Comparison tables: BBOB 2010 function testbed with BBOB 2009 as reference in 10-D

The BBOBies

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Abstract

This document provides tabular results of the workshop for Black Box Optimization Benchmarking at GECCO , see `http://coco.gforge.inria.fr/doku.php?id=bbob-2010`. More than algorithms have been tested on benchmark functions in dimensions between and . A description of the used objective functions can be found in , . The experimental set up is described in .

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 [7]) 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 [15] 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: 10-D, running time excess ERT/$\mathrm{ERT}_{\mathrm{best\ 2009}}$ 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

1 Sphere

Δftarget	1e+03	1e+02	1e+01	1e+00	1e-01	1e-02	1e-03	1e-04	1e-05	1e-07	Δftarget
$\mathrm{ERT}_{\mathrm{best}}$/D	0.10	0.10	2.2	2.3	2.3	2.3	2.3	2.3	2.3	2.3	$\mathrm{ERT}_{\mathrm{best}}$/D
(1,2)-CMA-ES	**1**	23	13	21	31	40	48	58	67	85	(1,2)-CMA-ES [5, 3]
(1,2m)-CMA-ES	**1**	13	6.5	12	17	23	28	34	40	52	(1,2m)-CMA-ES [5]
(1,2ms)-CMA-ES	**1**	8.3	5.9	11	15	20	25	31	36	45	(1,2ms)-CMA-ES [5]
(1,2s)-CMA-ES	**1**	20	10	19	28	35	45	53	62	81	(1,2s)-CMA-ES [3]
(1,4)-CMA-ES	**1**	11	4.7	10	14	20	25	30	36	46	(1,4)-CMA-ES [6, 4]
(1,4m)-CMA-ES	**1**	**2.7**	4.1	8.2	13	17	21	26	30	39	(1,4m)-CMA-ES [6]
(1,4ms)-CMA-ES	**1**	5.5	**3.6**	**6.7**	**10**	**13**	**16**	**20**	**23**	**29**	(1,4ms)-CMA-ES [1, 6]
(1,4s)-CMA-ES	**1**	14	4.3	8.3	13	16	21	25	29	38	(1,4s)-CMA-ES [4]
(1+1)-CMA-ES	**1**	11	4.1	8.1	12	15	19	23	27	34	(1+1)-CMA-ES [8]
(1+2ms)-CMA-ES	**1**	9.3	**3.7**	**6.8**	**10**	**13**	**17**	**20**	**24**	**31**	(1+2ms)-CMA-ES [2]
Artif Bee Colony	**1**	4.9	24	55	86	114	165	203	238	306	Artif Bee Colony [9]
avg NEWUOA	**1**	27	**1.7**	**1.7**	**1.7**	**1.7**	**1.7**	**1.7**	**1.7**	**1.7**	avg NEWUOA [24]
CMA-EGS (IPOP,r1)	7.7	85	11	19	26	34	42	49	57	72	CMA-EGS (IPOP,r1) [13]
Adap DE (F-AUC)	**1**	4.5	37	91	137	189	239	290	343	443	Adap DE (F-AUC) [11]
DE (Uniform)	**1**	4.9	48	121	198	269	344	423	496	649	DE (Uniform) [10]
IPOP-aCMA-ES	**1**	9.2	6.2	13	19	26	32	39	44	58	IPOP-aCMA-ES [17]
IPOP-CMA-ES	**1**	7.7	5.0	11	18	24	30	37	43	56	IPOP-CMA-ES [23]
CMA+DE-MOS	**1**	5.9	19	57	71	94	124	140	166	214	CMA+DE-MOS [19]
NBC-CMA	**1**	5.8	16	25	34	45	54	63	73	93	NBC-CMA [22]
POEMS	**1**	1684	130	244	608	1045	1469	1958	2403	3321	POEMS [18]
PM-AdapSS-DE	**1**	**4.3**	41	95	158	218	275	338	399	518	PM-AdapSS-DE [10, 11]
pPOEMS	**1**	527	125	252	1035	3154	5744	8009	10514	16455	pPOEMS [18, 21]
Basic RCGA	**1**	**4.0**	33	105	207	345	1034	1984	2693	3761	Basic RCGA [25]
SPSA	8.4	104	7.7	11	13	16	19	22	25	31	SPSA [14]

Table 2: 10-D, running time excess ERT/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

2 Ellipsoid separable

Δftarget	1e+03	1e+02	1e+01	1e+00	1e-01	1e-02	1e-03	1e-04	1e-05	1e-07	Δftarget
ERT$_{\text{best}}$/D	15	18	19	19	19	19	19	19	19	20	ERT$_{\text{best}}$/D
(1,2)-CMA-ES	56	75	90	93	99	101	103	104	106	108	(1,2)-CMA-ES [5, 3]
(1,2m)-CMA-ES	31	35	46	49	51	51	52	52	53	54	(1,2m)-CMA-ES [5]
(1,2ms)-CMA-ES	27	30	38	42	43	44	44	45	46	47	(1,2ms)-CMA-ES [5]
(1,2s)-CMA-ES	72	83	101	107	112	113	116	118	119	123	(1,2s)-CMA-ES [3]
(1,4)-CMA-ES	18	23	31	35	36	36	37	37	38	39	(1,4)-CMA-ES [6, 4]
(1,4m)-CMA-ES	11	19	27	30	32	32	33	33	34	35	(1,4m)-CMA-ES [6]
(1,4ms)-CMA-ES	10	15	21	23	23	24	24	25	25	26	(1,4ms)-CMA-ES [1, 6]
(1,4s)-CMA-ES	14	19	26	29	31	31	32	33	33	34	(1,4s)-CMA-ES [4]
(1+1)-CMA-ES	8.6	12	17	21	**21**	**22**	**22**	**23**	**23**	**24**	(1+1)-CMA-ES [8]
(1+2ms)-CMA-ES	**7.5**	**10**	**13**	**16**	**18**	**18**	**19**	**19**	**20**	**20**	(1+2ms)-CMA-ES [2]
Artif Bee Colony	**6.5**	**7.2**	**11**	**15**	22	28	38	48	56	68	Artif Bee Colony [9]
avg NEWUOA	**2.5**	**6.1**	16	39	67	90	124	157	184	250	avg NEWUOA [24]
CMA-EGS (IPOP,r1)	46	52	61	66	67	68	70	70	71	73	CMA-EGS (IPOP,r1) [13]
Adap DE (F-AUC)	20	22	29	34	40	46	52	58	64	75	Adap DE (F-AUC) [11]
DE (Uniform)	26	30	39	47	55	64	74	82	91	109	DE (Uniform) [10]
IPOP-aCMA-ES	7.9	11	**14**	**16**	**18**	**19**	**20**	**20**	**21**	**23**	IPOP-aCMA-ES [17]
IPOP-CMA-ES	12	15	21	25	26	26	27	28	28	30	IPOP-CMA-ES [23]
CMA+DE-MOS	20	22	30	37	43	48	53	57	62	71	CMA+DE-MOS [19]
NBC-CMA	14	21	32	37	41	43	45	46	47	49	NBC-CMA [22]
POEMS	134	160	214	267	327	369	427	478	533	641	POEMS [18]
PM-AdapSS-DE	23	25	32	39	46	53	59	67	74	87	PM-AdapSS-DE [10, 11]
pPOEMS	270	440	612	1018	1277	1785	2032	2336	2621	3285	pPOEMS [18, 21]
Basic RCGA	37	55	95	147	233	320	394	442	678	1482	Basic RCGA [25]
SPSA	7996	*69e+1/1e5*	.	.	.	.	.	.	.	.	SPSA [14]

Table 3: 10-D, running time excess ERT/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

3 Rastrigin separable

Δftarget	1e+03	1e+02	1e+01	1e+00	1e-01	1e-02	1e-03	1e-04	1e-05	1e-07	Δftarget
ERT$_{\text{best}}$/D	0.10	6.9	174	360	361	364	364	364	365	365	ERT$_{\text{best}}$/D
(1,2)-CMA-ES	4.4	61	*30e+0/1e4*	.	.	.	.	.	.	.	(1,2)-CMA-ES [5, 3]
(1,2m)-CMA-ES	**1.6**	5.3	274	*14e+0/1e4*	.	.	.	.	.	.	(1,2m)-CMA-ES [5]
(1,2ms)-CMA-ES	**1.3**	6.2	390	*17e+0/1e4*	.	.	.	.	.	.	(1,2ms)-CMA-ES [5]
(1,2s)-CMA-ES	4.0	83	398	*38e+0/1e4*	.	.	.	.	.	.	(1,2s)-CMA-ES [3]
(1,4)-CMA-ES	7.9	7.2	*15e+0/1e4*	.	.	.	.	.	.	.	(1,4)-CMA-ES [6, 4]
(1,4m)-CMA-ES	**2.2**	3.5	91	*11e+0/1e4*	.	.	.	.	.	.	(1,4m)-CMA-ES [6]
(1,4ms)-CMA-ES	3.3	3.5	76	*99e-1/1e4*	.	.	.	.	.	.	(1,4ms)-CMA-ES [1, 6]
(1,4s)-CMA-ES	3.1	6.0	376	*18e+0/1e4*	.	.	.	.	.	.	(1,4s)-CMA-ES [4]
(1+1)-CMA-ES	4.1	14	838	*18e+0/1e4*	.	.	.	.	.	.	(1+1)-CMA-ES [8]
(1+2ms)-CMA-ES	7.3	**2.4**	835	*20e+0/1e4*	.	.	.	.	.	.	(1+2ms)-CMA-ES [2]
Artif Bee Colony	**2.3**	6.0	**1.6**	**2.2**	**2.5**	**2.8**	**3.1**	**3.4**	**3.8**	**4.5**	Artif Bee Colony [9]
avg NEWUOA	11	16	*21e+0/7e3*	.	.	.	.	.	.	.	avg NEWUOA [24]
CMA-EGS (IPOP,r1)	51	5.0	78	3903	3893	3864	3859	3859	3857	*50e-1/1e5*	CMA-EGS (IPOP,r1) [13]
Adap DE (F-AUC)	**2.1**	15	200	1212	3965	3936	3930	3929	3926	3921	Adap DE (F-AUC) [11]
DE (Uniform)	**1.7**	20	211	4009	*30e-1/1e5*	.	.	.	.	.	DE (Uniform) [10]
IPOP-aCMA-ES	3.5	**2.9**	5.6	643	2678	2659	2656	2655	2653	2651	IPOP-aCMA-ES [17]
IPOP-CMA-ES	**2.6**	**3.2**	**2.7**	1658	5796	5752	5744	5742	5737	5729	IPOP-CMA-ES [23]
CMA+DE-MOS	**2.0**	8.1	**2.1**	**3.0**	**3.7**	**4.0**	**4.4**	**4.7**	**4.9**	**5.6**	CMA+DE-MOS [19]
NBC-CMA	**1.7**	6.0	8.2	1213	*40e-1/3e4*	.	.	.	.	.	NBC-CMA [22]
POEMS	678	43	6.8	**28**	**54**	**56**	**58**	**62**	**64**	**70**	POEMS [18]
PM-AdapSS-DE	**2.2**	18	93	508	646	1876	3944	*10e-1/1e5*	.	.	PM-AdapSS-DE [10, 11]
pPOEMS	**2.4**	45	8.2	54	134	140	154	165	186	227	pPOEMS [18, 21]
Basic RCGA	**2.4**	12	8.2	133	255	330	333	335	336	339	Basic RCGA [25]
SPSA	6.67e5	12992	*87e+0/1e5*	.	.	.	.	.	.	.	SPSA [14]

