Comparison tables: BBOB 2010 function testbed in 3-D

The BBOBies

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Abstract

This document provides tabular results of the workshop for Black-Box Optimization Benchmarking at GECCO 2010, see `http://coco.gforge.inria.fr/doku.php?id=bbob-2010`. More than 30 algorithms have been tested on 24 benchmark functions in dimensions between 2 and 40. A description of the used objective functions can be found in [15, 11]. The experimental set-up is described in [14].

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. Consequently, the best (smallest) value is 1 and the value 1 appears in each column at least once. See [14] 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: 03-D, running time excess ERT/$\mathrm{ERT}_{\mathrm{best}}$ 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	0.33	0.33	2.3	3.0	3.0	3.0	3.0	3.0	3.0	3.0	$\mathrm{ERT}_{\mathrm{best}}$/D
(1,2)-CMA-ES	**1**	**1**	3.3	8.3	14	23	27	36	41	58	(1,2)-CMA-ES [5, 3]
(1,2m)-CMA-ES	**1**	**1**	**1.5**	4.6	11	16	21	27	33	45	(1,2m)-CMA-ES [5]
(1,2ms)-CMA-ES	**1**	**1**	**1**	3.6	7.3	12	17	21	27	37	(1,2ms)-CMA-ES [5]
(1,2s)-CMA-ES	**1**	**1**	**2.9**	5.9	11	17	25	30	37	53	(1,2s)-CMA-ES [3]
(1,4)-CMA-ES	**1**	**1**	**1.6**	4.0	8.6	13	17	21	26	33	(1,4)-CMA-ES [6, 4]
(1,4m)-CMA-ES	**1**	**1.1**	**1.8**	4.0	7.3	10	15	19	24	31	(1,4m)-CMA-ES [6]
(1,4ms)-CMA-ES	**1**	**1**	**1.3**	**3.0**	**5.1**	**7.8**	**11**	**14**	**18**	**23**	(1,4ms)-CMA-ES [1, 6]
(1,4s)-CMA-ES	**1**	**1.2**	**1.4**	**3.3**	**5.9**	**10**	**13**	**16**	21	27	(1,4s)-CMA-ES [4]
(1+1)-CMA-ES	**1**	**1**	**1.2**	3.4	7.8	11	14	17	20	28	(1+1)-CMA-ES [7]
(1+2ms)-CMA-ES	**1**	**1**	**1.5**	4.3	7.5	11	14	17	**20**	**26**	(1+2ms)-CMA-ES [2]
Artif Bee Colony	**1**	**1**	**2.9**	17	36	57	78	105	131	187	Artif Bee Colony [8]
avg NEWUOA	**1**	**1.3**	**1.2**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	avg NEWUOA [23]
CMA-EGS (IPOP,r1)	**1.1**	23	7.1	12	21	35	61	95	124	175	CMA-EGS (IPOP,r1) [12]
Adap DE (F-AUC)	**1**	**1.1**	**1.3**	13	29	47	68	86	105	145	Adap DE (F-AUC) [10]
DE (Uniform)	**1**	**1**	**1.8**	12	31	50	71	93	112	154	DE (Uniform) [9]
IPOP-aCMA-ES	**1**	**1**	**1.9**	5.7	10	14	20	25	30	39	IPOP-aCMA-ES [16]
IPOP-CMA-ES	**1**	**1**	**1.9**	4.3	10	16	20	27	31	42	IPOP-CMA-ES [22]
CMA+DE-MOS	**1**	**1.1**	**1.3**	16	43	64	89	114	135	185	CMA+DE-MOS [18]
NBC-CMA	**1**	**1**	**1.2**	14	40	51	59	70	80	99	NBC-CMA [21]
POEMS	**1**	**1**	91	96	170	426	854	1164	1447	2228	POEMS [17]
PM-AdapSS-DE	**1**	**1.4**	**1.3**	14	29	49	68	88	107	148	PM-AdapSS-DE [9, 10]
pPOEMS	**1**	**1**	26	80	147	1351	3487	5838	8373	13687	pPOEMS [17, 20]
Basic RCGA	**1**	**1.1**	**1.0**	18	68	135	238	442	616	1169	Basic RCGA [24]
SPSA	**1**	33	10	10	12	15	18	21	24	30	SPSA [13]

Table 2: 03-D, running time excess ERT/$\mathrm{ERT}_{\mathrm{best}}$ 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
$\mathrm{ERT}_{\mathrm{best}}$/D	6.0	10	21	114	152	160	171	179	189	206	$\mathrm{ERT}_{\mathrm{best}}$/D
(1,2)-CMA-ES	22	30	26	6.3	5.9	5.8	5.6	5.5	5.3	5.1	(1,2)-CMA-ES [5, 3]
(1,2m)-CMA-ES	27	26	23	5.7	4.8	4.7	4.5	4.5	4.5	4.3	(1,2m)-CMA-ES [5]
(1,2ms)-CMA-ES	20	28	19	4.9	4.2	4.1	3.9	3.8	3.7	3.6	(1,2ms)-CMA-ES [5]
(1,2s)-CMA-ES	36	68	57	14	11	10	10	10	9.3	8.9	(1,2s)-CMA-ES [3]
(1,4)-CMA-ES	11	12	9.3	**2.6**	**2.1**	**2.2**	**2.1**	**2.1**	**2.1**	**2.1**	(1,4)-CMA-ES [6, 4]
(1,4m)-CMA-ES	10	15	11	**2.7**	**2.2**	**2.1**	**2.1**	**2.0**	**2.0**	**2.0**	(1,4m)-CMA-ES [6]
(1,4ms)-CMA-ES	9.2	11	7.0	**1.7**	**1.3**	**1.3**	**1.4**	**1.4**	**1.3**	**1.3**	(1,4ms)-CMA-ES [1, 6]
(1,4s)-CMA-ES	8.3	6.9	6.5	**2.1**	**1.8**	**1.8**	**1.8**	**1.7**	**1.7**	**1.7**	(1,4s)-CMA-ES [4]
(1+1)-CMA-ES	**7.1**	**6.9**	**5.9**	**1.5**	**1.2**	**1.2**	**1.2**	**1.1**	**1.1**	**1.1**	(1+1)-CMA-ES [7]
(1+2ms)-CMA-ES	**6.7**	**5.6**	**5.0**	**1.2**	**1**	**1**	**1**	**1**	**1**	**1**	(1+2ms)-CMA-ES [2]
Artif Bee Colony	15	13	11	**2.5**	**2.7**	3.3	3.8	4.4	4.4	5.0	Artif Bee Colony [8]
avg NEWUOA	**1**	**1**	**1**	**1**	**1.4**	**1.9**	**2.6**	3.1	3.6	4.5	avg NEWUOA [23]
CMA-EGS (IPOP,r1)	63	92	65	14	11	15	15	14	14	13	CMA-EGS (IPOP,r1) [12]
Adap DE (F-AUC)	13	12	8.0	**2.0**	**1.9**	**2.1**	**2.3**	**2.5**	**2.7**	**3.0**	Adap DE (F-AUC) [10]
DE (Uniform)	12	14	9.0	**2.2**	**2.1**	**2.3**	**2.6**	**2.8**	**2.9**	3.4	DE (Uniform) [9]
IPOP-aCMA-ES	8.1	8.6	6.8	**1.6**	**1.3**	**1.4**	**1.4**	**1.4**	**1.4**	**1.4**	IPOP-aCMA-ES [16]
IPOP-CMA-ES	11	10	7.3	**2.0**	**1.7**	**1.7**	**1.7**	**1.7**	**1.7**	**1.7**	IPOP-CMA-ES [22]
CMA+DE-MOS	19	20	13	3.2	3.2	3.5	3.9	4.3	4.8	5.2	CMA+DE-MOS [18]
NBC-CMA	18	19	12	3.7	3.8	4.1	4.6	4.6	4.5	4.4	NBC-CMA [21]
POEMS	149	203	155	39	35	43	44	48	52	56	POEMS [17]
PM-AdapSS-DE	11	13	8.5	**2.1**	**2.0**	**2.3**	**2.5**	**2.7**	**2.9**	3.2	PM-AdapSS-DE [9, 10]
pPOEMS	220	353	510	148	194	228	267	298	326	345	pPOEMS [17, 20]
Basic RCGA	27	34	42	15	16	20	28	33	61	152	Basic RCGA [24]
SPSA	2887	11651	66520	*95e+0/1e5*	.	.	.	.	.	.	SPSA [13]

