	1.5 (1)	0.92 (0.4)	0.96 (0.4)	1.6 (0.6)	1.6 (0.5)	15/15
CMA	0.96 (0.2)	0.70 (0.4)	0.89 (0.7)	0.98 (0.3)	1.1 (0.8)	1.1 (0.8)	15/15
CMAES	1.1 (0.4)	2.0 (2)	4.2(5)	∞	∞	∞ <i>1e6</i>	0/15
CMAa	0.96 (0.3)	0.96 (2)	0.96 (0.9)	0.79 (0.3)	0.85 (0.4)	0.87 (0.3)	15/15
CMAm	0.81 (0.3)	1.0 (1)	0.61 (0.7)	0.89 (0.3)	0.97 (0.3)	0.95 (0.3)	15/15
CMAma	0.85 (0.2)	0.57 (0.3)	0.78 (0.7)	0.68 (0.2)	0.77 (0.4)	0.74 (0.3)	15/15
CMAmah	0.95 (0.5)	2.5 (2)	1.2 (0.7)	0.79 (0.3)	0.88 (0.4)	0.91 (0.3)	15/15
CMAmh	3.3(8)	3.4(2)	1.2 (0.7)	1.1 (0.7)	1.1 (0.3)	1.1 (0.3)	15/15
DBRCGA	13(6)	7528(8309)	∞	∞	∞	∞ <i>2e6</i>	0/15
DE	17(4)	16(5)	15(7)	∞	∞	∞ <i>1e6</i>	0/15
DE-AUTO	131(69)	416(351)	∞	∞	∞	∞ <i>2e6</i>	0/15
DE-BFGS	69(61)	350(340)	1503(1587)	∞	∞	∞ <i>2e6</i>	0/15
DE-ROLL	87(28)	518(756)	1470(1740)	∞	∞	∞ <i>2e6</i>	0/15
DE-SIMPLEX	115(81)	1124(1284)	1462(1663)	∞	∞	∞ <i>2e6</i>	0/15
DEctpb	17(5)	14(4)	7.8(2)	50(54)	∞	∞ <i>1e6</i>	0/15
IPOPsaACM	0.96 (0.5)	1.4 (2)	0.91 (0.6)	0.78 (0.5)	0.88 (0.4)	1.3 (0.8)	15/15
JADEb	6.3(3)	13(15)	127(146)	∞	∞	∞ <i>1e6</i>	0/15
JADEctpb	7.2(2)	4.4(1)	1.5 (0.4)	19(22)	∞	∞ <i>1e6</i>	0/15
MVDE	23(4)	37(18)	133(136)	∞	∞	∞ <i>1e6</i>	0/15
NBIPOPacMA	1.0 (0.3)	1.4 (2)	1.4 (0.8)	1.2 (0.7)	0.97 (0.3)	0.92 (0.3)	15/15
NIPOPacMA	1.0 (0.3)	0.76 (0.1)	0.79 (0.4)	0.88 (0.3)	0.85 (0.4)	0.84 (0.3)	15/15
PSO-BFGS	210(159)	7505(7562)	∞	∞	∞	∞ <i>2e6</i>	0/15
SNES	1.0 (0.4)	2.0 (0.4)	6.3(4)	547(594)	∞	∞ <i>8e6</i>	0/15
xNES	1.3 (0.6)	2.0 (0.2)	0.84 (0.0) _{↓2}	0.50 (0.0) _{↓4}	1.3 (2)	11(14)	15/15
xNESas	1.2 (0.5)	1.9 (0.1)	0.81 (0.0) _{↓3}	0.48 (0.0) _{↓4}	0.58 (0.3)	5.6(6)	15/15

Table 20: 20-D, running time excess $ERT/ERT_{\text{best}} 2009$ on f_{19} , in italics is given the median final function value and the median number of function evaluations to reach this value divided by dimension.