Table 4: 10-D, running time excess ERT/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

4 Skew Rastrigin-Bueche separ

Δftarget	1e+03	1e+02	1e+01	1e+00	1e-01	1e-02	1e-03	1e-04	1e-05	1e-07	Δftarget
ERT$_{\text{best}}$/D	0.10	10	223	363	366	370	371	374	374	2877	ERT$_{\text{best}}$/D
(1,2)-CMA-ES	3.4	67	*41e+0/1e4*	.	.	.	.	.	.	.	(1,2)-CMA-ES [5, 3]
(1,2m)-CMA-ES	6.4	6.2	306	*18e+0/1e4*	.	.	.	.	.	.	(1,2m)-CMA-ES [5]
(1,2ms)-CMA-ES	7.8	8.7	209	*18e+0/1e4*	.	.	.	.	.	.	(1,2ms)-CMA-ES [5]
(1,2s)-CMA-ES	13	145	*51e+0/1e4*	.	.	.	.	.	.	.	(1,2s)-CMA-ES [3]
(1,4)-CMA-ES	5.6	6.2	*22e+0/1e4*	.	.	.	.	.	.	.	(1,4)-CMA-ES [6, 4]
(1,4m)-CMA-ES	5.7	**5.4**	*17e+0/1e4*	.	.	.	.	.	.	.	(1,4m)-CMA-ES [6]
(1,4ms)-CMA-ES	8.1	5.4	311	*15e+0/1e4*	.	.	.	.	.	.	(1,4ms)-CMA-ES [1, 6]
(1,4s)-CMA-ES	3.0	23	*20e+0/1e4*	.	.	.	.	.	.	.	(1,4s)-CMA-ES [4]
(1+1)-CMA-ES	5.7	19	317	*27e+0/1e4*	.	.	.	.	.	.	(1+1)-CMA-ES [8]
(1+2ms)-CMA-ES	4.1	21	*26e+0/1e4*	.	.	.	.	.	.	.	(1+2ms)-CMA-ES [2]
Artif Bee Colony	3.1	5.4	**1.3**	**3.2**	**4.4**	**5.1**	**5.7**	**6.3**	**6.7**	**0.99**	Artif Bee Colony [9]
avg NEWUOA	13	42	*27e+0/1e4*	.	.	.	.	.	.	.	avg NEWUOA [24]
CMA-EGS (IPOP,r1)	93	5.5	362	*90e-1/1e5*	.	.	.	.	.	.	CMA-EGS (IPOP,r1) [13]
Adap DE (F-AUC)	4.1	20	92	*60e-1/1e5*	.	.	.	.	.	.	Adap DE (F-AUC) [11]
DE (Uniform)	3.1	26	111	*50e-1/1e5*	.	.	.	.	.	.	DE (Uniform) [10]
IPOP-aCMA-ES	6.3	**3.1**	7.6	*60e-1/1e5*	.	.	.	.	.	.	IPOP-aCMA-ES [17]
IPOP-CMA-ES	**2.9**	**3.4**	7.5	*60e-1/2e5*	.	.	.	.	.	.	IPOP-CMA-ES [23]
CMA+DE-MOS	**2.2**	8.5	**1.9**	**6.8**	**8.2**	**8.6**	**9.1**	**9.4**	**10**	**1.4**	CMA+DE-MOS [19]
NBC-CMA	**2.6**	6.0	8.1	*60e-1/3e4*	.	.	.	.	.	.	NBC-CMA [22]
POEMS	1209	34	**6.6**	**40**	**114**	**116**	**120**	**120**	**123**	**17**	POEMS [18]
PM-AdapSS-DE	3.9	22	92	*60e-1/1e5*	.	.	.	.	.	.	PM-AdapSS-DE [10, 11]
pPOEMS	**2.3**	37	10	68	285	298	316	332	348	51	pPOEMS [18, 21]
Basic RCGA	**2.3**	19	107	*79e-1/5e4*	.	.	.	.	.	.	Basic RCGA [25]
SPSA	185	8979	*99e+0/1e5*	.	.	.	.	.	.	.	SPSA [14]

Table 5: 10-D, running time excess ERT/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

5 Linear slope

Δftarget	1e+03	1e+02	1e+01	1e+00	1e-01	1e-02	1e-03	1e-04	1e-05	1e-07	Δftarget
ERT$_{\text{best}}$/D	0.10	1.6	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	ERT$_{\text{best}}$/D
(1,2)-CMA-ES	**1**	**2.1**	5.7	6.9	7.1	7.1	7.1	7.1	7.1	7.1	(1,2)-CMA-ES [5, 3]
(1,2m)-CMA-ES	**1**	**1.0**	**2.9**	3.4	3.7	3.8	3.8	3.8	3.8	3.8	(1,2m)-CMA-ES [5]
(1,2ms)-CMA-ES	**1**	**0.97**	3.5	4.0	4.1	4.1	4.1	4.1	4.1	4.1	(1,2ms)-CMA-ES [5]
(1,2s)-CMA-ES	**1**	**1.5**	6.3	8.2	8.3	8.3	8.3	8.3	8.3	8.3	(1,2s)-CMA-ES [3]
(1,4)-CMA-ES	**1**	**1.3**	4.3	5.4	5.6	5.6	5.6	5.6	5.6	5.6	(1,4)-CMA-ES [6, 4]
(1,4m)-CMA-ES	**1**	**1.3**	4.2	5.2	5.3	5.3	5.3	5.3	5.3	5.3	(1,4m)-CMA-ES [6]
(1,4ms)-CMA-ES	**1**	**1.0**	3.4	4.1	4.1	4.2	4.2	4.2	4.2	4.2	(1,4ms)-CMA-ES [1, 6]
(1,4s)-CMA-ES	**1**	**1.3**	3.0	4.1	4.1	4.2	4.2	4.2	4.2	4.2	(1,4s)-CMA-ES [4]
(1+1)-CMA-ES	**1**	**0.75**	**2.8**	**3.2**	**3.3**	**3.3**	**3.4**	**3.4**	**3.4**	**3.4**	(1+1)-CMA-ES [8]
(1+2ms)-CMA-ES	**1**	**0.80**	**2.1**	**2.7**	**3.0**	**3.0**	**3.0**	**3.0**	**3.0**	**3.0**	(1+2ms)-CMA-ES [2]
Artif Bee Colony	**1**	8.8	51	71	75	75	75	75	75	75	Artif Bee Colony [9]
avg NEWUOA	**1**	**1.9**	**2.0**	**2.3**	**2.3**	**2.3**	**2.3**	**2.3**	**2.3**	**2.3**	avg NEWUOA [24]
CMA-EGS (IPOP,r1)	**1**	3.2	5.4	6.1	6.1	6.1	6.1	6.1	6.1	6.1	CMA-EGS (IPOP,r1) [13]
Adap DE (F-AUC)	**1**	4.7	31	39	44	44	44	44	44	44	Adap DE (F-AUC) [11]
DE (Uniform)	**1**	6.7	43	53	56	58	58	58	58	58	DE (Uniform) [10]
IPOP-aCMA-ES	**1**	**2.0**	5.2	6.7	6.8	6.8	6.8	6.8	6.8	6.8	IPOP-aCMA-ES [17]
IPOP-CMA-ES	**1**	**2.0**	4.9	5.9	6.2	6.2	6.2	6.2	6.2	6.2	IPOP-CMA-ES [23]
CMA+DE-MOS	**1**	6.2	34	54	54	54	54	54	54	54	CMA+DE-MOS [19]
NBC-CMA	**1**	8.2	36	43	43	43	43	43	43	43	NBC-CMA [22]
POEMS	**1**	135	198	235	263	274	277	277	277	277	POEMS [18]
PM-AdapSS-DE	**1**	4.8	39	52	54	54	54	54	54	54	PM-AdapSS-DE [10, 11]
pPOEMS	**1**	127	196	232	253	272	275	276	276	276	pPOEMS [18, 21]
Basic RCGA	**1**	28	391	791	1242	1958	3124	4360	5138	73940	Basic RCGA [25]
SPSA	**1**	**2.3**	6.2	8.2	8.6	8.7	8.7	8.7	8.7	8.7	SPSA [14]

Table 6: 10-D, running time excess ERT/ERT$_{\text{best 2009}}$ 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

6 Attractive sector

Δftarget	1e+03	1e+02	1e+01	1e+00	1e-01	1e-02	1e-03	1e-04	1e-05	1e-07	Δftarget
ERT$_{\text{best}}$/D	2.8	10	41	62	83	104	129	157	184	237	ERT$_{\text{best}}$/D
(1,2)-CMA-ES	4.0	8.8	7.1	9.2	12	19	21	25	35	90	(1,2)-CMA-ES [5, 3]
(1,2m)-CMA-ES	3.1	4.4	**2.4**	**2.2**	**2.3**	**2.4**	**2.3**	**2.4**	**2.4**	**2.4**	(1,2m)-CMA-ES [5]
(1,2ms)-CMA-ES	4.1	3.9	**1.9**	**1.9**	**2.1**	**2.1**	**2.1**	**2.1**	**2.2**	**2.5**	(1,2ms)-CMA-ES [5]
(1,2s)-CMA-ES	8.4	13	10	17	35	44	55	77	77	597	(1,2s)-CMA-ES [3]
(1,4)-CMA-ES	**2.7**	3.1	**2.1**	**2.3**	**2.4**	**2.5**	**2.6**	**2.6**	**2.7**	**2.8**	(1,4)-CMA-ES [6, 4]
(1,4m)-CMA-ES	**2.1**	**2.9**	**1.6**	**1.6**	**1.7**	**1.7**	**1.8**	**1.8**	**1.8**	**1.7**	(1,4m)-CMA-ES [6]
(1,4ms)-CMA-ES	**1.4**	**1.7**	**1.1**	**1.3**	**1.3**	**1.4**	**1.4**	**1.4**	**1.4**	**1.5**	(1,4ms)-CMA-ES [1, 6]
(1,4s)-CMA-ES	**1.7**	**3.0**	**1.7**	**2.2**	**2.6**	**2.8**	**2.9**	3.7	4.2	4.6	(1,4s)-CMA-ES [4]
(1+1)-CMA-ES	**1.9**	**2.3**	**1.4**	5.9	26	78	246	938	*26e-4/1e4*	.	(1+1)-CMA-ES [8]
(1+2ms)-CMA-ES	**1.5**	**1.6**	**1.1**	**2.6**	14	75	155	937	*21e-4/1e4*	.	(1+2ms)-CMA-ES [2]
Artif Bee Colony	10	4.7	12	232	598	2036	2247	2797	7830	6289	Artif Bee Colony [9]
avg NEWUOA	**1.5**	**1.6**	**0.97**	**0.99**	**1.0**	**1.0**	**1.1**	**1.1**	**1.1**	**1.1**	avg NEWUOA [24]
CMA-EGS (IPOP,r1)	11	14	35	73	188	269	239	212	198	209	CMA-EGS (IPOP,r1) [13]
Adap DE (F-AUC)	12	15	11	12	13	13	13	13	12	12	Adap DE (F-AUC) [11]
DE (Uniform)	12	23	15	16	17	17	17	16	16	16	DE (Uniform) [10]
IPOP-aCMA-ES	**2.1**	3.8	**1.8**	**1.9**	**1.8**	**1.8**	**1.7**	**1.7**	**1.6**	**1.6**	IPOP-aCMA-ES [17]
IPOP-CMA-ES	**2.5**	3.2	**1.9**	**1.9**	**1.9**	**1.9**	**1.8**	**1.8**	**1.7**	**1.7**	IPOP-CMA-ES [23]
CMA+DE-MOS	14	10	7.8	7.1	6.7	6.4	6.2	5.8	5.5	5.2	CMA+DE-MOS [19]
NBC-CMA	10	4.9	31	21	17	14	11	10	8.4	7.0	NBC-CMA [22]
POEMS	95	35	31	39	43	45	45	45	44	44	POEMS [18]
PM-AdapSS-DE	11	20	14	14	15	15	14	14	13	13	PM-AdapSS-DE [10, 11]
pPOEMS	99	35	40	71	128	138	149	151	156	168	pPOEMS [18, 21]
Basic RCGA	38	14	39	83	136	313	407	941	*56e-5/5e4*	.	Basic RCGA [25]
SPSA	1269	67510	35633	*22e+1/1e5*	.	.	.	.	.	.	SPSA [14]