Table 3: 03-D, running time excess $\mathrm{ERT}/\mathrm{ERT}_{\mathrm{best}}$ 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
$\mathrm{ERT}_{\mathrm{best}}$/D	0.33	0.96	38	315	500	656	787	951	1046	1261	$\mathrm{ERT}_{\mathrm{best}}$/D
(1,2)-CMA-ES	**1.3**	3.4	16	52	139	106	89	73	67	55	(1,2)-CMA-ES [5, 3]
(1,2m)-CMA-ES	**1.4**	**2.1**	**1.4**	14	60	46	38	32	29	24	(1,2m)-CMA-ES [5]
(1,2ms)-CMA-ES	**1.2**	**1.8**	**2.8**	8.9	56	53	44	37	33	28	(1,2ms)-CMA-ES [5]
(1,2s)-CMA-ES	**1.1**	4.7	20	68	*20e-1/1e4*	.	.	.	.	.	(1,2s)-CMA-ES [3]
(1,4)-CMA-ES	**1**	3.2	3.4	7.0	22	17	14	12	11	8.7	(1,4)-CMA-ES [6, 4]
(1,4m)-CMA-ES	**1.1**	**2.0**	**2.5**	6.7	20	18	15	12	11	9.2	(1,4m)-CMA-ES [6]
(1,4ms)-CMA-ES	**1.2**	**1.8**	**2.2**	8.5	23	18	15	12	11	9.3	(1,4ms)-CMA-ES [1, 6]
(1,4s)-CMA-ES	**1**	**2.0**	3.1	10	32	25	21	17	15	13	(1,4s)-CMA-ES [4]
(1+1)-CMA-ES	**1.5**	**2.3**	**3.0**	12	53	40	34	28	25	21	(1+1)-CMA-ES [7]
(1+2ms)-CMA-ES	**1.1**	**2.5**	4.7	5.3	26	20	16	14	12	10	(1+2ms)-CMA-ES [2]
Artif Bee Colony	**1.1**	**1.7**	**1.9**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	Artif Bee Colony [8]
avg NEWUOA	**1**	3.4	3.1	4.4	18	14	12	10	8.8	7.3	avg NEWUOA [23]
CMA-EGS (IPOP,r1)	7.5	11	29	299	450	348	363	424	386	320	CMA-EGS (IPOP,r1) [12]
Adap DE (F-AUC)	**1**	**1.8**	**2.2**	**2.2**	**2.0**	**1.7**	**1.5**	**1.3**	**1.2**	**1.1**	Adap DE (F-AUC) [10]
DE (Uniform)	**1.1**	**1**	**2.9**	**2.6**	75	57	48	40	36	30	DE (Uniform) [9]
IPOP-aCMA-ES	**1.1**	**2.7**	**1**	**2.4**	7.3	7.0	6.0	5.1	4.7	4.0	IPOP-aCMA-ES [16]
IPOP-CMA-ES	**1.1**	**2.8**	**2.5**	**3.0**	14	14	12	10	9.4	8.0	IPOP-CMA-ES [22]
CMA+DE-MOS	**1.1**	**1.8**	3.4	**1.4**	**1.5**	**1.4**	**1.3**	**1.2**	**1.2**	**1.2**	CMA+DE-MOS [18]
NBC-CMA	**1.1**	**1.6**	3.0	5.1	17	13	11	9.2	8.4	7.0	NBC-CMA [21]
POEMS	33	174	9.4	6.8	13	12	11	10	10	10	POEMS [17]
PM-AdapSS-DE	**1.5**	**1.7**	**2.6**	**2.2**	16	25	21	17	16	13	PM-AdapSS-DE [9, 10]
pPOEMS	**1.2**	33	10	17	33	37	44	45	47	53	pPOEMS [17, 20]
Basic RCGA	**1**	**1.7**	6.8	19	20	22	23	20	18	16	Basic RCGA [24]
SPSA	97	7526	1378	*25e-1/1e5*	.	.	.	.	.	.	SPSA [13]

Table 4: 03-D, running time excess ERT/$\mathrm{ERT}_{\mathrm{best}}$ 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
$\mathrm{ERT}_{\mathrm{best}}$/D	0.38	1.9	88	458	751	910	1095	1286	1482	1798	$\mathrm{ERT}_{\mathrm{best}}$/D
(1,2)-CMA-ES	**2.2**	3.7	5.2	40	*20e-1/1e4*	.	.	.	.	.	(1,2)-CMA-ES [5, 3]
(1,2m)-CMA-ES	**1.4**	**1.7**	3.8	13	59	48	40	34	30	25	(1,2m)-CMA-ES [5]
(1,2ms)-CMA-ES	**1**	**2.1**	3.9	22	90	75	62	53	46	38	(1,2ms)-CMA-ES [5]
(1,2s)-CMA-ES	**1.1**	**2.1**	10	97	190	157	130	111	96	79	(1,2s)-CMA-ES [3]
(1,4)-CMA-ES	**1.5**	**1.2**	**2.7**	11	42	35	29	25	21	18	(1,4)-CMA-ES [6, 4]
(1,4m)-CMA-ES	**1.4**	**1.4**	**1.7**	**6.0**	46	38	32	27	24	19	(1,4m)-CMA-ES [6]
(1,4ms)-CMA-ES	**1.1**	**1**	**1.4**	14	27	23	19	16	14	11	(1,4ms)-CMA-ES [1, 6]
(1,4s)-CMA-ES	**1.6**	**2.1**	4.0	12	22	18	15	13	11	**9.3**	(1,4s)-CMA-ES [4]
(1+1)-CMA-ES	**1.9**	**1.9**	5.4	19	91	75	62	53	46	38	(1+1)-CMA-ES [7]
(1+2ms)-CMA-ES	**1.3**	**1.3**	**3.0**	9.5	24	20	17	14	12	10	(1+2ms)-CMA-ES [2]
Artif Bee Colony	**1.2**	**1.3**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	Artif Bee Colony [8]
avg NEWUOA	**2.5**	8.8	**1.7**	8.0	62	52	43	36	32	26	avg NEWUOA [23]
CMA-EGS (IPOP,r1)	12	7.4	102	*42e-1/1e5*	.	.	.	.	.	.	CMA-EGS (IPOP,r1) [12]
Adap DE (F-AUC)	**1.3**	**1.4**	**1.6**	148	534	441	366	312	271	223	Adap DE (F-AUC) [10]
DE (Uniform)	**1.1**	**1.5**	**1.7**	18	202	166	138	118	102	84	DE (Uniform) [9]
IPOP-aCMA-ES	**1.6**	**2.2**	**1.2**	272	*92e-2/2e5*	.	.	.	.	.	IPOP-aCMA-ES [16]
IPOP-CMA-ES	**1.6**	**2.3**	**1.8**	259	1744	1438	1195	1018	883	728	IPOP-CMA-ES [22]
CMA+DE-MOS	**1.5**	**1.4**	**1.7**	**1.3**	**2.1**	**2.0**	**1.7**	**1.6**	**1.5**		