Δf_{opt}	1e1	1e0	1e-1	1e-3	1e-5	1e-7	#succ
f19	1	1	3.4e5	6.2e6	6.7e6	6.7e6	15/15
ACOR	686(252)	∞	∞	∞	∞	∞ <i>1e7</i>	0/15
BIPOPacCMA	184(66)	2.9e4(2e4)	1.4 (1)	1.0 (0.4)	1.0 (0.4)	1.0 (0.4)	15/15
BIPOPsaACM	143(52)	2.5e4 (1e4)	0.42 (0.3)	0.72 (0.4) \downarrow	0.73 (0.4)	0.73 (0.4)	15/15
CMA	170(56)	3.1e4(3e4)	2.0 (3)	0.94 (0.7)	1.7 (2)	1.7 (1)	5/15
CMAES	162(70)	4.8e4(4e4)	∞	∞	∞	∞ <i>1e6</i>	0/15
CMAa	156(72)	7.7e4(1e4)	2.5 (4)	0.73 (0.5)	0.88 (0.9)	0.88 (0.7)	8/15
CMAm	134(58)	1.8e4 (1e4)	1.1 (0.6)	2.3 (2)	2.9 (3)	2.8 (3)	3/15
CMAMA	135(44)	4.2e4(3e4)	3.2(4)	1.0 (0.9)	1.6 (2)	2.1 (2)	4/15
CMAmah	95 (46)	8.5e4(2e5)	2.5 (4)	0.91 (0.8)	1.3 (1)	1.3 (1)	6/15
CMAmh	82 (52)	2.4e4 (3e4)	3.3(4)	1.8 (2)	2.9 (3)	2.8 (3)	3/15
DBRCGA	975(165)	6.9e5(8e5)	∞	∞	∞	∞ <i>2e6</i>	0/15
DE	2739(802)	∞	∞	∞	∞	∞ <i>1e6</i>	0/15
DE-AUTO	2751(2816)	1.1e5(8e4)	87(98)	∞	∞	∞ <i>2e6</i>	0/15
DE-BFGS	3206(3658)	3.8e4(2e4)	5.4(6)	∞	∞	∞ <i>2e6</i>	0/15
DE-ROLL	3941(5048)	2.2e5(3e5)	∞	∞	∞	∞ <i>2e6</i>	0/15
DE-SIMPLEX	8348(6218)	1.5e5(5e4)	∞	∞	∞	∞ <i>2e6</i>	0/15
DEctpb	2148(731)	∞	∞	∞	∞	∞ <i>1e6</i>	0/15
IPOPsaACM	154(50)	3.0e4(2e4)	0.61 (0.5)	0.33 (0.1)	0.32 (0.2)	0.32 (0.2)	14/15
JADEb	826(254)	3.1e6(4e6)	∞	∞	∞	∞ <i>1e6</i>	0/15
JADEctpb	856(206)	7.0e5(6e5)	∞	∞	∞	∞ <i>1e6</i>	0/15
MVDE	2928(795)	∞	∞	∞	∞	∞ <i>1e6</i>	0/15
NBIPOPacCMA	180(56)	2.9e4(2e4)	0.98 (0.9)	0.69 (0.3) \downarrow	0.64 (0.3) $\downarrow 2$	0.65 (0.3) $\downarrow 2$	15/15
NIPOPacCMA	169(62)	2.8e4 (2e4)	1.7 (2)	0.59 (0.4) $\downarrow 2$	0.56 (0.3) $\downarrow 2$	0.56 (0.3) $\downarrow 2$	15/15
PSO-BFGS	3614(6276)	3.5e4(1e4)	1.4 (1)	∞	∞	∞ <i>2e6</i>	0/15
SNES	118(40)	1.3e5(1e5)	∞	∞	∞	∞ <i>8e6</i>	0/15
xNES	105 (59)	∞	∞	∞	∞	∞ <i>6e6</i>	0/15
xNESas	108 (35)	∞	∞	∞	∞	∞ <i>1e7</i>	0/15

Table 21: 20-D, running time excess $ERT/ERT_{\text{best } 2009}$ on f_{20} , in italics is given the median final function value and the median number of function evaluations to reach this value divided by dimension.