Table 7: 10-D, running time excess ERT/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

7 Step-ellipsoid

Δftarget	1e+03	1e+02	1e+01	1e+00	1e-01	1e-02	1e-03	1e-04	1e-05	1e-07	Δftarget
ERT$_{\text{best}}$/D	0.10	3.3	17	161	420	510	514	514	514	539	ERT$_{\text{best}}$/D
(1,2)-CMA-ES	5.9	16	56	*35e-1/1e4*	.	.	.	.	.	.	(1,2)-CMA-ES [5, 3]
(1,2m)-CMA-ES	4.5	5.0	12	47	164	*73e-2/1e4*	.	.	.	.	(1,2m)-CMA-ES [5]
(1,2ms)-CMA-ES	**2.3**	6.2	8.8	47	*59e-2/1e4*	.	.	.	.	.	(1,2ms)-CMA-ES [5]
(1,2s)-CMA-ES	4.7	16	102	*40e-1/1e4*	.	.	.	.	.	.	(1,2s)-CMA-ES [3]
(1,4)-CMA-ES	3.9	3.6	5.1	53	*65e-2/1e4*	.	.	.	.	.	(1,4)-CMA-ES [6, 4]
(1,4m)-CMA-ES	8.6	3.1	3.6	25	337	*56e-2/1e4*	.	.	.	.	(1,4m)-CMA-ES [6]
(1,4ms)-CMA-ES	5.7	3.2	4.9	21	161	*69e-2/1e4*	.	.	.	.	(1,4ms)-CMA-ES [1, 6]
(1,4s)-CMA-ES	5.3	**2.2**	11	75	339	*10e-1/1e4*	.	.	.	.	(1,4s)-CMA-ES [4]
(1+1)-CMA-ES	4.0	**2.7**	18	6.4	6.5	10	12	12	12	12	(1+1)-CMA-ES [8]
(1+2ms)-CMA-ES	3.1	**2.0**	14	5.6	7.4	13	13	13	13	13	(1+2ms)-CMA-ES [2]
Artif Bee Colony	**2.7**	8.2	27	512	1627	*95e-2/1e5*	.	.	.	.	Artif Bee Colony [9]
avg NEWUOA	3.0	**1.4**	16	38	*73e-2/1e4*	.	.	.	.	.	avg NEWUOA [24]
CMA-EGS (IPOP,r1)	64	11	10	2491	*31e-1/1e5*	.	.	.	.	.	CMA-EGS (IPOP,r1) [13]
Adap DE (F-AUC)	**2.3**	11	10	**2.1**	**1.2**	**1.3**	**1.4**	**1.4**	**1.4**	**1.4**	Adap DE (F-AUC) [11]
DE (Uniform)	**2.9**	14	12	**2.8**	**1.7**	**1.9**	**1.9**	**1.9**	**1.9**	**2.0**	DE (Uniform) [10]
IPOP-aCMA-ES	7.2	3.3	**2.7**	**1.2**	**0.75**	**0.77**	**0.77**	**0.77**	**0.77**	**0.75**	IPOP-aCMA-ES [17]
IPOP-CMA-ES	4.7	**2.7**	**2.6**	**1.9**	**1.5**	**1.4**	**1.4**	**1.4**	**1.4**	**1.4**	IPOP-CMA-ES [23]
CMA+DE-MOS	**2.6**	7.7	7.8	**3.0**	**2.3**	**2.1**	**2.1**	**2.1**	**2.1**	**2.0**	CMA+DE-MOS [19]
NBC-CMA	**2.6**	5.0	**3.4**	**1.5**	4.0	13	15	15	15	16	NBC-CMA [22]
POEMS	791	79	35	12	147	123	123	123	123	117	POEMS [18]
PM-AdapSS-DE	**2.4**	12	10	**2.4**	**1.4**	**1.5**	**1.5**	**1.5**	**1.5**	**1.5**	PM-AdapSS-DE [10, 11]
pPOEMS	**2.1**	83	40	35	29	43	46	46	46	44	pPOEMS [18, 21]
Basic RCGA	3.1	8.3	82	81	298	*12e-2/5e4*	.	.	.	.	Basic RCGA [25]
SPSA	390	64	81647	*28e+0/1e5*	.	.	.	.	.	.	SPSA [14]

Table 8: 10-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

8 Rosenbrock original

Δftarget	1e+03	1e+02	1e+01	1e+00	1e-01	1e-02	1e-03	1e-04	1e-05	1e-07	Δftarget
ERT$_{\text{best}}$/D	4.2	13	33	92	111	122	127	129	132	134	ERT$_{\text{best}}$/D
(1,2)-CMA-ES	13	14	10	20	19	19	19	19	19	19	(1,2)-CMA-ES [5, 3]
(1,2m)-CMA-ES	4.8	3.0	**2.3**	7.6	7.7	7.7	7.7	7.7	7.7	7.8	(1,2m)-CMA-ES [5]
(1,2ms)-CMA-ES	3.9	4.8	**2.9**	6.8	6.7	6.6	6.6	6.7	6.7	6.8	(1,2ms)-CMA-ES [5]
(1,2s)-CMA-ES	8.9	12	8.4	24	23	22	22	22	22	22	(1,2s)-CMA-ES [3]
(1,4)-CMA-ES	4.4	4.8	**3.0**	7.0	6.8	6.7	6.6	6.7	6.7	6.8	(1,4)-CMA-ES [6, 4]
(1,4m)-CMA-ES	3.1	**2.3**	**1.6**	6.1	5.9	5.8	5.8	5.8	5.8	5.9	(1,4m)-CMA-ES [6]
(1,4ms)-CMA-ES	**2.9**	**1.7**	**1.2**	5.3	5.1	4.9	4.9	4.9	4.9	4.9	(1,4ms)-CMA-ES [1, 6]
(1,4s)-CMA-ES	3.3	3.1	3.3	5.0	5.0	4.9	5.0	5.0	5.0	5.1	(1,4s)-CMA-ES [4]
(1+1)-CMA-ES	**2.3**	**2.8**	**2.2**	**3.5**	**3.5**	**3.5**	**3.5**	**3.6**	**3.6**	**3.8**	(1+1)-CMA-ES [8]
(1+2ms)-CMA-ES	**2.5**	**2.1**	**1.9**	**3.5**	**3.4**	**3.3**	**3.3**	**3.4**	**3.4**	**3.6**	(1+2ms)-CMA-ES [2]
Artif Bee Colony	11	8.6	7.2	7.4	19	77	549	*40e-5/1e5*	.	.	Artif Bee Colony [9]
avg NEWUOA	**1.2**	**1.2**	**0.99**	**0.87**	**0.84**	**0.83**	**0.82**	**0.82**	**0.82**	**0.82**	avg NEWUOA [24]
CMA-EGS (IPOP,r1)	8.9	7.2	5.2	8.4	8.3	8.3	8.4	8.7	9.1	10	CMA-EGS (IPOP,r1) [13]
Adap DE (F-AUC)	23	16	14	14	15	15	15	16	16	18	Adap DE (F-AUC) [11]
DE (Uniform)	33	24	20	20	21	21	22	23	23	26	DE (Uniform) [10]
IPOP-aCMA-ES	3.9	3.2	**2.6**	4.4	4.4	4.3	4.3	4.4	4.4	4.6	IPOP-aCMA-ES [17]
IPOP-CMA-ES	4.0	3.1	**2.3**	3.7	3.9	3.9	4.0	4.1	4.2	4.3	IPOP-CMA-ES [23]
CMA+DE-MOS	16	10	6.7	12	12	12	12	12	13	13	CMA+DE-MOS [19]
NBC-CMA	9.4	4.3	3.1	6.4	7.1	7.5	7.6	7.8	7.9	8.1	NBC-CMA [22]
POEMS	74	57	64	706	1065	1469	2026	2936	*40e-6/3e5*	.	POEMS [18]
PM-AdapSS-DE	25	19	16	20	21	22	22	23	23	25	PM-AdapSS-DE [10, 11]
pPOEMS	75	53	162	200	199	198	207	233	270	378	pPOEMS [18, 21]
Basic RCGA	17	22	102	1998	6723	*56e-1/5e4*	.	.	.	.	Basic RCGA [25]
SPSA	457	1339	8736	*13e+0/1e5*	.	.	.	.	.	.	SPSA [14]

Table 9: 10-D, running time excess $\mathrm{ERT}/\mathrm{ERT}_{\mathrm{best\ 2009}}$ 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