Table 5: 03-D, running time excess ERT/$\mathrm{ERT}_{\mathrm{best}}$ 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
$\mathrm{ERT}_{\mathrm{best}}$/D	0.33	0.33	2.9	3.3	3.3	3.3	3.3	3.3	3.3	3.3	$\mathrm{ERT}_{\mathrm{best}}$/D
(1,2)-CMA-ES	**1**	**1.7**	3.0	4.7	5.0	5.1	5.1	5.1	5.1	5.1	(1,2)-CMA-ES [5, 3]
(1,2m)-CMA-ES	**1**	**1.2**	**1.9**	**2.7**	**2.8**	**2.8**	**2.8**	**2.8**	**2.8**	**2.8**	(1,2m)-CMA-ES [5]
(1,2ms)-CMA-ES	**1**	**1.3**	**1.5**	**2.1**	**2.2**	**2.2**	**2.2**	**2.2**	**2.2**	**2.2**	(1,2ms)-CMA-ES [5]
(1,2s)-CMA-ES	**1**	**1.1**	3.5	5.3	5.6	5.6	5.6	5.6	5.6	5.6	(1,2s)-CMA-ES [3]
(1,4)-CMA-ES	**1**	**1.7**	**2.3**	3.6	3.8	3.8	3.8	3.8	3.8	3.8	(1,4)-CMA-ES [6, 4]
(1,4m)-CMA-ES	**1**	**1.3**	**1.9**	**2.4**	**2.5**	**2.5**	**2.5**	**2.5**	**2.5**	**2.5**	(1,4m)-CMA-ES [6]
(1,4ms)-CMA-ES	**1**	**1.1**	**1.1**	**1.7**	**1.8**	**1.8**	**1.8**	**1.8**	**1.8**	**1.8**	(1,4ms)-CMA-ES [1, 6]
(1,4s)-CMA-ES	**1**	**1.6**	**2.0**	**2.4**	**2.5**	**2.5**	**2.5**	**2.5**	**2.5**	**2.5**	(1,4s)-CMA-ES [4]
(1+1)-CMA-ES	**1**	**1**	**1.7**	**2.5**	**2.6**	**2.6**	**2.6**	**2.6**	**2.6**	**2.6**	(1+1)-CMA-ES [7]
(1+2ms)-CMA-ES	**1**	**1.8**	**1.8**	**2.6**	**2.7**	**2.7**	**2.7**	**2.7**	**2.7**	**2.7**	(1+2ms)-CMA-ES [2]
Artif Bee Colony	**1**	**1.5**	12	21	23	23	23	23	23	23	Artif Bee Colony [8]
avg NEWUOA	**1**	**1.5**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	avg NEWUOA [23]
CMA-EGS (IPOP,r1)	**1**	10	3.8	5.1	5.3	5.3	5.3	5.3	5.3	5.3	CMA-EGS (IPOP,r1) [12]
Adap DE (F-AUC)	**1**	**1.2**	6.5	10	11	11	11	11	11	11	Adap DE (F-AUC) [10]
DE (Uniform)	**1**	**1.3**	4.9	12	13	13	13	13	13	13	DE (Uniform) [9]
IPOP-aCMA-ES	**1**	**1**	**2.5**	4.0	4.2	4.2	4.2	4.2	4.2	4.2	IPOP-aCMA-ES [16]
IPOP-CMA-ES	**1**	**1.3**	**2.6**	3.8	3.8	3.8	3.8	3.8	3.8	3.8	IPOP-CMA-ES [22]
CMA+DE-MOS	**1**	**1.3**	7.4	15	23	23	23	23	23	23	CMA+DE-MOS [18]
NBC-CMA	**1**	**1.3**	14	33	34	35	35	35	35	35	NBC-CMA [21]
POEMS	**1**	19	88	101	115	123	123	124	124	124	POEMS [17]
PM-AdapSS-DE	**1**	**1.4**	4.8	12	13	13	13	13	13	13	PM-AdapSS-DE [9, 10]
pPOEMS	**1**	**1.1**	83	96	113	118	123	123	124	124	pPOEMS [17, 20]
Basic RCGA	**1**	**1.3**	111	441	732	1042	1326	3031	19735	*11e-6/5e4*	Basic RCGA [24]
SPSA	**1**	15	8.0	12	13	13	13	13	13	13	SPSA [13]

Table 6: 03-D, running time excess ERT/$\mathrm{ERT}_{\mathrm{best}}$ 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
$\mathrm{ERT}_{\mathrm{best}}$/D	1.7	3.9	16	34	52	65	81	94	109	143	$\mathrm{ERT}_{\mathrm{best}}$/D
(1,2)-CMA-ES	3.2	**2.1**	3.4	4.2	3.6	3.7	3.6	3.5	3.3	3.4	(1,2)-CMA-ES [5, 3]
(1,2m)-CMA-ES	**2.1**	**1.7**	**2.6**	**2.4**	**2.4**	**2.6**	**2.9**	**2.9**	**2.7**	**2.5**	(1,2m)-CMA-ES [5]
(1,2ms)-CMA-ES	**1.9**	**1.3**	**2.0**	**1.9**	**2.0**	**2.2**	**2.1**	**2.2**	**2.2**	**2.1**	(1,2ms)-CMA-ES [5]
(1,2s)-CMA-ES	**2.6**	**3.0**	5.6	4.6	4.0	4.8	4.6	4.4	4.5	4.4	(1,2s)-CMA-ES [3]
(1,4)-CMA-ES	**2.4**	**1.7**	**1.3**	**1.4**	**1.3**	**1.5**	**1.5**	**1.5**	**1.6**	**1.5**	(1,4)-CMA-ES [6, 4]
(1,4m)-CMA-ES	**1.9**	**1.2**	**1.6**	**1.5**	**1.5**	**1.5**	**1.6**	**1.5**	**1.6**	**1.5**	(1,4m)-CMA-ES [6]
(1,4ms)-CMA-ES	**1.7**	**1.1**	**1**	**1**	**1.0**	**1.1**	**1.1**	**1.2**	**1.1**	**1.1**	(1,4ms)-CMA-ES [1, 6]
(1,4s)-CMA-ES	3.2	**1.6**	**1.2**	**1.2**	**1.1**	**1.2**	**1.2**	**1.3**	**1.3**	**1.3**	(1,4s)-CMA-ES [4]
(1+1)-CMA-ES	**1.4**	**1.5**	**1.1**	**1.1**	**1.1**	**1.1**	**1.1**	**1.2**	**1.2**	**1.1**	(1+1)-CMA-ES [7]
(1+2ms)-CMA-ES	**1.6**	**1**	**1.2**	**1.1**	**1**	**1**	**1**	**1**	**1**	**1**	(1+2ms)-CMA-ES [2]
Artif Bee Colony	**2.8**	**1.4**	**2.6**	7.0	25	97	274	319	388	323	Artif Bee Colony [8]
avg NEWUOA	**1**	**1.5**	**1.8**	**1.6**	**1.7**	**2.3**	**2.4**	**2.7**	**2.8**	**2.9**	avg NEWUOA [23]
CMA-EGS (IPOP,r1)	5.9	47	78	172	119	292	374	343	395	1449	CMA-EGS (IPOP,r1) [12]
Adap DE (F-AUC)	3.9	**1.8**	3.6	4.9	5.1	5.4	5.5	5.9	5.7	5.8	Adap DE (F-AUC) [10]
DE (Uniform)	**2.9**	**2.6**	**2.9**	5.1	5.4	5.8	6.1	6.4	6.5	6.3	DE (Uniform) [9]
IPOP-aCMA-ES	3.2	**2.8**	**2.2**	**1.8**	**1.8**	**2.0**	**2.0**	**1.9**	**1.9**	**1.9**	IPOP-aCMA-ES [16]
IPOP-CMA-ES	3.2	**1.8**	**1.9**	**1.8**	**1.9**	**2.0**	**2.0**	**2.0**	**2.0**	**1.9**	IPOP-CMA-ES [22]
CMA+DE-MOS	3.4	**2.2**	4.0	7.7	7.6	8.9	8.6	8.6	8.7	8.4	CMA+DE-MOS [18]
NBC-CMA	4.8	**2.2**	3.1	7.7	6.4	5.6	5.2	5.0	4.7	4.2	NBC-CMA [21]
POEMS	121	54	23	33	48	55	62	62	63	67	POEMS [17]
PM-AdapSS-DE	4.1	**2.1**	**2.5**	4.7	5.0	5.5	5.8	6.1	6.2	6.1	PM-AdapSS-DE [9, 10]
pPOEMS	72	48	25	125	262	371	388	436	470	494	pPOEMS [17, 20]
Basic RCGA	19	9.3	8.6	88	174	488	919	2286	3118	*18e-4/5e4*	Basic RCGA [24]
SPSA	19	3020	7848	6492	8303	*11e+0/1e5*	.	.	.	.	SPSA [13]