Δf_{opt}	1e1	1e0	1e-1	1e-3	1e-5	1e-7	#succ
f20	82	46150	3.1e6	5.5e6	5.6e6	5.6e6	14/15
ACOR	16(4)	1.6 (1)	24(24)	27(27)	26(28)	26(28)	1/15
BIPOPacMA	4.9(1)	4.8(2)	1.4 (0.6)	0.95 (0.3)	0.95 (0.3)	0.95 (0.3)	15/15
BIPOPsaACM	2.9 (0.5)	2.1 (1)	0.97 (0.7)	0.87 (0.4)	0.86 (0.4)	0.85 (0.4)	15/15
CMA	4.8(1)	5.4(2)	0.79 (0.4)	1.2 (1)	1.2 (1)	1.2 (1)	6/15
CMAES	5.2(1)	156(163)	∞	∞	∞	∞ <i>1e6</i>	0/15
CMAa	4.8(1)	3.2(1)	0.90 (0.4)	1.1 (1)	1.1 (1)	1.7 (2)	5/15
CMAm	3.4(0.7)	5.4(3)	1.1 (0.7)	1.4 (1)	2.0 (2)	3.3(4)	3/15
CMama	3.9(0.7)	3.0 (1)	1.1 (0.7)	5.0(5)	5.0(5)	4.9(5)	2/15
CMAmah	2.5 (0.8)	3.4(1)	0.87 (0.4)	2.4 (3)	3.2(4)	3.2(3)	3/15
CMAmh	2.6 (0.8)	6.1(3)	1.3 (1)	10(12)	10(11)	10(11)	1/15
DBRCGA	34(6)	148(130)	∞	∞	∞	∞ <i>2e6</i>	0/15
DE	51(9)	2.4 (1)	0.79 (0.9)	∞	∞	∞ <i>1e6</i>	0/15
DE-AUTO	2.1 (0.5)	3.4(2)	∞	∞	∞	∞ <i>2e6</i>	0/15
DE-BFGS	6.3(4)	1.0 (1.0)	∞	∞	∞	∞ <i>2e6</i>	0/15
DE-ROLL	21(18)	0.84 (0.8)	4.4(5)	5.3(6)	5.3(6)	5.2(6)	1/15
DE-SIMPLEX	21(27)	3.6(3)	∞	∞	∞	∞ <i>2e6</i>	0/15
DEctpb	56(8)	104(108)	4.8(5)	2.7 (3)	2.7 (3)	2.7 (3)	1/15
IPOPsaACM	2.8 (0.5)	1.7 (0.8)	0.49 (0.2) \downarrow 3	0.45 (0.2) \downarrow	0.45 (0.2) \downarrow	0.45 (0.2) \downarrow	15/15
JADEb	19(3)	0.56 (0.6)	∞	∞	∞	∞ <i>1e6</i>	0/15
JADEctpb	24(3)	1.2 (0.2)	0.46 (0.4)	0.85 (0.8)	2.7 (3)	∞ <i>1e6</i>	0/15
MVDE	83(11)	4.3(1)	0.26 (0.2)	0.31 (0.3)	0.36 (0.4)	0.36 (0.4)	6/15
NBIPOPacMA	4.3(0.7)	4.6(2)	1.1 (0.5)	0.98 (0.6)	0.98 (0.6)	0.98 (0.6)	15/15
NIPOPacMA	4.5(1)	3.1(1)	0.73 (0.3)	0.59 (0.2)	0.60 (0.2)	0.60 (0.2)	15/15
PSO-BFGS	7.1(1)	0.87 (1)	∞	∞	∞	∞ <i>2e6</i>	0/15
SNES	3.1(0.9)	18(19)	∞	∞	∞	∞ <i>7e6</i>	0/15
xNES	5.6(2)	1.1 (0.9)	∞	∞	∞	∞ <i>6e6</i>	0/15
xNESas	5.4(3)	1.1 (0.7)	∞	∞	∞	∞ <i>1e7</i>	0/15

Table 22: 20-D, running time excess $ERT/ERT_{\text{best } 2009}$ on f_{21} , in italics is given the median final function value and the median number of function evaluations to reach this value divided by dimension.