9 Rosenbrock rotated

Δftarget	1e+03	1e+02	1e+01	1e+00	1e-01	1e-02	1e-03	1e-04	1e-05	1e-07	Δftarget
$\mathrm{ERT}_{\mathrm{best}}/\mathrm{D}$	0.10	0.10	20	65	86	99	107	111	114	119	$\mathrm{ERT}_{\mathrm{best}}/\mathrm{D}$
(1,2)-CMA-ES	444	824	7.0	27	24	22	21	21	21	21	(1,2)-CMA-ES [5, 3]
(1,2m)-CMA-ES	191	326	5.0	11	10	9.1	8.8	8.7	8.7	8.7	(1,2m)-CMA-ES [5]
(1,2ms)-CMA-ES	282	609	5.0	9.3	8.5	7.9	7.7	7.6	7.6	7.5	(1,2ms)-CMA-ES [5]
(1,2s)-CMA-ES	454	2209	15	30	27	25	24	23	23	23	(1,2s)-CMA-ES [3]
(1,4)-CMA-ES	145	657	5.2	9.2	8.3	7.7	7.5	7.3	7.3	7.3	(1,4)-CMA-ES [6, 4]
(1,4m)-CMA-ES	139	717	5.1	8.0	7.2	6.7	6.5	6.4	6.4	6.3	(1,4m)-CMA-ES [6]
(1,4ms)-CMA-ES	**91**	**309**	**3.1**	6.4	5.7	5.3	5.1	5.0	5.0	5.0	(1,4ms)-CMA-ES [1, 6]
(1,4s)-CMA-ES	144	487	3.6	6.2	5.8	5.4	5.3	5.3	5.3	5.3	(1,4s)-CMA-ES [4]
(1+1)-CMA-ES	105	312	**2.7**	7.2	6.3	5.7	5.5	5.4	5.5	5.5	(1+1)-CMA-ES [8]
(1+2ms)-CMA-ES	**90**	**230**	3.8	**5.8**	**5.1**	**4.6**	**4.5**	**4.5**	**4.5**	**4.5**	(1+2ms)-CMA-ES [2]
Artif Bee Colony	489	1323	14	996	5680	*51e-2/1e5*	.	.	.	.	Artif Bee Colony [9]
avg NEWUOA	**69**	**148**	**1.3**	**1.8**	**1.5**	**1.4**	**1.3**	**1.3**	**1.2**	**1.2**	avg NEWUOA [24]
CMA-EGS (IPOP,r1)	435	909	8.8	12	12	11	11	11	11	11	CMA-EGS (IPOP,r1) [13]
Adap DE (F-AUC)	721	1759	22	21	20	19	19	19	20	21	Adap DE (F-AUC) [11]
DE (Uniform)	1175	2869	31	29	28	27	27	27	28	30	DE (Uniform) [10]
IPOP-aCMA-ES	134	322	4.1	**5.2**	**4.8**	**4.5**	**4.4**	**4.4**	**4.4**	**4.5**	IPOP-aCMA-ES [17]
IPOP-CMA-ES	127	328	3.2	6.2	5.8	5.4	5.3	5.2	5.3	5.4	IPOP-CMA-ES [23]
CMA+DE-MOS	659	785	6.4	12	12	11	11	11	11	11	CMA+DE-MOS [19]
NBC-CMA	293	672	5.6	11	11	11	11	11	11	11	NBC-CMA [22]
POEMS	3170	6784	113	1062	1614	2927	*70e-4/3e5*	.	.	.	POEMS [18]
PM-AdapSS-DE	894	2289	26	31	30	29	28	28	29	30	PM-AdapSS-DE [10, 11]
pPOEMS	2956	9087	326	268	313	426	560	694	853	1255	pPOEMS [18, 21]
Basic RCGA	350	811	54	*68e-1/5e4*	.	.	.	.	.	.	Basic RCGA [25]
SPSA	24148	4.43e5	10555	*43e+0/1e5*	.	.	.	.	.	.	SPSA [14]

Table 10: 10-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

10 Ellipsoid

Δftarget	1e+03	1e+02	1e+01	1e+00	1e-01	1e-02	1e-03	1e-04	1e-05	1e-07	Δftarget
ERT$_{\text{best}}$/D	46	104	184	217	245	273	280	308	454	474	ERT$_{\text{best}}$/D
(1,2)-CMA-ES	24	14	9.4	8.8	8.1	7.5	7.4	6.8	4.7	4.6	(1,2)-CMA-ES [5, 3]
(1,2m)-CMA-ES	10	6.6	4.7	4.3	3.9	3.6	3.6	3.3	**2.3**	**2.3**	(1,2m)-CMA-ES [5]
(1,2ms)-CMA-ES	7.7	5.8	4.3	3.8	3.4	3.1	3.1	**2.9**	**2.0**	**1.9**	(1,2ms)-CMA-ES [5]
(1,2s)-CMA-ES	18	13	8.5	8.7	8.1	7.5	7.5	6.9	4.8	4.8	(1,2s)-CMA-ES [3]
(1,4)-CMA-ES	5.5	3.8	**2.9**	**3.0**	**2.8**	**2.6**	**2.6**	**2.4**	**1.6**	**1.6**	(1,4)-CMA-ES [6, 4]
(1,4m)-CMA-ES	4.2	3.3	**2.6**	**2.6**	**2.4**	**2.3**	**2.2**	**2.1**	**1.4**	**1.4**	(1,4m)-CMA-ES [6]
(1,4ms)-CMA-ES	3.4	**2.7**	**2.0**	**2.0**	**1.8**	**1.7**	**1.7**	**1.6**	**1.1**	**1.1**	(1,4ms)-CMA-ES [1, 6]
(1,4s)-CMA-ES	5.4	3.4	**2.5**	**2.5**	**2.3**	**2.2**	**2.2**	**2.0**	**1.4**	**1.4**	(1,4s)-CMA-ES [4]
(1+1)-CMA-ES	**2.6**	**1.9**	**1.8**	**1.8**	**1.7**	**1.6**	**1.6**	**1.4**	**1.0**	**1.0**	(1+1)-CMA-ES [8]
(1+2ms)-CMA-ES	**2.1**	**1.6**	**1.4**	**1.4**	**1.4**	**1.3**	**1.3**	**1.2**	**0.82**	**0.82**	(1+2ms)-CMA-ES [2]
Artif Bee Colony	3835	*11e+2/1e5*	.	.	.	.	.	.	.	.	Artif Bee Colony [9]
avg NEWUOA	**1.3**	**1.3**	**1.9**	3.5	5.4	6.6	9.0	10	8.1	10	avg NEWUOA [24]
CMA-EGS (IPOP,r1)	17	10	6.2	5.6	5.2	4.7	4.7	4.3	**3.0**	**2.9**	CMA-EGS (IPOP,r1) [13]
Adap DE (F-AUC)	6.2	4.0	**2.9**	3.0	3.1	3.3	3.6	3.7	**2.7**	3.1	Adap DE (F-AUC) [11]
DE (Uniform)	7.8	5.2	3.9	4.1	4.4	4.6	5.1	5.2	3.9	4.5	DE (Uniform) [10]
IPOP-aCMA-ES	**2.4**	**1.8**	**1.5**	**1.4**	**1.4**	**1.3**	**1.3**	**1.3**	**0.89**	**0.91**	IPOP-aCMA-ES [17]
IPOP-CMA-ES	4.0	**2.6**	**2.0**	**2.0**	**2.0**	**1.9**	**1.9**	**1.8**	**1.2**	**1.2**	IPOP-CMA-ES [23]
CMA+DE-MOS	8.9	6.0	4.5	4.4	4.3	4.1	4.2	3.9	**2.7**	**2.8**	CMA+DE-MOS [19]
NBC-CMA	4.9	3.7	3.1	3.2	3.2	3.1	3.2	3.0	**2.1**	**2.1**	NBC-CMA [22]
POEMS	353	1546	24342	*33e+0/3e5*	.	.	.	.	.	.	POEMS [18]
PM-AdapSS-DE	7.1	4.5	3.4	3.4	3.6	3.8	4.1	4.2	3.2	3.6	PM-AdapSS-DE [10, 11]
pPOEMS	195	363	1202	6015	8674	*27e-1/3e5*	.	.	.	.	pPOEMS [18, 21]
Basic RCGA	1504	*99e+1/5e4*	.	.	.	.	.	.	.	.	Basic RCGA [25]
SPSA	15075	*19e+2/1e5*	.	.	.	.	.	.	.	.	SPSA [14]

Table 11: 10-D, running time excess $\mathrm{ERT}/\mathrm{ERT}_{\mathrm{best}\ 2009}$ 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

11 Discus

Δftarget	1e+03	1e+02	1e+01	1e+00	1e-01	1e-02	1e-03	1e-04	1e-05	1e-07	Δftarget
$\mathrm{ERT}_{\mathrm{best}}$/D	2.0	2.3	27	104	260	295	334	375	409	484	$\mathrm{ERT}_{\mathrm{best}}$/D
(1,2)-CMA-ES	55	346	38	12	5.3	5.1	4.8	4.4	4.1	3.6	(1,2)-CMA-ES [5, 3]
(1,2m)-CMA-ES	55	228	25	7.4	3.3	3.0	**2.8**	**2.6**	**2.4**	**2.1**	(1,2m)-CMA-ES [5]
(1,2ms)-CMA-ES	53	211	23	6.5	**2.8**	**2.6**	**2.4**	**2.2**	**2.1**	**1.8**	(1,2ms)-CMA-ES [5]
(1,2s)-CMA-ES	117	396	44	13	5.7	5.5	5.2	4.8	4.6	4.0	(1,2s)-CMA-ES [3]
(1,4)-CMA-ES	40	157	19	5.5	**2.4**	**2.3**	**2.2**	**2.0**	**1.9**	**1.7**	(1,4)-CMA-ES [6, 4]
(1,4m)-CMA-ES	51	179	20	5.8	**2.5**	**2.3**	**2.1**	**2.0**	**1.8**	**1.6**	(1,4m)-CMA-ES [6]
(1,4ms)-CMA-ES	33	118	13	3.8	**1.7**	**1.6**	**1.4**	**1.3**	**1.2**	**1.1**	(1,4ms)-CMA-ES [1, 6]
(1,4s)-CMA-ES	28	143	15	4.5	**2.0**	**1.8**	**1.7**	**1.6**	**1.5**	**1.3**	(1,4s)-CMA-ES [4]
(1+1)-CMA-ES	**2.3**	34	10	4.2	**2.2**	**2.1**	**2.0**	**1.8**	**1.7**	**1.5**	(1+1)-CMA-ES [8]
(1+2ms)-CMA-ES	**2.2**	36	**9.2**	**3.7**	**1.8**	**1.8**	**1.7**	**1.6**	**1.5**	**1.3**	(1+2ms)-CMA-ES [2]
Artif Bee Colony	3.3	30	*18e+0/1e5*	.	.	.	.	.	.	.	Artif Bee Colony [9]
avg NEWUOA	10	223	36	18	10	12	14	14	15	15	avg NEWUOA [24]
CMA-EGS (IPOP,r1)	67	621	90	96	40	36	32	29	27	23	CMA-EGS (IPOP,r1) [13]
Adap DE (F-AUC)	6.9	31	**9.2**	**3.6**	**1.9**	**2.1**	**2.2**	**2.3**	**2.4**	**2.5**	Adap DE (F-AUC) [11]
DE (Uniform)	7.8	52	11	4.6	**2.5**	**2.8**	3.0	3.2	3.3	3.5	DE (Uniform) [10]
IPOP-aCMA-ES	**3.2**	51	**7.0**	**2.0**	**0.89**	**0.84**	**0.80**	**0.75**	**0.73**	**0.68**	IPOP-aCMA-ES [17]
IPOP-CMA-ES	4.5	102	13	3.9	**1.7**	**1.6**	**1.5**	**1.4**	**1.3**	**1.2**	IPOP-CMA-ES [23]
CMA+DE-MOS	4.4	**30**	27	8.1	3.6	3.4	3.1	**2.9**	**2.8**	**2.5**	CMA+DE-MOS [19]
NBC-CMA	3.9	**30**	158	43	17	15	14	12	11	10	NBC-CMA [22]
POEMS	92	162	210	204	153	182	206	225	246	260	POEMS [18]
PM-AdapSS-DE	6.1	43	10	4.0	**2.1**	**2.3**	**2.5**	**2.6**	**2.7**	**2.8**	PM-AdapSS-DE [10, 11]
pPOEMS	82	212	206	169	117	150	166	182	196	213	pPOEMS [18, 21]
Basic RCGA	8.7	**21**	3809	*11e+0/5e4*	.	.	.	.	.	.	Basic RCGA [25]
SPSA	75	*34e+1/1e5*	.	.	.	.	.	.	.	.	SPSA [14]

Table 12: 10-D, running time excess $\mathrm{ERT}/\mathrm{ERT}_{\mathrm{best}\ 2009}$ 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