Table 7: 03-D, running time excess ERT/$\mathrm{ERT}_{\mathrm{best}}$ 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
$\mathrm{ERT}_{\mathrm{best}}$/D	0.36	1.3	4.6	38	94	140	162	162	162	190	$\mathrm{ERT}_{\mathrm{best}}$/D
(1,2)-CMA-ES	**1.2**	**2.4**	12	6.5	21	92	200	200	200	241	(1,2)-CMA-ES [5, 3]
(1,2m)-CMA-ES	**1.4**	**2.2**	**2.8**	3.9	10	23	27	27	27	48	(1,2m)-CMA-ES [5]
(1,2ms)-CMA-ES	**1.2**	**1.6**	3.2	**1.9**	6.4	28	44	44	44	56	(1,2ms)-CMA-ES [5]
(1,2s)-CMA-ES	**1**	**1.5**	5.7	10	20	119	178	178	178	365	(1,2s)-CMA-ES [3]
(1,4)-CMA-ES	**1.2**	3.3	3.2	**1.2**	3.8	3.7	6.7	6.7	6.7	15	(1,4)-CMA-ES [6, 4]
(1,4m)-CMA-ES	**1.2**	**1.4**	**1.8**	**1.2**	**2.3**	3.6	3.2	3.2	3.2	3.7	(1,4m)-CMA-ES [6]
(1,4ms)-CMA-ES	**1.3**	**1.3**	11	**2.2**	**1.9**	**2.4**	3.8	3.8	3.8	6.4	(1,4ms)-CMA-ES [1, 6]
(1,4s)-CMA-ES	**1.1**	**1.7**	**2.8**	**1.5**	3.2	3.6	5.5	5.5	5.5	10	(1,4s)-CMA-ES [4]
(1+1)-CMA-ES	**1.8**	**1.2**	**2.3**	**1.1**	**1**	**2.5**	**2.5**	**2.5**	**2.5**	**2.2**	(1+1)-CMA-ES [7]
(1+2ms)-CMA-ES	**1.4**	**1.4**	**1.8**	**1.2**	**1.6**	**1.4**	**1.5**	**1.5**	**1.5**	**1.3**	(1+2ms)-CMA-ES [2]
Artif Bee Colony	**1.1**	**1.1**	5.0	4.6	12	25	84	84	84	118	Artif Bee Colony [8]
avg NEWUOA	**1.2**	**2.4**	**1**	3.9	5.8	21	40	40	40	34	avg NEWUOA [23]
CMA-EGS (IPOP,r1)	16	112	202	447	3034	10058	8677	8677	8677	7398	CMA-EGS (IPOP,r1) [12]
Adap DE (F-AUC)	**1.2**	**1**	**2.0**	**1.9**	**1.4**	**1.4**	**1.4**	**1.4**	**1.4**	**1.4**	Adap DE (F-AUC) [10]
DE (Uniform)	**1.2**	**1.0**	4.5	**2.4**	**1.5**	**1.6**	**1.6**	**1.6**	**1.6**	**1.5**	DE (Uniform) [9]
IPOP-aCMA-ES	**1.2**	**1.8**	**2.4**	**1**	**1.1**	**1**	**1**	**1**	**1**	**1**	IPOP-aCMA-ES [16]
IPOP-CMA-ES	**1.4**	**1.7**	**2.8**	4.1	**2.4**	**1.8**	**1.9**	**1.9**	**1.9**	**1.7**	IPOP-CMA-ES [22]
CMA+DE-MOS	**1**	**1.5**	**2.5**	**2.5**	**2.8**	**2.4**	**2.3**	**2.3**	**2.3**	**2.3**	CMA+DE-MOS [18]
NBC-CMA	**1.1**	**1.5**	3.4	**2.8**	3.0	**2.4**	**2.2**	**2.2**	**2.2**	**2.0**	NBC-CMA [21]
POEMS	86	164	62	16	33	28	28	28	28	26	POEMS [17]
PM-AdapSS-DE	**1.4**	**1.2**	3.5	**2.0**	**1.5**	**1.5**	**1.6**	**1.6**	**1.6**	**1.5**	PM-AdapSS-DE [9, 10]
pPOEMS	**1.5**	23	50	17	49	74	90	90	90	99	pPOEMS [17, 20]
Basic RCGA	**1**	**1.4**	4.6	24	97	179	211	211	211	195	Basic RCGA [24]
SPSA	55	132	16995	17233	*69e-1/1e5*	.	.	.	.	.	SPSA [13]

Table 8: 03-D, running time excess $\mathrm{ERT}/\mathrm{ERT}_{\mathrm{best}}$ 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
$\mathrm{ERT}_{\mathrm{best}}$/D	2.4	7.9	18	39	51	58	62	65	67	71	$\mathrm{ERT}_{\mathrm{best}}$/D
(1,2)-CMA-ES	**2.9**	6.5	6.3	11	16	17	18	18	18	18	(1,2)-CMA-ES [5, 3]
(1,2m)-CMA-ES	**1.6**	**1.4**	5.3	7.8	9.2	11	11	11	11	11	(1,2m)-CMA-ES [5]
(1,2ms)-CMA-ES	**1.5**	3.8	6.3	11	12	13	13	13	12	12	(1,2ms)-CMA-ES [5]
(1,2s)-CMA-ES	**1.0**	**1.4**	**2.0**	19	23	26	29	29	28	28	(1,2s)-CMA-ES [3]
(1,4)-CMA-ES	**2.5**	**2.6**	**2.0**	4.2	5.2	5.5	5.8	5.9	5.9	6.0	(1,4)-CMA-ES [6, 4]
(1,4m)-CMA-ES	**2.2**	**2.0**	**1.8**	5.1	6.6	6.8	6.9	6.8	6.8	6.8	(1,4m)-CMA-ES [6]
(1,4ms)-CMA-ES	**1.4**	**1.6**	**1.8**	3.6	4.2	4.4	4.6	4.6	4.6	4.6	(1,4ms)-CMA-ES [1, 6]
(1,4s)-CMA-ES	**1.5**	**1**	**1.0**	3.8	4.9	5.5	5.8	5.7	5.7	5.6	(1,4s)-CMA-ES [4]
(1+1)-CMA-ES	**1.4**	**1.6**	**1.3**	**2.5**	**2.8**	**3.0**	**3.1**	**3.1**	**3.2**	**3.3**	(1+1)-CMA-ES [7]
(1+2ms)-CMA-ES	**1**	**1.1**	**1.1**	**1.8**	**2.3**	**2.4**	**2.5**	**2.5**	**2.6**	**2.7**	(1+2ms)-CMA-ES [2]
Artif Bee Colony	**1.2**	**2.4**	**2.0**	6.6	26	239	3138	22009	*12e-4/1e5*	.	Artif Bee Colony [8]
avg NEWUOA	**1.8**	**1.2**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	avg NEWUOA [23]
CMA-EGS (IPOP,r1)	20	11	13	19	21	23	22	22	23	25	CMA-EGS (IPOP,r1) [12]
Adap DE (F-AUC)	**2.0**	**2.9**	4.7	5.0	7.1	8.1	8.6	9.1	10	10	Adap DE (F-AUC) [10]
DE (Uniform)	**3.0**	3.2	4.3	6.3	9.3	11	12	13	13	14	DE (Uniform) [9]
IPOP-aCMA-ES	**2.1**	**2.5**	**1.8**	**2.8**	3.7	4.1	4.3	4.4	4.4	4.6	IPOP-aCMA-ES [16]
IPOP-CMA-ES	**2.2**	**2.9**	**2.5**	4.9	5.7	5.8	5.9	5.9	6.0	6.2	IPOP-CMA-ES [22]
CMA+DE-MOS	**2.0**	3.7	5.6	7.2	12	13	13	14	14	15	CMA+DE-MOS [18]
NBC-CMA	**2.8**	3.6	4.5	5.0	6.7	7.5	8.0	8.1	8.2	8.7	NBC-CMA [21]
POEMS	85	34	23	34	54	75	165	283	293	370	POEMS [17]
PM-AdapSS-DE	**1.3**	**2.8**	4.5	4.9	6.9	8.9	10	56	54	53	PM-AdapSS-DE [9, 10]
pPOEMS	72	32	22	56	217	383	487	644	778	1038	pPOEMS [17, 20]
Basic RCGA	**1.5**	4.3	6.8	24	628	1170	3518	*14e-3/5e4*	.	.	Basic RCGA [24]
SPSA	283	170	138	3304	5722	24451	*12e-1/1e5*	.	.	.	SPSA [13]