Δf_{opt}	1e1	1e0	1e-1	1e-3	1e-5	1e-7	#succ
f21	561	6541	14103	14643	15567	17589	15/15
ACOR	2743(8907)	9938(1e4)	9927(1e4)	9561(1e4)	8994(9957)	7960(9665)	1/15
BIPOPacMA	7.8(12)	110(57)	72(89)	69(86)	65(81)	58(71)	15/15
BIPOPsaACM	2.6 (4)	1.5 (1)	6.0 (11)	5.8 (11)	5.5 (10)	4.8 (9)	15/15
CMA	5.0(5)	122(182)	57(85)	55(81)	52(76)	46(68)	9/15
CMAES	5.4(4)	9.4 (10)	5.5 (6)	5.3 (6)	5.0 (5)	4.5 (5)	15/15
CMAa	3.2(4)	95(101)	77(121)	74(89)	70(111)	62(99)	8/15
CMAm	3.5(4)	109(147)	80(116)	77(109)	73(109)	65(97)	8/15
CMAMA	3.0(5)	92(170)	95(124)	92(121)	86(114)	76(101)	7/15
CMAmah	25(22)	124(178)	76(105)	73(85)	69(111)	61(96)	8/15
CMAmh	8.7(7)	102(175)	75(123)	73(89)	69(111)	61(75)	8/15
DBRCGA	103(6)	162(255)	97(142)	95(137)	90(128)	81(98)	10/15
DE	33(64)	45(68)	30(35)	29(37)	28(32)	25(32)	13/15
DE-AUTO	50(111)	52(72)	37(48)	36(47)	34(44)	30(39)	14/15
DE-BFGS	10(11)	33(56)	17(26)	16(25)	15(24)	205(247)	1/15
DE-ROLL	84(121)	66(79)	66(94)	64(87)	60(79)	53(75)	12/15
DE-SIMPLEX	89(131)	208(309)	159(215)	154(205)	145(165)	196(241)	5/15
DEctpb	22(11)	139(229)	65(73)	63(102)	61(96)	55(60)	8/15
IPOPsaACM	2.6 (4)	53(94)	157(308)	151(297)	142(279)	126(247)	15/15
JADEb	20(34)	24(36)	19(22)	18(22)	17(20)	15 (18)	14/15
JADEctpb	7.2(2)	33(62)	21(37)	20(37)	19(33)	18(29)	13/15
MVDE	29(17)	64(81)	36(40)	62(76)	73(96)	81(95)	7/15
NBIPOPacMA	1.9 (4)	1.5 (1)	13 (18)	12 (18)	12 (17)	10 (15)	15/15
NIPOPacMA	2.5 (5)	129(193)	135(138)	130(133)	123(126)	109(111)	15/15
PSO-BFGS	1.7 (1)	0.64 (0.6)	0.56 (0.9)	0.55 (0.9)	0.57 (1)	96(119)	1/15
SNES	76(71)	93(116)	70(84)	67(81)	63(76)	56(67)	15/15
xNES	142(281)	112(168)	54(75)	53(72)	50(68)	44(60)	15/15
xNESas	45(71)	66(98)	37(44)	35(42)	33(40)	30(45)	30/30

Table 23: 20-D, running time excess $ERT/ERT_{\text{best } 2009}$ on f_{22} , in italics is given the median final function value and the median number of function evaluations to reach this value divided by dimension.

Δf_{opt}	1e1	1e0	1e-1	1e-3	1e-5	1e-7	#succ
f_{22}	467	5580	23491	24948	26847	1.3e5	12/15
ACOR	1.4e4(2e4)	3585(4480)	∞	∞	∞	∞ <i>1e7</i>	0/15
BIPOPacMA	37(59)	260(240)	273(465)	257(405)	239(400)	48(75)	13/15
BIPOPsaACM	7.7(9)	100(96)	178(320)	173(301)	168(274)	35(54)	15/15
CMA	12(14)	433(619)	∞	∞	∞	∞ <i>1e6</i>	0/15
CMAES	3.8 (5)	42 (90)	142 (146)	133 (146)	124 (136)	25 (26)	4/15
CMAa	10(13)	232(307)	∞	∞	∞	∞ <i>1e6</i>	0/15
CMAm	7.0(12)	188(306)	∞	∞	∞	∞ <i>1e6</i>	0/15
CMAma	6.7 (12)	235(312)	∞	∞	∞	∞ <i>1e6</i>	0/15
CMAmah	187(29)	185(264)	∞	∞	∞	∞ <i>1e6</i>	0/15
CMAmh	6.9(8)	314(411)	∞	∞	∞	∞ <i>1e6</i>	0/15
DBRCGA	100(259)	259(304)	392(437)	372(397)	350(357)	70(81)	3/15
DE	23(10)	92(111)	∞	∞	∞	∞ <i>1e6</i>	0/15
DE-AUTO	128(88)	234(273)	281(305)	265(281)	246(249)	216(230)	0/15
DE-BFGS	5.7 (13)	135(186)	151(148)	142(134)	132(124)	∞ <i>2e6</i>	0/15
DE-ROLL	68(139)	199(199)	396(416)	374(392)	348(343)	221(223)	0/15
DE-SIMPLEX	38(81)	338(538)	1194(1364)	1125(1324)	1046(1193)	208(241)	0/15
DEctpb	98(14)	282(367)	∞	∞	∞	∞ <i>1e6</i>	0/15
IPOPsaACM	175(98)	978(1833)	∞	∞	∞	∞ <i>2e7</i>	0/15
JADEb	46(66)	75 (92)	143 (149)	135 (141)	126 (131)	25 (24)	4/15
JADEctpb	25(45)	261(298)	638(660)	601(641)	559(615)	∞ <i>1e6</i>	0/15
MVDE	40(28)	397(516)	∞	∞	∞	∞ <i>1e6</i>	0/15
NBIPOPacMA	32(41)	17 (16)	51 (89)	48 (84)	44 (78)	8.8 (15)	15/15
NIPOPacMA	42(93)	319(438)	861(1086)	811(830)	754(950)	150(198)	9/15
PSO-BFGS	1.7 (2)	3.0 (5)	10 (13)	9.0 (13)	8.6 (12)	209(238)	0/15
SNES	205(255)	227(281)	312(302)	294(277)	317(339)	111(126)	4/15
xNES	104(171)	231(329)	168(181)	158(155)	147(163)	29 (30)	12/15
xNESas	50(86)	132(176)	226(236)	213(241)	198(203)	39(41)	22/30