12 Bent cigar

Δftarget	1e+03	1e+02	1e+01	1e+00	1e-01	1e-02	1e-03	1e-04	1e-05	1e-07	Δftarget
$\mathrm{ERT}_{\mathrm{best}}$/D	21	28	52	90	124	139	157	197	366	515	$\mathrm{ERT}_{\mathrm{best}}$/D
(1,2)-CMA-ES	6.1	14	21	24	22	23	23	20	12	9.1	(1,2)-CMA-ES [5, 3]
(1,2m)-CMA-ES	3.3	6.1	8.9	10	9.4	10	10	8.5	5.0	4.0	(1,2m)-CMA-ES [5]
(1,2ms)-CMA-ES	**2.8**	4.4	7.3	7.8	7.5	7.8	7.9	7.0	4.2	3.3	(1,2ms)-CMA-ES [5]
(1,2s)-CMA-ES	4.7	7.0	20	23	24	25	25	21	13	10	(1,2s)-CMA-ES [3]
(1,4)-CMA-ES	**2.8**	**2.6**	5.0	6.9	7.1	7.5	7.5	6.7	3.9	3.1	(1,4)-CMA-ES [6, 4]
(1,4m)-CMA-ES	**2.4**	**2.2**	3.5	5.0	5.5	5.8	5.8	5.2	3.1	**2.5**	(1,4m)-CMA-ES [6]
(1,4ms)-CMA-ES	**1.8**	**2.2**	3.5	**4.8**	**5.1**	**5.4**	**5.4**	**4.8**	**2.9**	**2.3**	(1,4ms)-CMA-ES [1, 6]
(1,4s)-CMA-ES	**2.2**	3.0	7.3	6.9	6.7	6.9	6.8	6.0	3.5	**2.8**	(1,4s)-CMA-ES [4]
(1+1)-CMA-ES	**2.0**	3.4	5.6	5.9	6.4	6.7	6.9	6.0	3.6	3.1	(1+1)-CMA-ES [8]
(1+2ms)-CMA-ES	**1.6**	**1.9**	4.5	6.2	6.5	6.7	6.6	5.9	3.4	**2.8**	(1+2ms)-CMA-ES [2]
Artif Bee Colony	12	19	45	101	631	5044	9120	*41e-3/1e5*	.	.	Artif Bee Colony [9]
avg NEWUOA	**1.1**	**1.7**	4.7	8.0	10	12	12	12	6.9	10	avg NEWUOA [24]
CMA-EGS (IPOP,r1)	5.0	7.9	21	26	27	29	28	25	16	16	CMA-EGS (IPOP,r1) [13]
Adap DE (F-AUC)	26	25	16	12	13	14	15	14	8.9	7.6	Adap DE (F-AUC) [11]
DE (Uniform)	37	36	24	16	17	19	21	21	13	11	DE (Uniform) [10]
IPOP-aCMA-ES	3.6	3.7	**3.3**	**3.4**	**3.7**	**4.0**	**4.1**	**3.8**	**2.3**	**1.9**	IPOP-aCMA-ES [17]
IPOP-CMA-ES	3.4	3.2	**2.0**	**2.6**	**3.7**	**4.4**	**4.6**	**4.4**	**2.7**	**2.2**	IPOP-CMA-ES [23]
CMA+DE-MOS	13	12	9.1	9.4	11	11	12	11	6.3	5.0	CMA+DE-MOS [19]
NBC-CMA	5.9	5.5	**3.4**	5.6	7.1	8.6	9.0	8.4	5.1	4.2	NBC-CMA [22]
POEMS	159	163	3019	6767	33921	*40e-1/3e5*	.	.	.	.	POEMS [18]
PM-AdapSS-DE	30	30	19	14	15	17	19	20	13	11	PM-AdapSS-DE [10, 11]
pPOEMS	535	736	992	3368	10102	30597	27208	21660	*92e-2/3e5*	.	pPOEMS [18, 21]
Basic RCGA	121	162	120	261	1179	2405	*39e-2/5e4*	.	.	.	Basic RCGA [25]
SPSA	3471	2878	4252	*21e+0/1e5*	.	.	.	.	.	.	SPSA [14]

Table 13: 10-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

13 Sharp ridge

Δftarget	1e+03	1e+02	1e+01	1e+00	1e-01	1e-02	1e-03	1e-04	1e-05	1e-07	Δftarget
ERT$_{\text{best}}$/D	1.2	7.8	39	60	80	101	459	534	621	778	ERT$_{\text{best}}$/D
(1,2)-CMA-ES	20	10	17	29	51	91	42	130	233	*44e-4/1e4*	(1,2)-CMA-ES [5, 3]
(1,2m)-CMA-ES	6.8	5.3	10	26	37	53	24	58	108	*37e-5/1e4*	(1,2m)-CMA-ES [5]
(1,2ms)-CMA-ES	6.1	6.7	4.2	15	20	46	26	82	110	182	(1,2ms)-CMA-ES [5]
(1,2s)-CMA-ES	15	9.1	19	45	99	188	99	280	*18e-3/1e4*	.	(1,2s)-CMA-ES [3]
(1,4)-CMA-ES	5.7	4.5	6.5	15	18	17	9.3	14	20	27	(1,4)-CMA-ES [6, 4]
(1,4m)-CMA-ES	4.1	3.9	5.0	13	14	13	5.5	6.4	15	39	(1,4m)-CMA-ES [6]
(1,4ms)-CMA-ES	**3.2**	3.3	3.9	6.4	12	12	4.3	4.9	6.1	19	(1,4ms)-CMA-ES [1, 6]
(1,4s)-CMA-ES	4.9	3.6	6.4	14	13	16	6.3	6.7	11	26	(1,4s)-CMA-ES [4]
(1+1)-CMA-ES	3.9	**3.2**	**3.1**	6.5	**6.1**	10	**2.5**	**2.4**	4.0	5.9	(1+1)-CMA-ES [8]
(1+2ms)-CMA-ES	**2.7**	**2.6**	4.3	**6.0**	7.0	**8.8**	**2.8**	**2.9**	**2.7**	6.6	(1+2ms)-CMA-ES [2]
Artif Bee Colony	15	26	19	202	2453	*18e-2/1e5*	.	.	.	.	Artif Bee Colony [9]
avg NEWUOA	**3.6**	**1.4**	**3.0**	13	30	76	32	70	278	*39e-5/1e4*	avg NEWUOA [24]
CMA-EGS (IPOP,r1)	12	7.3	6.2	21	316	887	196	380	448	1804	CMA-EGS (IPOP,r1) [13]
Adap DE (F-AUC)	16	33	12	12	12	11	3.0	3.0	**3.0**	**2.9**	Adap DE (F-AUC) [11]
DE (Uniform)	17	43	17	17	17	16	4.4	4.4	4.3	4.3	DE (Uniform) [10]
IPOP-aCMA-ES	4.2	4.9	**2.4**	**3.5**	**3.2**	**3.3**	**1.00**	**1.0**	**1.0**	**1.1**	IPOP-aCMA-ES [17]
IPOP-CMA-ES	5.6	5.4	3.8	**5.0**	**5.1**	**4.4**	**1.2**	**1.2**	**1.5**	**1.6**	IPOP-CMA-ES [23]
CMA+DE-MOS	9.2	19	7.3	12	15	12	3.2	3.2	3.1	3.0	CMA+DE-MOS [19]
NBC-CMA	7.6	9.4	4.4	10	11	9.0	**2.8**	**2.7**	3.2	3.5	NBC-CMA [22]
POEMS	191	139	85	3446	15152	19327	*61e-2/3e5*	.	.	.	POEMS [18]
PM-AdapSS-DE	20	36	14	14	13	13	3.5	3.5	3.4	3.4	PM-AdapSS-DE [10, 11]
pPOEMS	182	167	291	812	3189	12540	9357	8099	7024	*70e-3/3e5*	pPOEMS [18, 21]
Basic RCGA	11	88	158	1230	2678	7130	*17e-1/5e4*	.	.	.	Basic RCGA [25]
SPSA	93	894	12420	*13e+0/1e5*	.	.	.	.	.	.	SPSA [14]

Table 14: 10-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

14 Sum of different powers

Δftarget	1e+03	1e+02	1e+01	1e+00	1e-01	1e-02	1e-03	1e-04	1e-05	1e-07	Δftarget
ERT$_{\text{best}}$/D	0.10	0.10	3.7	10	13	20	39	50	69	430	ERT$_{\text{best}}$/D
(1,2)-CMA-ES	**1**	3.8	9.1	6.7	6.9	7.6	7.9	10	12	4.3	(1,2)-CMA-ES [5, 3]
(1,2m)-CMA-ES	**1**	4.0	4.2	3.7	3.9	4.2	4.4	6.3	7.7	**2.5**	(1,2m)-CMA-ES [5]
(1,2ms)-CMA-ES	**1**	**2.9**	3.4	**2.8**	3.0	3.3	3.6	5.3	6.7	**2.1**	(1,2ms)-CMA-ES [5]
(1,2s)-CMA-ES	**1**	23	10	6.6	7.1	7.7	7.6	11	13	4.0	(1,2s)-CMA-ES [3]
(1,4)-CMA-ES	**1**	7.5	**2.8**	**2.8**	3.2	3.7	3.6	5.3	6.1	**1.8**	(1,4)-CMA-ES [6, 4]
(1,4m)-CMA-ES	**1**	3.3	**2.3**	**2.4**	**2.7**	**3.0**	3.1	4.4	5.5	**1.6**	(1,4m)-CMA-ES [6]
(1,4ms)-CMA-ES	**1**	**1.9**	**2.1**	**1.9**	**2.2**	**2.5**	**2.6**	**3.6**	**4.4**	**1.3**	(1,4ms)-CMA-ES [1, 6]
(1,4s)-CMA-ES	**1**	7.3	**2.8**	**2.5**	**2.9**	3.1	3.1	4.1	4.8	**1.4**	(1,4s)-CMA-ES [4]
(1+1)-CMA-ES	**1**	3.4	**2.0**	**1.9**	**2.3**	**2.4**	**2.4**	3.8	4.9	**1.1**	(1+1)-CMA-ES [8]
(1+2ms)-CMA-ES	**1**	3.1	**1.8**	**1.6**	**2.0**	**2.1**	**2.1**	**3.0**	**3.7**	**1.0**	(1+2ms)-CMA-ES [2]
Artif Bee Colony	**1**	**1.9**	6.4	17	22	35	703	*64e-5/1e5*	.	.	Artif Bee Colony [9]
avg NEWUOA	**1**	9.2	**1.7**	**1.3**	**1.3**	**1.2**	**1.1**	**2.2**	7.1	64	avg NEWUOA [24]
CMA-EGS (IPOP,r1)	8.9	71	9.2	5.7	6.1	6.2	8.4	19	26	64	CMA-EGS (IPOP,r1) [13]
Adap DE (F-AUC)	**1**	**2.1**	10	18	26	24	16	15	13	**2.8**	Adap DE (F-AUC) [11]
DE (Uniform)	**1**	**2.0**	9.5	25	34	33	22	22	19	4.1	DE (Uniform) [10]
IPOP-aCMA-ES	**1**	3.7	**2.1**	**2.8**	3.7	3.8	3.1	3.6	**3.5**	**0.84**	IPOP-aCMA-ES [17]
IPOP-CMA-ES	**1**	5.4	**2.2**	**2.9**	3.8	4.2	3.8	4.8	5.0	**1.3**	IPOP-CMA-ES [23]
CMA+DE-MOS	**1**	3.0	7.5	13	14	14	13	15	14	3.2	CMA+DE-MOS [19]
NBC-CMA	**1**	**2.3**	5.2	5.7	6.5	6.3	5.1	6.6	7.1	**1.9**	NBC-CMA [22]
POEMS	**1**	847	73	53	105	142	116	186	1491	*33e-7/3e5*	POEMS [18]
PM-AdapSS-DE	**1**	**1.9**	13	21	29	27	19	18	15	3.2	PM-AdapSS-DE [10, 11]
pPOEMS	**1**	103	73	61.3							