Table 9: 03-D, running time excess ERT/ERT_{best} 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
ERT_{best}/D	1.8	6.5	12	38	50	57	61	63	65	69	ERT_{best}/D
(1,2)-CMA-ES	**2.7**	4.4	6.2	8.1	13	15	16	16	16	16	(1,2)-CMA-ES [5, 3]
(1,2m)-CMA-ES	**2.8**	**2.2**	**3.0**	6.0	8.2	9.5	10	10	10	10	(1,2m)-CMA-ES [5]
(1,2ms)-CMA-ES	**1.4**	**2.0**	9.2	10	11	12	12	12	12	12	(1,2ms)-CMA-ES [5]
(1,2s)-CMA-ES	**1.8**	**2.8**	**2.8**	3.9	13	19	20	21	21	21	(1,2s)-CMA-ES [3]
(1,4)-CMA-ES	**1.8**	**1.9**	**2.4**	4.3	5.4	5.8	6.0	6.1	6.2	6.2	(1,4)-CMA-ES [6, 4]
(1,4m)-CMA-ES	**2.0**	**1.9**	**1.7**	**2.2**	3.4	4.0	4.4	4.5	4.6	4.8	(1,4m)-CMA-ES [6]
(1,4ms)-CMA-ES	**1.7**	**1.2**	**1.4**	**1.8**	**2.9**	3.4	3.6	3.6	3.7	3.8	(1,4ms)-CMA-ES [1, 6]
(1,4s)-CMA-ES	**1.9**	**2.0**	**1.5**	5.2	6.1	6.4	6.4	6.3	6.3	6.3	(1,4s)-CMA-ES [4]
(1+1)-CMA-ES	**1.8**	**1.6**	**1.5**	**1.9**	**2.5**	**2.7**	**2.7**	**2.8**	**2.9**	**3.1**	(1+1)-CMA-ES [7]
(1+2ms)-CMA-ES	**2.0**	**1.3**	**1.6**	**2.3**	**2.8**	**2.9**	**3.0**	**3.1**	**3.1**	**3.2**	(1+2ms)-CMA-ES [2]
Artif Bee Colony	**1.9**	**2.8**	**3.0**	4.2	79	416	4246	23320	*24e-4/1e5*	.	Artif Bee Colony [8]
avg NEWUOA	**2.0**	**1.0**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	avg NEWUOA [23]
CMA-EGS (IPOP,r1)	23	8.4	15	21	24	23	24	24	24	25	CMA-EGS (IPOP,r1) [12]
Adap DE (F-AUC)	**2.5**	**2.2**	4.4	5.7	7.9	10	17	20	20	21	Adap DE (F-AUC) [10]
DE (Uniform)	**1.9**	**2.3**	5.2	5.2	8.4	10	11	12	12	13	DE (Uniform) [9]
IPOP-aCMA-ES	**1.7**	**1.9**	**2.0**	3.4	4.1	4.2	4.5	4.6	4.7	4.9	IPOP-aCMA-ES [16]
IPOP-CMA-ES	**1**	**1**	**1.7**	**2.8**	3.7	4.2	4.4	4.5	4.7	4.9	IPOP-CMA-ES [22]
CMA+DE-MOS	**1.8**	**2.8**	6.1	**2.8**	5.9	8.2	9.1	10	11	12	CMA+DE-MOS [18]
NBC-CMA	**1.6**	**2.9**	5.8	5.2	7.3	8.2	8.4	8.5	8.8	9.1	NBC-CMA [21]
POEMS	109	39	31	123	116	154	220	307	398	522	POEMS [17]
PM-AdapSS-DE	**1.4**	**1.6**	4.4	4.9	7.1	8.4	8.9	9.5	10	11	PM-AdapSS-DE [9, 10]
pPOEMS	84	40	34	84	272	410	546	663	815	1101	pPOEMS [17, 20]
Basic RCGA	**2.1**	3.6	7.1	104	1323	6254	*94e-3/5e4*	.	.	.	Basic RCGA [24]
SPSA	1081	636	811	5621	*12e-1/1e5*	.	.	.	.	.	SPSA [13]

Table 10: 03-D, running time excess ERT/$\mathrm{ERT}_{\mathrm{best}}$ 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
$\mathrm{ERT}_{\mathrm{best}}$/D	10	23	71	138	157	173	184	193	203	223	$\mathrm{ERT}_{\mathrm{best}}$/D
(1,2)-CMA-ES	17	14	9.2	6.0	5.8	5.5	5.3	5.2	5.0	4.9	(1,2)-CMA-ES [5, 3]
(1,2m)-CMA-ES	15	14	8.6	5.2	4.7	4.4	4.2	4.2	4.1	3.9	(1,2m)-CMA-ES [5]
(1,2ms)-CMA-ES	14	12	5.5	3.9	3.6	3.4	3.2	3.2	3.2	3.0	(1,2ms)-CMA-ES [5]
(1,2s)-CMA-ES	35	22	13	11	10	10	9.3	9.1	8.8	8.3	(1,2s)-CMA-ES [3]
(1,4)-CMA-ES	7.9	5.2	**2.6**	**1.9**	**1.9**	**1.8**	**1.8**	**1.8**	**1.8**	**1.8**	(1,4)-CMA-ES [6, 4]
(1,4m)-CMA-ES	5.7	4.8	**2.8**	**1.9**	**2.0**	**2.0**	**2.0**	**2.0**	**1.9**	**1.8**	(1,4m)-CMA-ES [6]
(1,4ms)-CMA-ES	4.2	**2.8**	**2.0**	**1.4**	**1.4**	**1.4**	**1.4**	**1.4**	**1.4**	**1.3**	(1,4ms)-CMA-ES [1, 6]
(1,4s)-CMA-ES	7.0	4.9	**2.4**	**1.9**	**1.9**	**1.8**	**1.8**	**1.7**	**1.7**	**1.6**	(1,4s)-CMA-ES [4]
(1+1)-CMA-ES	**3.9**	**2.7**	**1.7**	**1.2**	**1.1**	**1.1**	**1.1**	**1.1**	**1.1**	**1.1**	(1+1)-CMA-ES [7]
(1+2ms)-CMA-ES	**4.1**	**2.8**	**1.6**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	(1+2ms)-CMA-ES [2]
Artif Bee Colony	15	110	641	10176	9219	*29e-1/1e5*	.	.	.	.	Artif Bee Colony [8]
avg NEWUOA	**1**	**1**	**1**	**1.3**	**2.1**	**2.4**	**2.8**	3.2	3.4	4.1	avg NEWUOA [23]
CMA-EGS (IPOP,r1)	44	39	22	12	11	52	49	47	45	42	CMA-EGS (IPOP,r1) [12]
Adap DE (F-AUC)	6.2	4.9	**2.5**	**1.6**	**1.8**	**2.0**	**2.2**	**2.3**	**2.5**	**2.8**	Adap DE (F-AUC) [10]
DE (Uniform)	5.9	5.1	**2.7**	**1.7**	**1.9**	**2.1**	**2.4**	**2.5**	**2.7**	3.0	DE (Uniform) [9]
IPOP-aCMA-ES	4.1	3.3	**1.7**	**1.3**	**1.2**	**1.2**	**1.2**	**1.2**	**1.2**	**1.3**	IPOP-aCMA-ES [16]
IPOP-CMA-ES	4.1	**2.9**	**2.1**	**1.6**	**1.6**	**1.6**	**1.5**	**1.6**	**1.6**	**1.6**	IPOP-CMA-ES [22]
CMA+DE-MOS	16	12	6.0	4.7	5.2	5.3	5.8	6.0	6.1	6.1	CMA+DE-MOS [18]
NBC-CMA	10	7.5	4.1	3.3	3.7	4.3	4.5	4.5	4.4	4.3	NBC-CMA [21]
POEMS	36	46	441	713	1449	2215	3517	5419	10852	19919	POEMS [17]
PM-AdapSS-DE	5.5	5.0	**2.5**	**1.7**	**1.9**	**2.0**	**2.3**	**2.5**	**2.7**	**2.9**	PM-AdapSS-DE [9, 10]
pPOEMS	66	132	194	173	254	288	324	371	424	471	pPOEMS [17, 20]
Basic RCGA	292	458	302	887	4682	*25e-1/5e4*	.	.	.	.	Basic RCGA [24]
SPSA	1328	4948	9226	*84e+0/1e5*	.	.	.	.	.	.	SPSA [13]