Table 24: 20-D, running time excess $ERT/ERT_{\text{best } 2009}$ on f_{23} , in italics is given the median final function value and the median number of function evaluations to reach this value divided by dimension.

Δf_{opt}	1e1	1e0	1e-1	1e-3	1e-5	1e-7	#succ
f23	3.2	1614	67457	4.9e5	8.1e5	8.4e5	15/15
ACOR	1.8 (2)	∞	∞	∞	∞	∞ <i>1e7</i>	0/15
BIPOPacCMA	4.7(9)	43(44)	1.2 (1)	1.4 (1)	0.85 (0.7)	0.90 (0.6)	15/15
BIPOPsaACM	3.0 (6)	21(13)	0.61 (0.3)	1.4 (1)	1.3 (1)	1.3 (1)	15/15
CMA	3.4(4)	∞	∞	∞	∞	∞ <i>3e6</i>	0/15
CMAES	2.9 (3)	571(707)	63(73)	∞	∞	∞ <i>1e6</i>	0/15
CMAa	6.5(5)	1.1e4(1e4)	556(628)	∞	∞	∞ <i>3e6</i>	0/15
CMAm	3.9(4)	1.1e4(1e4)	577(620)	∞	∞	∞ <i>3e6</i>	0/15
CMAma	2.5 (3)	1.1e4(1e4)	255(315)	∞	∞	∞ <i>3e6</i>	0/15
CMAmah	2.9 (3)	4164(4936)	516(601)	∞	∞	∞ <i>2e6</i>	0/15
CMAmh	2.8 (3)	4205(4701)	519(585)	∞	∞	∞ <i>2e6</i>	0/15
DBRCGA	1.7 (2)	415(427)	∞	∞	∞	∞ <i>2e6</i>	0/15
DE	2.4 (2)	∞	∞	∞	∞	∞ <i>1e6</i>	0/15
DE-AUTO	2.2 (2)	3.8 (3)	36(44)	∞	∞	∞ <i>2e6</i>	0/15
DE-BFGS	2.1 (2)	7.0 (7)	54(66)	∞	∞	∞ <i>2e6</i>	0/15
DE-ROLL	1.9 (2)	15(14)	∞	∞	∞	∞ <i>2e6</i>	0/15
DE-SIMPLEX	1.6 (1)	1.3 (0.9)* ²	36(43)	∞	∞	∞ <i>2e6</i>	0/15
DEctpb	1.2 (0.6)	∞	∞	∞	∞	∞ <i>1e6</i>	0/15
IPOPsaACM	4.3(6)	2.9e4(3e4)	906(1043)	∞	∞	∞ <i>2e7</i>	0/15
JADEb	1.4 (0.9)	673(625)	∞	∞	∞	∞ <i>1e6</i>	0/15
JADEctpb	2.0 (2)	131(68)	∞	∞	∞	∞ <i>1e6</i>	0/15
MVDE	2.2 (3)	∞	∞	∞	∞	∞ <i>1e6</i>	0/15
NBIPOPacCMA	3.1(3)	28(34)	0.86 (0.7)	1.4 (0.4)	0.89 (0.2)	0.90 (0.2)	15/15
NIPOPacCMA	3.8(5)	142(65)	3.9 (2)	0.72 (0.4)	0.48 (0.2)	0.50 (0.2)	15/15
PSO-BFGS	1.6 (2)	4.7 (4)	66(74)	∞	∞	∞ <i>2e6</i>	0/15
SNES	1.5 (1)	102(102)	261(335)	∞	∞	∞ <i>7e6</i>	0/15
xNES	2.0 (2)	∞	∞	∞	∞	∞ <i>6e6</i>	0/15
xNESas	1.5 (2)	9.9e4(1e5)	∞	∞	∞	∞ <i>1e7</i>	0/30