Table 15: 10-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

15 Rastrigin

Δftarget	1e+03	1e+02	1e+01	1e+00	1e-01	1e-02	1e-03	1e-04	1e-05	1e-07	Δftarget
ERT$_{\text{best}}$/D	0.10	19	477	3925	7364	7467	7579	7674	7781	7983	ERT$_{\text{best}}$/D
(1,2)-CMA-ES	8.3	18	*31e+0/1e4*	.	.	.	.	.	.	.	(1,2)-CMA-ES [5, 3]
(1,2m)-CMA-ES	**1.1**	**2.0**	72	*14e+0/1e4*	.	.	.	.	.	.	(1,2m)-CMA-ES [5]
(1,2ms)-CMA-ES	**1.5**	**2.0**	62	*12e+0/1e4*	.	.	.	.	.	.	(1,2ms)-CMA-ES [5]
(1,2s)-CMA-ES	4.5	39	*29e+0/1e4*	.	.	.	.	.	.	.	(1,2s)-CMA-ES [3]
(1,4)-CMA-ES	**1.4**	4.8	146	*15e+0/1e4*	.	.	.	.	.	.	(1,4)-CMA-ES [6, 4]
(1,4m)-CMA-ES	**1.6**	**1.1**	55	*11e+0/1e4*	.	.	.	.	.	.	(1,4m)-CMA-ES [6]
(1,4ms)-CMA-ES	**1**	**1.6**	24	*90e-1/1e4*	.	.	.	.	.	.	(1,4ms)-CMA-ES [1, 6]
(1,4s)-CMA-ES	**1.7**	4.1	137	*13e+0/1e4*	.	.	.	.	.	.	(1,4s)-CMA-ES [4]
(1+1)-CMA-ES	3.5	3.6	148	*16e+0/1e4*	.	.	.	.	.	.	(1+1)-CMA-ES [8]
(1+2ms)-CMA-ES	4.8	5.2	143	*16e+0/1e4*	.	.	.	.	.	.	(1+2ms)-CMA-ES [2]
Artif Bee Colony	**1.7**	7.3	*14e+0/1e5*	.	.	.	.	.	.	.	Artif Bee Colony [9]
avg NEWUOA	5.5	4.3	231	*25e+0/7e3*	.	.	.	.	.	.	avg NEWUOA [24]
CMA-EGS (IPOP,r1)	61	**1.8**	17	370	*30e-1/1e5*	.	.	.	.	.	CMA-EGS (IPOP,r1) [13]
Adap DE (F-AUC)	**1.8**	6.1	65	110	194	191	188	186	183	179	Adap DE (F-AUC) [11]
DE (Uniform)	**2.2**	7.8	68	50	93	92	91	89	88	86	DE (Uniform) [10]
IPOP-aCMA-ES	**2.3**	**0.99**	**0.91**	**1.0**	**0.83**	**0.84**	**0.84**	**0.85**	**0.85**	**0.86**	IPOP-aCMA-ES [17]
IPOP-CMA-ES	4.1	**1.2**	**1.3**	**1.0**	**0.82**	**0.82**	**0.83**	**0.83**	**0.84**	**0.85**	IPOP-CMA-ES [23]
CMA+DE-MOS	**2.1**	4.4	**1.3**	**1.7**	**1.3**	**1.3**	**1.3**	**1.3**	**1.3**	**1.3**	CMA+DE-MOS [19]
NBC-CMA	**1.7**	**2.2**	**2.5**	108	*30e-1/3e4*	.	.	.	.	.	NBC-CMA [22]
POEMS	438	18	321	*80e-1/3e5*	.	.	.	.	.	.	POEMS [18]
PM-AdapSS-DE	**2.1**	7.1	72	18	17	26	59	189	*66e-3/1e5*	.	PM-AdapSS-DE [10, 11]
pPOEMS	**1.8**	18	140	*60e-1/3e5*	.	.	.	.	.	.	pPOEMS [18, 21]
Basic RCGA	**1.4**	5.0	17	86	98	97	96	94	93	91	Basic RCGA [25]
SPSA	6.71e5	3796	*72e+0/1e5*	.	.	.	.	.	.	.	SPSA [14]

Table 16: 10-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

16 Weierstrass

Δftarget	1e+03	1e+02	1e+01	1e+00	1e-01	1e-02	1e-03	1e-04	1e-05	1e-07	Δftarget
ERT$_{\text{best}}$/D	0.10	0.10	43	703	1578	4567	5115	6511	6580	7157	ERT$_{\text{best}}$/D
(1,2)-CMA-ES	**1**	**1.7**	553	*11e+0/1e4*	.	.	.	.	.	.	(1,2)-CMA-ES [5, 3]
(1,2m)-CMA-ES	**1**	**1.4**	26	96	*25e-1/1e4*	.	.	.	.	.	(1,2m)-CMA-ES [5]
(1,2ms)-CMA-ES	**1**	**1.3**	32	96	*32e-1/1e4*	.	.	.	.	.	(1,2ms)-CMA-ES [5]
(1,2s)-CMA-ES	**1**	**1.3**	779	*15e+0/1e4*	.	.	.	.	.	.	(1,2s)-CMA-ES [3]
(1,4)-CMA-ES	**1**	**1.5**	22	45	*20e-1/1e4*	.	.	.	.	.	(1,4)-CMA-ES [6, 4]
(1,4m)-CMA-ES	**1**	**1.4**	11	14	91	*64e-2/1e4*	.	.	.	.	(1,4m)-CMA-ES [6]
(1,4ms)-CMA-ES	**1**	**1.4**	12	24	*13e-1/1e4*	.	.	.	.	.	(1,4ms)-CMA-ES [1, 6]
(1,4s)-CMA-ES	**1**	**1.5**	27	97	*28e-1/1e4*	.	.	.	.	.	(1,4s)-CMA-ES [4]
(1+1)-CMA-ES	**1**	**1.7**	5.2	46	*16e-1/1e4*	.	.	.	.	.	(1+1)-CMA-ES [8]
(1+2ms)-CMA-ES	**1**	**1.2**	4.2	97	*13e-1/1e4*	.	.	.	.	.	(1+2ms)-CMA-ES [2]
Artif Bee Colony	**1**	**1.3**	3.3	149	*92e-2/1e5*	.	.	.	.	.	Artif Bee Colony [9]
avg NEWUOA	**1**	**1.5**	**3.3**	41	*13e-1/1e4*	.	.	.	.	.	avg NEWUOA [24]
CMA-EGS (IPOP,r1)	**1**	53	14	20	89	308	*10e-2/1e5*	.	.	.	CMA-EGS (IPOP,r1) [13]
Adap DE (F-AUC)	**1**	**1.7**	70	*51e-1/1e5*	.	.	.	.	.	.	Adap DE (F-AUC) [11]
DE (Uniform)	**1**	**1.7**	104	*45e-1/1e5*	.	.	.	.	.	.	DE (Uniform) [10]
IPOP-aCMA-ES	**1**	**1.3**	**1.6**	**0.95**	**1.2**	**0.84**	**1.1**	**0.91**	**0.92**	**0.87**	IPOP-aCMA-ES [17]
IPOP-CMA-ES	**1**	**1.3**	3.5	**1.2**	**1.2**	**0.87**	**0.90**	**0.72**	**0.75**	**0.71**	IPOP-CMA-ES [23]
CMA+DE-MOS	**1**	**1.3**	**2.6**	**0.55**	**0.99**	**1.2**	**1.4**	**1.1**	**1.2**	**1.2**	CMA+DE-MOS [19]
NBC-CMA	**1**	**1.5**	9.4	**0.71**	**1.3**	**1.8**	**2.9**	3.5	11	19	NBC-CMA [22]
POEMS	**1**	**1**	11	3.8	130	428	382	301	298	274	POEMS [18]
PM-AdapSS-DE	**1**	**1.5**	70	*34e-1/1e5*	.	.	.	.	.	.	PM-AdapSS-DE [10, 11]
pPOEMS	**1**	**1.3**	16	18	89	189	243	192	192	178	pPOEMS [18, 21]
Basic RCGA	**1**	**1.3**	7.9	13	38	50	142	112	*87e-3/5e4*	.	Basic RCGA [25]
SPSA	**1**	1551	1239	2107	*56e-1/1e5*	.	.	.	.	.	SPSA [14]

Table 17: 10-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

Table 18: 10-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

18 Schaffer F7, condition 1000

Δftarget	1e+03	1e+02	1e+01	1e+00	1e-01	1e-02	1e-03	1e-04	1e-05	1e-07	Δftarget
ERT$_{\text{best}}$/D	0.10	0.19	24	84	701	1593	2754	3161	3723	4271	ERT$_{\text{best}}$/D
(1,2)-CMA-ES	**2.6**	18	139	*78e-1/1e4*	.	.	.	.	.	.	(1,2)-CMA-ES [5, 3]
(1,2m)-CMA-ES	**1**	4.2	**1.8**	171	*11e-1/1e4*	.	.	.	.	.	(1,2m)-CMA-ES [5]
(1,2ms)-CMA-ES	**1.1**	8.8	7.6	224	*13e-1/1e4*	.	.	.	.	.	(1,2ms)-CMA-ES [5]
(1,2s)-CMA-ES	**1.9**	19	297	*74e-1/1e4*	.	.	.	.	.	.	(1,2s)-CMA-ES [3]
(1,4)-CMA-ES	**1**	10	61	384	*18e-1/1e4*	.	.	.	.	.	(1,4)-CMA-ES [6, 4]
(1,4m)-CMA-ES	**1**	5.7	13	82	205	*58e-2/1e4*	.	.	.	.	(1,4m)-CMA-ES [6]
(1,4ms)-CMA-ES	**1**	**1.8**	6.4	137	*83e-2/1e4*	.	.	.	.	.	(1,4ms)-CMA-ES [1, 6]
(1,4s)-CMA-ES	**1**	6.6	39	811	*23e-1/1e4*	.	.	.	.	.	(1,4s)-CMA-ES [4]
(1+1)-CMA-ES	**1.4**	6.6	93	*48e-1/1e4*	.	.	.	.	.	.	(1+1)-CMA-ES [8]
(1+2ms)-CMA-ES	**1**	**2.5**	63	*39e-1/1e4*	.	.	.	.	.	.	(1+2ms)-CMA-ES [2]
Artif Bee Colony	**1**	4.7	63	7923	*18e-1/1e5*	.	.	.	.	.	Artif Bee Colony [9]
avg NEWUOA	**1**	10	73	*32e-1/9e4*	.	.	.	.	.	.	avg NEWUOA [24]
CMA-EGS (IPOP,r1)	40	46	**1.8**	4.7	3.7	4.3	23	135	*54e-5/1e5*	.	CMA-EGS (IPOP,r1) [13]
Adap DE (F-AUC)	**1**	**2.9**	7.6	6.5	**1.4**	**0.96**	**0.76**	**0.81**	**0.90**	**0.99**	Adap DE (F-AUC) [11]
DE (Uniform)	**1.3**	3.4	9.5	9.0	**2.0**	**1.3**	**1.0**	**1.1**	**1.2**	**1.4**	DE (Uniform) [10]
IPOP-aCMA-ES	**1**	7.7	**1.2**	**1.6**	**0.82**	**0.97**	**0.78**	**0.88**	**0.80**	**0.88**	IPOP-aCMA-ES [17]
IPOP-CMA-ES	**1**	**2.1**	**1.1**	**1.7**	**0.95**	**0.95**	**0.84**	**1.0**	**0.97**	**0.91**	IPOP-CMA-ES [23]
CMA+DE-MOS	**1.1**	**2.8**	5.4	3.5	**0.85**	**1.2**	**0.87**	**1.0**	**1.1**	**1.3**	CMA+DE-MOS [19]
NBC-CMA	**1**	3.0	**2.0**	**1.5**	**0.54**	**2.4**	9.1	139	118	*31e-5/3e4*	NBC-CMA [22]
POEMS	**1**	613	20	285	162	287	439	1332	*25e-3/3e5*	.	POEMS [18]
PM-AdapSS-DE	**1.1**	**1.8**	8.4	7.4	**1.6**	**1.1**	**0.81**	**0.89**	**0.95**	**1.0**	PM-AdapSS-DE [10, 11]
pPOEMS	**1**	74	20	116	42	46	54	93	123	230	pPOEMS [18, 21]
Basic RCGA	**1**	**1.6**	8.3	114	36	48	58	229	*14e-3/5e4*	.	Basic RCGA [25]
SPSA	8.78e5	1.04e6	*66e+1/1e5*	.	.	.	.	.	.	.	SPSA [14]