Table 11: 03-D, running time excess ERT/$\mathrm{ERT}_{\mathrm{best}}$ 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	6.1	10	45	117	181	197	207	215	225	245	$\mathrm{ERT}_{\mathrm{best}}$/D
(1,2)-CMA-ES	5.2	29	18	8.3	5.9	5.5	5.4	5.3	5.2	4.9	(1,2)-CMA-ES [5, 3]
(1,2m)-CMA-ES	9.5	31	14	7.0	4.9	4.6	4.5	4.5	4.4	4.2	(1,2m)-CMA-ES [5]
(1,2ms)-CMA-ES	8.1	17	10	5.6	4.0	3.8	3.7	3.6	3.7	3.5	(1,2ms)-CMA-ES [5]
(1,2s)-CMA-ES	17	46	18	11	8.1	7.8	7.6	7.5	7.3	6.8	(1,2s)-CMA-ES [3]
(1,4)-CMA-ES	**2.7**	6.8	4.9	**2.7**	**2.0**	**1.9**	**1.9**	**1.9**	**1.9**	**1.9**	(1,4)-CMA-ES [6, 4]
(1,4m)-CMA-ES	**2.2**	9.1	5.7	**2.8**	**2.0**	**1.9**	**1.9**	**1.9**	**1.9**	**1.9**	(1,4m)-CMA-ES [6]
(1,4ms)-CMA-ES	3.4	4.3	3.5	**2.1**	**1.5**	**1.4**	**1.4**	**1.4**	**1.4**	**1.3**	(1,4ms)-CMA-ES [1, 6]
(1,4s)-CMA-ES	**1.9**	5.8	4.6	**2.3**	**1.7**	**1.6**	**1.6**	**1.6**	**1.6**	**1.6**	(1,4s)-CMA-ES [4]
(1+1)-CMA-ES	**1.9**	5.1	**2.9**	**1.6**	**1.2**	**1.1**	**1.1**	**1.1**	**1.1**	**1.1**	(1+1)-CMA-ES [7]
(1+2ms)-CMA-ES	**2.0**	**2.6**	**2.6**	**1.3**	**1.0**	**1**	**1**	**1**	**1**	**1**	(1+2ms)-CMA-ES [2]
Artif Bee Colony	3.6	**3.1**	14	79	1016	*14e-2/1e5*	.	.	.	.	Artif Bee Colony [8]
avg NEWUOA	**1**	**1**	**1**	**1**	**1.0**	**1.2**	**1.5**	**1.7**	**1.9**	**2.2**	avg NEWUOA [23]
CMA-EGS (IPOP,r1)	6.1	66	39	18	12	11	11	11	10	10	CMA-EGS (IPOP,r1) [12]
Adap DE (F-AUC)	6.9	7.8	**2.8**	**1.6**	**1.3**	**1.5**	**1.7**	**1.9**	**2.1**	**2.3**	Adap DE (F-AUC) [10]
DE (Uniform)	5.2	5.6	**2.9**	**1.7**	**1.4**	**1.6**	**1.8**	**2.0**	**2.2**	**2.5**	DE (Uniform) [9]
IPOP-aCMA-ES	3.1	3.5	**2.6**	**1.3**	**1**	**1.0**	**1.0**	**1.1**	**1.1**	**1.1**	IPOP-aCMA-ES [16]
IPOP-CMA-ES	3.1	5.1	4.5	**2.3**	**1.7**	**1.6**	**1.6**	**1.7**	**1.6**	**1.6**	IPOP-CMA-ES [22]
CMA+DE-MOS	6.6	9.0	8.5	5.0	3.7	3.8	3.9	4.0	4.0	4.2	CMA+DE-MOS [18]
NBC-CMA	5.8	9.4	5.5	4.7	3.8	3.9	4.1	4.1	4.0	4.0	NBC-CMA [21]
POEMS	41	31	68	215	268	396	563	728	755	1055	POEMS [17]
PM-AdapSS-DE	5.7	6.4	3.0	**1.7**	**1.4**	**1.6**	**1.8**	**2.0**	**2.2**	**2.5**	PM-AdapSS-DE [9, 10]
pPOEMS	36	24	42	115	130	198	239	304	353	419	pPOEMS [17, 20]
Basic RCGA	5.9	6.7	169	362	1232	3613	*58e-2/5e4*	.	.	.	Basic RCGA [24]
SPSA	5.2	86	1751	5582	*58e-1/1e5*	.	.	.	.	.	SPSA [13]

Table 12: 03-D, running time excess ERT/$\mathrm{ERT}_{\mathrm{best}}$ 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	10	25	96	179	252	291	320	364	411	489	$\mathrm{ERT}_{\mathrm{best}}$/D
(1,2)-CMA-ES	22	23	12	12	12	13	12	13	12	11	(1,2)-CMA-ES [5, 3]
(1,2m)-CMA-ES	5.6	6.1	5.6	5.0	4.8	4.7	4.8	4.7	4.6	4.4	(1,2m)-CMA-ES [5]
(1,2ms)-CMA-ES	9.1	7.9	5.6	5.3	4.9	4.6	4.4	4.2	3.9	3.6	(1,2ms)-CMA-ES [5]
(1,2s)-CMA-ES	17	27	22	28	27	25	24	28	26	36	(1,2s)-CMA-ES [3]
(1,4)-CMA-ES	4.4	4.8	4.2	4.0	3.6	3.4	3.3	3.1	**3.0**	**2.8**	(1,4)-CMA-ES [6, 4]
(1,4m)-CMA-ES	4.2	4.7	3.8	3.8	3.5	3.4	3.3	3.1	**3.0**	**2.8**	(1,4m)-CMA-ES [6]
(1,4ms)-CMA-ES	**2.9**	**1.6**	**2.8**	3.2	3.0	**3.0**	**2.9**	**2.8**	**2.7**	**2.5**	(1,4ms)-CMA-ES [1, 6]
(1,4s)-CMA-ES	**2.9**	**1.8**	**1.5**	**2.2**	**2.5**	**2.6**	**2.5**	**2.5**	**2.4**	**2.3**	(1,4s)-CMA-ES [4]
(1+1)-CMA-ES	**2.9**	**2.0**	**2.2**	**1.9**	**1.8**	**1.8**	**1.8**	**1.7**	**1.6**	**1.6**	(1+1)-CMA-ES [7]
(1+2ms)-CMA-ES	**2.9**	**1.9**	**2.3**	**2.5**	**2.3**	**2.3**	**2.2**	**2.1**	**2.0**	**1.9**	(1+2ms)-CMA-ES [2]
Artif Bee Colony	9.2	10	12	88	738	4889	*12e-2/1e5*	.	.	.	Artif Bee Colony [8]
avg NEWUOA	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	avg NEWUOA [23]
CMA-EGS (IPOP,r1)	23	18	305	433	837	958	1263	1800	1597	1343	CMA-EGS (IPOP,r1) [12]
Adap DE (F-AUC)	14	7.8	3.3	14	65	60	80	72	64	78	Adap DE (F-AUC) [10]
DE (Uniform)	15	8.5	3.1	**2.5**	101	127	116	140	125	106	DE (Uniform) [9]
IPOP-aCMA-ES	4.4	**2.5**	**2.3**	**2.4**	**2.8**	**2.7**	**2.8**	**2.7**	**2.6**	**2.5**	IPOP-aCMA-ES [16]
IPOP-CMA-ES	5.6	3.9	**2.0**	**2.1**	**2.0**	**2.1**	**2.1**	**2.1**	**2.1**	**2.2**	IPOP-CMA-ES [22]
CMA+DE-MOS	22	12	5.5	5.8	5.7	5.5	5.5	5.3	5.2	4.9	CMA+DE-MOS [18]
NBC-CMA	15	8.4	5.5	4.6	4.6	5.1	5.2	5.0	4.8	4.7	NBC-CMA [21]
POEMS	115	92	491	1169	1997	2513	*22e-2/3e5*	.	.	.	POEMS [17]
PM-AdapSS-DE	13	9.1	77	89	103	232	211	206	183	154	PM-AdapSS-DE [9, 10]
pPOEMS	179	229	191	188	198	248	286	310	329	351	pPOEMS [17, 20]
Basic RCGA	39	22	133	180	185	507	529	2009	*96e-3/5e4*	.	Basic RCGA [24]
SPSA	3645	2752	1612	3638	5591	*21e+0/1e5*	.	.	.	.	SPSA [13]