Table 25: 20-D, running time excess $ERT/ERT_{\text{best } 2009}$ on f_{24} , in italics is given the median final function value and the median number of function evaluations to reach this value divided by dimension.

Δf_{opt}	1e1	1e0	1e-1	1e-3	1e-5	1e-7	#succ
f24	1.3e6	7.5e6	5.2e7	5.2e7	5.2e7	5.2e7	3/15
ACOR	∞	∞	∞	∞	∞	∞ <i>1e7</i>	0/15
BIPOPacCMA	1.00 (1)	0.94 (0.9)	2.8 (3)	2.8 (3)	2.8 (3)	2.8 (3)	2/15
BIPOPsaACM	0.99 (1)	0.88 (0.7)	0.80 (0.8)	0.80 (0.8)	0.80 (0.8)	0.79 (0.8)	6/15
CMA	∞	∞	∞	∞	∞	∞ <i>4e6</i>	0/15
CMAES	∞	∞	∞	∞	∞	∞ <i>1e6</i>	0/15
CMAa	42(46)	∞	∞	∞	∞	∞ <i>4e6</i>	0/15
CMAm	12(14)	3.6(4)	∞	∞	∞	∞ <i>4e6</i>	0/15
CMAma	19(22)	∞	∞	∞	∞	∞ <i>4e6</i>	0/15
CMAmah	42(45)	∞	∞	∞	∞	∞ <i>4e6</i>	0/15
CMAmh	42(49)	∞	∞	∞	∞	∞ <i>4e6</i>	0/15
DBRCGA	∞	∞	∞	∞	∞	∞ <i>2e6</i>	0/15
DE	∞	∞	∞	∞	∞	∞ <i>1e6</i>	0/15
DE-AUTO	∞	∞	∞	∞	∞	∞ <i>2e6</i>	0/15
DE-BFGS	4.3(5)	∞	∞	∞	∞	∞ <i>2e6</i>	0/15
DE-ROLL	4.7(5)	∞	∞	∞	∞	∞ <i>2e6</i>	0/15
DE-SIMPLEX	22(24)	∞	∞	∞	∞	∞ <i>2e6</i>	0/15
DEctpb	∞	∞	∞	∞	∞	∞ <i>1e6</i>	0/15
IPOPsaACM	28(32)	38(40)	∞	∞	∞	∞ <i>2e7</i>	0/15
JADEb	∞	∞	∞	∞	∞	∞ <i>1e6</i>	0/15
JADEctpb	∞	∞	∞	∞	∞	∞ <i>1e6</i>	0/15
MVDE	∞	∞	∞	∞	∞	∞ <i>1e6</i>	0/15
NBIPOPacCMA	1.3 (1.0)	0.35 (0.3)	0.61 (0.6)	0.61 (0.6)	0.61 (0.6)	0.61 (0.7)	7/15
NIPOPacCMA	1.6 (2)	0.42 (0.4)	0.35 (0.3)	0.35 (0.3)	0.35 (0.3)	0.35 (0.3)	11/15
PSO-BFGS	∞	∞	∞	∞	∞	∞ <i>2e6</i>	0/15
SNES	12(12)	∞	∞	∞	∞	∞ <i>8e6</i>	0/15
xNES	∞	∞	∞	∞	∞	∞ <i>6e6</i>	0/15
xNESas	∞	∞	∞	∞	∞	∞ <i>1e7</i>	0/30

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