Table 19: 10-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

19 Griewank-Rosenbrock F8F2

Δftarget	1e+03	1e+02	1e+01	1e+00	1e-01	1e-02	1e-03	1e-04	1e-05	1e-07	Δftarget
ERT$_{\text{best}}$/D	0.10	0.10	0.10	0.10	1061	98379	1.37e5	1.37e5	1.38e5	1.39e5	ERT$_{\text{best}}$/D
(1,2)-CMA-ES	**1**	**1**	514	7.33e5	*24e-1/1e4*	.	.	.	.	.	(1,2)-CMA-ES [5, 3]
(1,2m)-CMA-ES	**1**	**1**	128	1.55e5	*90e-2/1e4*	.	.	.	.	.	(1,2m)-CMA-ES [5]
(1,2ms)-CMA-ES	**1**	**1**	164	2.24e5	*11e-1/1e4*	.	.	.	.	.	(1,2ms)-CMA-ES [5]
(1,2s)-CMA-ES	**1**	**1**	239	1.46e6	*32e-1/1e4*	.	.	.	.	.	(1,2s)-CMA-ES [3]
(1,4)-CMA-ES	**1**	**1**	82	1.99e5	*13e-1/1e4*	.	.	.	.	.	(1,4)-CMA-ES [6, 4]
(1,4m)-CMA-ES	**1**	**1**	68	45284	*58e-2/1e4*	.	.	.	.	.	(1,4m)-CMA-ES [6]
(1,4ms)-CMA-ES	**1**	**1**	57	43406	*68e-2/1e4*	.	.	.	.	.	(1,4ms)-CMA-ES [1, 6]
(1,4s)-CMA-ES	**1**	**1**	79	75584	*77e-2/1e4*	.	.	.	.	.	(1,4s)-CMA-ES [4]
(1+1)-CMA-ES	**1**	**1**	63	65610	*85e-2/1e4*	.	.	.	.	.	(1+1)-CMA-ES [8]
(1+2ms)-CMA-ES	**1**	**1**	**54**	22281	*55e-2/1e4*	.	.	.	.	.	(1+2ms)-CMA-ES [2]
Artif Bee Colony	**1**	**1.1**	410	4.22e6	*12e-1/1e5*	.	.	.	.	.	Artif Bee Colony [9]
avg NEWUOA	**1**	**1**	**48**	7.08e5	*83e-2/1e5*	.	.	.	.	.	avg NEWUOA [24]
CMA-EGS (IPOP,r1)	23	64	223	28056	422	*20e-2/1e5*	.	.	.	.	CMA-EGS (IPOP,r1) [13]
Adap DE (F-AUC)	**1**	**1.2**	303	4.04e5	*59e-2/1e5*	.	.	.	.	.	Adap DE (F-AUC) [11]
DE (Uniform)	**1**	**1.2**	390	8.37e5	*52e-2/1e5*	.	.	.	.	.	DE (Uniform) [10]
IPOP-aCMA-ES	**1**	**1**	68	**9042**	**10**	**0.61**	**0.53**	**0.53**	**0.53**	**0.54**	IPOP-aCMA-ES [17]
IPOP-CMA-ES	**1**	**1**	**56**	**12509**	**8.9**	**0.55**	**0.53**	**0.53**	**0.53**	**0.53**	IPOP-CMA-ES [23]
CMA+DE-MOS	**1**	**1.1**	212	**5852**	**6.5**	**1.2**	**1.1**	**1.1**	**1.1**	**1.1**	CMA+DE-MOS [19]
NBC-CMA	**1**	**1.2**	117	2.11e6	*15e-1/3e4*	.	.	.	.	.	NBC-CMA [22]
POEMS	**1**	253	2538	5.19e5	4011	*55e-2/3e5*	.	.	.	.	POEMS [18]
PM-AdapSS-DE	**1**	**1.7**	256	5.48e5	*81e-2/1e5*	.	.	.	.	.	PM-AdapSS-DE [10, 11]
pPOEMS	**1**	**1.2**	2624	3.58e5	4022	*23e-2/3e5*	.	.	.	.	pPOEMS [18, 21]
Basic RCGA	**1**	**1.2**	167	70727	157	*17e-2/5e4*	.	.	.	.	Basic RCGA [25]
SPSA	44	126	658	6.65e6	*18e-1/1e5*	.	.	.	.	.	SPSA [14]

Table 20: 10-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

20 Schwefel x*sin(x)

Δftarget	1e+03	1e+02	1e+01	1e+00	1e-01	1e-02	1e-03	1e-04	1e-05	1e-07	Δftarget
ERT$_{\text{best}}$/D	2.6	3.0	3.2	1543	55001	56739	57252	57645	58096	58926	ERT$_{\text{best}}$/D
(1,2)-CMA-ES	11	12	12	10	*99e-2/1e4*	.	.	.	.	.	(1,2)-CMA-ES [5, 3]
(1,2m)-CMA-ES	6.2	6.6	6.7	5.6	*91e-2/1e4*	.	.	.	.	.	(1,2m)-CMA-ES [5]
(1,2ms)-CMA-ES	5.7	5.8	5.9	**2.3**	*87e-2/1e4*	.	.	.	.	.	(1,2ms)-CMA-ES [5]
(1,2s)-CMA-ES	11	11	12	9.5	*10e-1/1e4*	.	.	.	.	.	(1,2s)-CMA-ES [3]
(1,4)-CMA-ES	4.9	5.1	5.3	**2.6**	*89e-2/1e4*	.	.	.	.	.	(1,4)-CMA-ES [6, 4]
(1,4m)-CMA-ES	3.9	4.5	4.5	**2.3**	*79e-2/1e4*	.	.	.	.	.	(1,4m)-CMA-ES [6]
(1,4ms)-CMA-ES	**3.2**	3.6	3.9	**2.6**	*69e-2/1e4*	.	.	.	.	.	(1,4ms)-CMA-ES [1, 6]
(1,4s)-CMA-ES	3.8	4.0	4.4	3.1	*87e-2/1e4*	.	.	.	.	.	(1,4s)-CMA-ES [4]
(1+1)-CMA-ES	3.4	**3.4**	**3.8**	3.9	*87e-2/1e4*	.	.	.	.	.	(1+1)-CMA-ES [8]
(1+2ms)-CMA-ES	**2.5**	**2.7**	**2.9**	3.3	*83e-2/1e4*	.	.	.	.	.	(1+2ms)-CMA-ES [2]
Artif Bee Colony	8.6	9.5	10	**0.18**	**1.3**	**1.3**	**1.3**	**1.4**	**2.1**	6.0	Artif Bee Colony [9]
avg NEWUOA	**1.5**	**1.3**	**1.2**	37	*12e-1/8e3*	.	.	.	.	.	avg NEWUOA [24]
CMA-EGS (IPOP,r1)	10	11	11	*18e-1/1e5*	.	.	.	.	.	.	CMA-EGS (IPOP,r1) [13]
Adap DE (F-AUC)	19	27	28	18	26	25	25	25	25	24	Adap DE (F-AUC) [11]
DE (Uniform)	30	35	38	15	5.4	5.3	5.2	5.2	5.1	5.1	DE (Uniform) [10]
IPOP-aCMA-ES	3.4	4.3	4.3	**2.3**	**0.84**	**0.86**	**0.87**	**0.87**	**0.88**	**0.89**	IPOP-aCMA-ES [17]
IPOP-CMA-ES	3.5	4.3	4.6	**2.8**	**0.78**	**0.79**	**0.79**	**0.80**	**0.80**	**0.81**	IPOP-CMA-ES [23]
CMA+DE-MOS	15	20	21	**0.76**	**0.14**	**0.19**	**0.26**	**0.29**	**0.30**	**0.42**	CMA+DE-MOS [19]
NBC-CMA	6.2	11	12	5.9	*77e-2/3e4*	.	.	.	.	.	NBC-CMA [22]
POEMS	99	100	104	**1.1**	15	15	15	15	14	14	POEMS [18]
PM-AdapSS-DE	24	30	31	23	*36e-2/1e5*	.	.	.	.	.	PM-AdapSS-DE [10, 11]
pPOEMS	104	105	104	3.4	15	15	15	15	15	15	pPOEMS [18, 21]
Basic RCGA	10	13	14	484	*17e-1/5e4*	.	.	.	.	.	Basic RCGA [25]
SPSA	12	15	19	*19e-1/1e5*	.	.	.	.	.	.	SPSA [14]