Table 13: 03-D, running time excess ERT/$\mathrm{ERT}_{\mathrm{best}}$ 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
$\mathrm{ERT}_{\mathrm{best}}$/D	0.47	5.8	55	101	141	196	236	275	318	411	$\mathrm{ERT}_{\mathrm{best}}$/D
(1,2)-CMA-ES	3.0	7.0	6.2	8.1	6.8	6.8	7.8	7.0	7.2	12	(1,2)-CMA-ES [5, 3]
(1,2m)-CMA-ES	**1.0**	**2.7**	5.0	7.4	8.4	7.5	7.6	10	11	17	(1,2m)-CMA-ES [5]
(1,2ms)-CMA-ES	**2.1**	4.0	4.4	5.2	5.3	5.1	6.2	5.8	8.3	21	(1,2ms)-CMA-ES [5]
(1,2s)-CMA-ES	**2.0**	7.5	5.0	13	12	11	11	14	20	27	(1,2s)-CMA-ES [3]
(1,4)-CMA-ES	**2.1**	**2.8**	**2.0**	**2.3**	**2.2**	**1.8**	**1.9**	**2.1**	**2.0**	**2.4**	(1,4)-CMA-ES [6, 4]
(1,4m)-CMA-ES	**1.1**	**3.0**	**1.6**	**2.4**	**2.1**	**1.8**	**1.8**	**2.2**	**2.1**	**2.2**	(1,4m)-CMA-ES [6]
(1,4ms)-CMA-ES	**2.1**	**2.0**	**1.0**	**1.4**	**1.5**	**1.4**	**1.4**	**1.6**	**1.8**	**2.0**	(1,4ms)-CMA-ES [1, 6]
(1,4s)-CMA-ES	**1.7**	**2.2**	**2.2**	**2.2**	**2.0**	**1.7**	**1.7**	**1.8**	**1.8**	**1.6**	(1,4s)-CMA-ES [4]
(1+1)-CMA-ES	**1.5**	**2.2**	**1.2**	**2.2**	**1.8**	**1.5**	**1.6**	**1.6**	**1.5**	**1.8**	(1+1)-CMA-ES [7]
(1+2ms)-CMA-ES	**1**	3.4	**1.5**	**1.4**	**1.3**	**1.1**	**1.0**	**1.1**	**1.1**	**1.3**	(1+2ms)-CMA-ES [2]
Artif Bee Colony	**1.3**	6.4	3.6	45	974	7254	*86e-3/1e5*	.	.	.	Artif Bee Colony [8]
avg NEWUOA	**2.9**	**1**	**1.7**	3.8	11	26	48	86	76	*36e-4/8e3*	avg NEWUOA [23]
CMA-EGS (IPOP,r1)	19	8.1	485	737	4650	*61e-2/1e5*	.	.	.	.	CMA-EGS (IPOP,r1) [12]
Adap DE (F-AUC)	**1.8**	5.6	**2.2**	**2.1**	**2.2**	**2.0**	**2.1**	**2.2**	**2.2**	**2.1**	Adap DE (F-AUC) [10]
DE (Uniform)	**1.6**	6.8	**2.6**	**2.5**	**2.5**	**2.2**	**2.3**	**2.4**	**2.3**	**2.3**	DE (Uniform) [9]
IPOP-aCMA-ES	**2.6**	**2.6**	**1.0**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	IPOP-aCMA-ES [16]
IPOP-CMA-ES	**2.5**	**2.9**	**1**	**1.4**	**1.5**	**1.3**	**1.4**	**1.4**	**1.4**	**1.3**	IPOP-CMA-ES [22]
CMA+DE-MOS	**1.6**	4.3	4.1	4.1	3.9	3.5	3.4	3.3	3.3	3.0	CMA+DE-MOS [18]
NBC-CMA	**1.7**	7.5	**2.8**	**2.5**	3.1	**2.8**	**2.7**	**2.7**	**2.6**	**2.5**	NBC-CMA [21]
POEMS	219	46	20	331	886	944	3531	*43e-4/3e5*	.	.	POEMS [17]
PM-AdapSS-DE	**2.3**	5.6	**2.3**	**2.3**	**2.4**	**2.3**	**2.3**	**2.3**	**2.3**	**2.3**	PM-AdapSS-DE [9, 10]
pPOEMS	**1.9**	49	30	166	236	286	310	359	410	489	pPOEMS [17, 20]
Basic RCGA	**1.4**	10	34	123	321	870	1550	1334	1155	*46e-3/5e4*	Basic RCGA [24]
SPSA	24	33	33	760	10631	*67e-2/1e5*	.	.	.	.	SPSA [13]

Table 14: 03-D, running time excess ERT/$\mathrm{ERT}_{\mathrm{best}}$ 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
$\mathrm{ERT}_{\mathrm{best}}$/D	0.33	0.33	0.84	6.7	11	16	29	49	99	211	$\mathrm{ERT}_{\mathrm{best}}$/D
(1,2)-CMA-ES	**1**	**1.2**	12	5.4	5.7	6.8	10	11	7.6	5.5	(1,2)-CMA-ES [5, 3]
(1,2m)-CMA-ES	**1**	**1.1**	**1.4**	3.6	3.9	4.5	5.5	6.4	5.4	4.8	(1,2m)-CMA-ES [5]
(1,2ms)-CMA-ES	**1**	**1**	**2.0**	**2.2**	**2.7**	3.6	4.1	5.9	4.7	3.8	(1,2ms)-CMA-ES [5]
(1,2s)-CMA-ES	**1**	**1.3**	3.1	**2.8**	4.5	7.9	10	16	11	8.1	(1,2s)-CMA-ES [3]
(1,4)-CMA-ES	**1**	**1.7**	4.1	**2.4**	**2.8**	3.6	3.4	3.6	**2.9**	**2.1**	(1,4)-CMA-ES [6, 4]
(1,4m)-CMA-ES	**1**	**1.1**	**2.6**	**1.7**	**2.3**	**2.8**	**2.9**	3.6	**2.7**	**2.1**	(1,4m)-CMA-ES [6]
(1,4ms)-CMA-ES	**1**	**1.3**	**1.6**	**1.3**	**2.0**	**2.4**	**2.5**	**2.4**	**1.9**	**1.5**	(1,4ms)-CMA-ES [1, 6]
(1,4s)-CMA-ES	**1**	**1.5**	3.6	**1.6**	**2.3**	3.3	3.6	3.3	**2.4**	**1.8**	(1,4s)-CMA-ES [4]
(1+1)-CMA-ES	**1**	**1.1**	**3.0**	**1.9**	**2.6**	**2.7**	**2.7**	**2.5**	**1.6**	**1.2**	(1+1)-CMA-ES [7]
(1+2ms)-CMA-ES	**1**	**1**	**1.6**	**1.8**	**2.3**	**2.4**	**2.2**	**2.1**	**1.4**	**1**	(1+2ms)-CMA-ES [2]
Artif Bee Colony	**1**	**1.2**	**1.3**	7.7	12	24	257	1608	4666	*55e-6/1e5*	Artif Bee Colony [8]
avg NEWUOA	**1**	**1.2**	4.1	**1**	**1**	**1**	**1**	**1**	**1**	**2.1**	avg NEWUOA [23]
CMA-EGS (IPOP,r1)	5.7	25	38	12	11	14	21	24	13	129	CMA-EGS (IPOP,r1) [12]
Adap DE (F-AUC)	**1**	**1.1**	**1.8**	3.2	9.1	11	8.0	6.2	3.9	**2.5**	Adap DE (F-AUC) [10]
DE (Uniform)	**1**	**1.1**	**1.4**	3.8	10	13	9.3	7.3	4.3	**2.7**	DE (Uniform) [9]
IPOP-aCMA-ES	**1**	**1**	**2.0**	**2.4**	3.2	3.9	**3.0**	**2.8**	**1.8**	**1.3**	IPOP-aCMA-ES [16]
IPOP-CMA-ES	**1**	**1.5**	**2.5**	3.2	3.5	4.3	3.9	3.6	**2.5**	**1.8**	IPOP-CMA-ES [22]
CMA+DE-MOS	**1**	**1.1**	**1**	3.5	13	15	12	11	6.5	4.3	CMA+DE-MOS [18]
NBC-CMA	**1**	**1.3**	**1.9**	5.0	11	11	7.7	6.1	4.0	**2.7**	NBC-CMA [21]
POEMS	**1**	39	233	46	55	105	113	101	115	4485	POEMS [17]
PM-AdapSS-DE	**1**	**1.6**	**1.7**	4.7	10	12	9.0	6.8	4.2	**2.7**	PM-AdapSS-DE [9, 10]
pPOEMS	**1**	**1.1**	35	37	80	434	599	637	451	462	pPOEMS [17, 20]
Basic RCGA	**1**	**1.1**	**1.7**	8.6	32	66	171	408	696	*51e-7/5e4*	Basic RCGA [24]
SPSA	10	47	464	254	179	153	349	496	837	*48e-7/1e5*	SPSA [13]