Table 21: 10-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

21 Gallagher 101 peaks

Δftarget	1e+03	1e+02	1e+01	1e+00	1e-01	1e-02	1e-03	1e-04	1e-05	1e-07	Δftarget
ERT$_{\text{best}}$/D	0.10	0.10	13	224	439	449	462	486	507	1133	ERT$_{\text{best}}$/D
(1,2)-CMA-ES	**1**	**1**	18	14	22	21	21	20	19	8.4	(1,2)-CMA-ES [5, 3]
(1,2m)-CMA-ES	**1**	**1**	8.4	11	14	14	13	13	12	5.5	(1,2m)-CMA-ES [5]
(1,2ms)-CMA-ES	**1**	**1**	4.3	**5.4**	7.3	7.1	7.0	6.6	6.4	**2.9**	(1,2ms)-CMA-ES [5]
(1,2s)-CMA-ES	**1**	**1**	39	20	18	18	17	17	16	7.2	(1,2s)-CMA-ES [3]
(1,4)-CMA-ES	**1**	**1**	6.2	6.4	11	11	10	10	10	4.3	(1,4)-CMA-ES [6, 4]
(1,4m)-CMA-ES	**1**	**1**	4.2	6.7	**4.7**	**4.6**	**4.5**	**4.3**	**4.1**	**1.9**	(1,4m)-CMA-ES [6]
(1,4ms)-CMA-ES	**1**	**1**	4.8	**4.3**	**3.6**	**3.5**	**3.4**	**3.3**	**3.1**	**1.4**	(1,4ms)-CMA-ES [1, 6]
(1,4s)-CMA-ES	**1**	**1**	7.0	6.4	6.9	6.8	6.6	6.3	6.0	**2.7**	(1,4s)-CMA-ES [4]
(1+1)-CMA-ES	**1**	**1**	4.2	6.3	**4.4**	**4.3**	**4.2**	**4.0**	**3.8**	**1.7**	(1+1)-CMA-ES [8]
(1+2ms)-CMA-ES	**1**	**1**	**4.1**	6.5	6.0	5.8	5.7	5.4	5.2	**2.3**	(1+2ms)-CMA-ES [2]
Artif Bee Colony	**1**	**1**	8.0	**2.9**	8.5	10	12	24	39	82	Artif Bee Colony [9]
avg NEWUOA	**1**	**1**	**3.2**	8.2	4.7	4.7	4.5	4.3	4.1	**1.9**	avg NEWUOA [24]
CMA-EGS (IPOP,r1)	**1**	62	13	101	60	59	58	56	55	25	CMA-EGS (IPOP,r1) [13]
Adap DE (F-AUC)	**1**	**1**	23	114	84	83	81	77	74	33	Adap DE (F-AUC) [11]
DE (Uniform)	**1**	**1**	25	115	116	113	110	105	101	45	DE (Uniform) [10]
IPOP-aCMA-ES	**1**	**1**	**2.6**	31	58	57	55	53	50	23	IPOP-aCMA-ES [17]
IPOP-CMA-ES	**1**	**1**	5.9	14	52	51	50	47	45	21	IPOP-CMA-ES [23]
CMA+DE-MOS	**1**	**1**	25	347	512	503	489	466	447	201	CMA+DE-MOS [19]
NBC-CMA	**1**	**1**	12	275	188	184	179	170	163	73	NBC-CMA [22]
POEMS	**1**		3498	2668	1648	1615	1570	1494	1431	642	POEMS [18]
PM-AdapSS-DE	**1**										

Table 22: 10-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

22 Gallagher 21 peaks

Δftarget	1e+03	1e+02	1e+01	1e+00	1e-01	1e-02	1e-03	1e-04	1e-05	1e-07	Δftarget
ERT$_{\text{best}}$/D	0.10	0.1[illegible]	10	284	635	662	680	692	830	1035	ERT$_{\text{best}}$/D
(1,2)-CMA-ES	**1**	**1**	19	9.2	30	29	28	28	23	19	(1,2)-CMA-ES [5, 3]
(1,2m)-CMA-ES	**1**	**1**	[illegible]	9.3	18	17	16	16	14	11	(1,2m)-CMA-ES [5]
(1,2ms)-CMA-ES	**1**	**1**	[illegible]	11	25	24	24	23	19	16	(1,2ms)-CMA-ES [5]
(1,2s)-CMA-ES	**1**	**1**	62								

Table 23: 10-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

23 Katsuuras

Δftarget	1e+03	1e+02	1e+01	1e+00	1e-01	1e-02	1e-03	1e-04	1e-05	1e-07	Δftarget
ERT$_{\text{best}}$/D	0.10	0.10	0.28	92	1643	18390	20350	20641	20893	21351	ERT$_{\text{best}}$/D
(1,2)-CMA-ES	**1**	**1**	38	1557	*14e-1/1e4*	.	.	.	.	.	(1,2)-CMA-ES [5, 3]
(1,2m)-CMA-ES	**1**	**1**	4.7	68	*35e-2/1e4*	.	.	.	.	.	(1,2m)-CMA-ES [5]
(1,2ms)-CMA-ES	**1**	**1**	8.6	70	*39e-2/1e4*	.	.	.	.	.	(1,2ms)-CMA-ES [5]
(1,2s)-CMA-ES	**1**	**1**	44	797	*14e-1/1e4*	.	.	.	.	.	(1,2s)-CMA-ES [3]
(1,4)-CMA-ES	**1**	**1**	7.5	33	*35e-2/1e4*	.	.	.	.	.	(1,4)-CMA-ES [6, 4]
(1,4m)-CMA-ES	**1**	**1**	5.7	33	*34e-2/1e4*	.	.	.	.	.	(1,4m)-CMA-ES [6]
(1,4ms)-CMA-ES	**1**	**1**	5.0	15	91	*23e-2/1e4*	.	.	.	.	(1,4ms)-CMA-ES [1, 6]
(1,4s)-CMA-ES	**1**	**1**	5.7	58	*60e-2/1e4*	.	.	.	.	.	(1,4s)-CMA-ES [4]
(1+1)-CMA-ES	**1**	**1**	6.5	**4.5**	*28e-2/1e4*	.	.	.	.	.	(1+1)-CMA-ES [8]
(1+2ms)-CMA-ES	**1**	**1**	5.1	**4.5**	*26e-2/1e4*	.	.	.	.	.	(1+2ms)-CMA-ES [2]
Artif Bee Colony	**1**	**1**	**2.5**	33	*49e-2/1e5*	.	.	.	.	.	Artif Bee Colony [9]
avg NEWUOA	**1**	**1**	11	**2.6**	*21e-2/1e4*	.	.	.	.	.	avg NEWUOA [24]
CMA-EGS (IPOP,r1)	**1**	35	34	397	*84e-2/1e5*	.	.	.	.	.	CMA-EGS (IPOP,r1) [13]
Adap DE (F-AUC)	**1**	**1**	**2.3**	85	160	*15e-2/1e5*	.	.	.	.	Adap DE (F-AUC) [11]
DE (Uniform)	**1**	**1**	**1.5**	97	278	**80**	**72**	**71**	**70**	**69**	DE (Uniform) [10]
IPOP-aCMA-ES	**1**	**1**	**1.8**	458	*71e-2/2e5*	.	.	.	.	.	IPOP-aCMA-ES [17]
IPOP-CMA-ES	**1**	**1**	**2.4**	376	308	**65**	**59**	**58**	**57**	**56**	IPOP-CMA-ES [23]
CMA+DE-MOS	**1**	**1**	**1.7**	24	**15**	**4.0**	**3.6**	**3.6**	**3.6**	**3.5**	CMA+DE-MOS [19]
NBC-CMA	**1**	**1**	**1.4**	692	*11e-1/3e4*	.	.	.	.	.	NBC-CMA [22]
POEMS	**1**	**1**	9.1	26	**50**	107	*36e-3/3e5*	.	.	.	POEMS [18]
PM-AdapSS-DE	**1**	**1**	**1.6**	81	*28e-2/1e5*	.	.	.	.	.	PM-AdapSS-DE [10, 11]
pPOEMS	**1**	**1**	5.7	161	**77**	111	211	*25e-3/3e5*	.	.	pPOEMS [18, 21]
Basic RCGA	**1**	**1**	**2.5**	162	436	*44e-2/5e4*	.	.	.	.	Basic RCGA [25]
SPSA	**1**	173	1046	3799	*11e-1/1e5*	.	.	.	.	.	SPSA [14]

Table 24: 10-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

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Δftarget	1e+03	1e+02	1e+01	1e+00	1e-01	1e-02	1e-03	1e-04	1e-05	1e-07	Δftarget
ERT$_{\text{best}}$/D	0.10	6.6	9876	1.04e5	7.47e6	7.48e6	7.48e6	7.48e6	7.48e6	7.48e6	ERT$_{\text{best}}$/D
(1,2)-CMA-ES	**1**	54	*50e+0/1e4*	.	.	.	.	.	.	.	(1,2)-CMA-ES [5, 3]
(1,2m)-CMA-ES	**1**	4.7	*23e+0/1e4*	.	.	.	.	.	.	.	(1,2m)-CMA-ES [5]
(1,2ms)-CMA-ES	**1**	5.9	*22e+0/1e4*	.	.	.	.	.	.	.	(1,2ms)-CMA-ES [5]
(1,2s)-CMA-ES	**1**	71	*53e+0/1e4*	.	.	.	.	.	.	.	(1,2s)-CMA-ES [3]
(1,4)-CMA-ES	**1**	4.9	15	*25e+0/1e4*	.	.	.	.	.	.	(1,4)-CMA-ES [6, 4]
(1,4m)-CMA-ES	**1**	3.6	**4.8**	*12e+0/1e4*	.	.	.	.	.	.	(1,4m)-CMA-ES [6]
(1,4ms)-CMA-ES	**1**	**2.7**	*17e+0/1e4*	.	.	.	.	.	.	.	(1,4ms)-CMA-ES [1, 6]
(1,4s)-CMA-ES	**1**	4.8	*23e+0/1e4*	.	.	.	.	.	.	.	(1,4s)-CMA-ES [4]
(1+1)-CMA-ES	**1**	8.9	*24e+0/1e4*	.	.	.	.	.	.	.	(1+1)-CMA-ES [8]
(1+2ms)-CMA-ES	**1**	4.2	**4.8**	*18e+0/1e4*	.	.	.	.	.	.	(1+2ms)-CMA-ES [2]
Artif Bee Colony	**1**	24	*24e+0/1e5*	.	.	.	.	.	.	.	Artif Bee Colony [9]
avg NEWUOA	**1**	**1.4**	*21e+0/8e3*	.	.	.	.	.	.	.	avg NEWUOA [24]
CMA-EGS (IPOP,r1)	78	4.8	**3.6**	*41e-1/1e5*	.	.	.	.	.	.	CMA-EGS (IPOP,r1) [13]
Adap DE (F-AUC)	**1**	16	47	*14e+0/1e5*	.	.	.	.	.	.	Adap DE (F-AUC) [11]
DE (Uniform)	**1**	20	47	*16e+0/1e5*	.	.	.	.	.	.	DE (Uniform) [10]
IPOP-aCMA-ES	**1**	**2.1**	50	**33**	*10e+0/2e5*	.	.	.	.	.	IPOP-aCMA-ES [17]
IPOP-CMA-ES	**1**	**2.0**	24	**6.9**	**0.48**	**0.48**	**0.48**	**0.48**	**0.48**	*81e-1/2e5*	IPOP-CMA-ES [23]
CMA+DE-MOS	**1**	11	5.8	**2.9**	**0.26**	**0.26**	**0.26**	**0.26**	**0.26**	**0.26**	CMA+DE-MOS [19]
NBC-CMA	**1**	4.9	*32e+0/3e4*	.	.	.	.	.	.	.	NBC-CMA [22]
POEMS	**1**	49	122	*16e+0/3e5*	.	.	.	.	.	.	POEMS [18]
PM-AdapSS-DE	**1**	16	69	*12e+0/1e5*	.	.	.	.	.	.	PM-AdapSS-DE [10, 11]
pPOEMS	**1**	47	24	*89e-1/3e5*	.	.	.	.	.	.	pPOEMS [18, 21]
Basic RCGA	**1**	7.3	37	*12e+0/5e4*	.	.	.	.	.	.	Basic RCGA [25]
SPSA	118	*32e+1/1e5*	.	.	.	.	.	.	.	.	SPSA [14]

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