Table 15: 03-D, running time excess ERT/$\mathrm{ERT}_{\mathrm{best}}$ 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
$\mathrm{ERT}_{\mathrm{best}}$/D	0.33	1.0	40	617	856	1025	1078	1132	1184	1296	$\mathrm{ERT}_{\mathrm{best}}$/D
(1,2)-CMA-ES	**2.1**	5.9	7.7	23	164	137	130	124	118	108	(1,2)-CMA-ES [5, 3]
(1,2m)-CMA-ES	**1.1**	**2.4**	**2.7**	6.0	29	24	23	22	21	19	(1,2m)-CMA-ES [5]
(1,2ms)-CMA-ES	**1.6**	**2.8**	3.7	7.6	27	23	22	21	20	18	(1,2ms)-CMA-ES [5]
(1,2s)-CMA-ES	**1.4**	3.5	9.1	29	81	68	64	61	59	54	(1,2s)-CMA-ES [3]
(1,4)-CMA-ES	**1.8**	**1.9**	4.0	4.2	17	14	14	13	12	11	(1,4)-CMA-ES [6, 4]
(1,4m)-CMA-ES	**1**	**1.6**	**1.2**	**2.1**	20	17	16	15	15	13	(1,4m)-CMA-ES [6]
(1,4ms)-CMA-ES	**1.5**	**2.0**	**2.2**	**1.5**	6.3	5.3	5.0	4.8	4.6	4.2	(1,4ms)-CMA-ES [1, 6]
(1,4s)-CMA-ES	**1.1**	**2.4**	4.3	**2.9**	55	46	44	41	40	36	(1,4s)-CMA-ES [4]
(1+1)-CMA-ES	**1.8**	**2.4**	**2.5**	**2.8**	27	22	21	20	19	18	(1+1)-CMA-ES [7]
(1+2ms)-CMA-ES	**1.4**	**1.9**	**2.1**	5.2	18	15	14	13	13	12	(1+2ms)-CMA-ES [2]
Artif Bee Colony	**1.1**	**1.3**	3.6	25	103	236	651	1255	*29e-3/1e5*	.	Artif Bee Colony [8]
avg NEWUOA	**2.0**	**2.5**	3.3	**2.8**	7.5	6.3	6.0	5.7	5.4	5.0	avg NEWUOA [23]
CMA-EGS (IPOP,r1)	18	17	12	27	795	1398	*99e-2/1e5*	.	.	.	CMA-EGS (IPOP,r1) [12]
Adap DE (F-AUC)	**1.3**	**1.4**	**1.9**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	Adap DE (F-AUC) [10]
DE (Uniform)	**1**	**2.9**	**2.4**	**1.2**	10	8.1	7.8	7.5	7.2	6.7	DE (Uniform) [9]
IPOP-aCMA-ES	**2.5**	3.1	**1**	**1.2**	**2.6**	**2.3**	**2.2**	**2.1**	**2.1**	**2.0**	IPOP-aCMA-ES [16]
IPOP-CMA-ES	**1.3**	**2.2**	**2.5**	**1.0**	**2.9**	**2.5**	**2.4**	**2.3**	**2.3**	**2.2**	IPOP-CMA-ES [22]
CMA+DE-MOS	**1.3**	**1.1**	5.0	**2.8**	3.7	4.4	4.3	4.1	4.0	3.8	CMA+DE-MOS [18]
NBC-CMA	**1.2**	**1**	3.2	**2.3**	7.6	6.4	6.1	5.8	5.6	5.2	NBC-CMA [21]
POEMS	**1**	161	15	19	209	176	168	161	155	143	POEMS [17]
PM-AdapSS-DE	**1.4**	**1.9**	**2.3**	**1.1**	10	8.1	7.8	7.5	7.3	6.7	PM-AdapSS-DE [9, 10]
pPOEMS	**1.1**	15	17	34	57	56	61	65	68	75	pPOEMS [17, 20]
Basic RCGA	**1.3**	**1.5**	5.4	18	23	20	25	29	42	90	Basic RCGA [24]
SPSA	282	7237	481	2407	*21e-1/1e5*	.	.	.	.	.	SPSA [13]

Table 16: 03-D, running time excess ERT/$\mathrm{ERT}_{\mathrm{best}}$ 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
$\mathrm{ERT}_{\mathrm{best}}$/D	0.33	0.40	16	333	532	809	885	915	945	1043	$\mathrm{ERT}_{\mathrm{best}}$/D
(1,2)-CMA-ES	**1**	**1.5**	16	12	35	52	48	72	*25e-2/1e4*	.	(1,2)-CMA-ES [5, 3]
(1,2m)-CMA-ES	**1**	**1**	**2.0**	3.8	7.5	13	18	22	26	45	(1,2m)-CMA-ES [5]
(1,2ms)-CMA-ES	**1**	**1.7**	**2.1**	3.5	6.8	8.3	12	18	18	68	(1,2ms)-CMA-ES [5]
(1,2s)-CMA-ES	**1**	**1.4**	23	10	35	42	81	*17e-2/1e4*	.	.	(1,2s)-CMA-ES [3]
(1,4)-CMA-ES	**1**	**1.5**	**2.8**	4.2	5.5	6.0	7.3	7.2	10	65	(1,4)-CMA-ES [6, 4]
(1,4m)-CMA-ES	**1**	**1.3**	4.5	**1.7**	**2.9**	**2.8**	4.0	4.2	5.7	5.4	(1,4m)-CMA-ES [6]
(1,4ms)-CMA-ES	**1**	**1.2**	**1.6**	**1.4**	**1.9**	**2.1**	5.1	7.8	7.8	7.4	(1,4ms)-CMA-ES [1, 6]
(1,4s)-CMA-ES	**1**	**1.8**	5.2	**2.6**	4.4	6.0	10	15	18	24	(1,4s)-CMA-ES [4]
(1+1)-CMA-ES	**1**	**1.4**	**2.6**	**1.2**	3.7	6.5	20	23	31	71	(1+1)-CMA-ES [7]
(1+2ms)-CMA-ES	**1**	**1.2**	**1.6**	**1.1**	**1.7**	4.1	8.7	26	46	64	(1+2ms)-CMA-ES [2]
Artif Bee Colony	**1**	**1.8**	**1**	**1**	7.0	46	1596	*45e-4/1e5*	.	.	Artif Bee Colony [8]
avg NEWUOA	**1**	**1.3**	3.1	**2.0**	8.2	19	51	*19e-3/7e3*	.	.	avg NEWUOA [23]
CMA-EGS (IPOP,r1)	**1.2**	15	11	29	162	1853	*80e-3/1e5*	.	.	.	CMA-EGS (IPOP,r1) [12]
Adap DE (F-AUC)	**1**	**1.3**	**2.1**	**1.4**	**2.4**	**1.9**	**1.9**	10	10	8.8	Adap DE (F-AUC) [10]
DE (Uniform)	**1**	**1.2**	**1.8**	**1.4**	**2.7**	**2.4**	**2.4**	**2.5**	**2.5**	**2.4**	DE (Uniform) [9]
IPOP-aCMA-ES	**1**	**1.2**	**1.3**	**1.0**	**1**	**1**	**1.1**	**1.1**	**1.1**	**1**	IPOP-aCMA-ES [16]
IPOP-CMA-ES	**1**	**1.7**	**1.9**	**1.0**	**1.4**	**1.1**	**1**	**1**	**1**	**1.1**	IPOP-CMA-ES [22]
CMA+DE-MOS	**1**	**1.2**	**1.3**	**1.7**	**1.6**	**1.2**	**1.4**	**1.4**	**1.5**	**1.5**	CMA+DE-MOS [18]
NBC-CMA	**1**	**1.5**	**1.3**	**2.4**	**2.6**	**2.8**	**2.7**	**2.7**	**2.7**	**2.6**	NBC-CMA [21]
POEMS	**1**	20	15	9.0	191	169	158	154	150	138	POEMS [17]
PM-AdapSS-DE	**1**	**1.4**	**1.4**	**2.0**	4.0	3.4	12	12	11	11	PM-AdapSS-DE [9, 10]
pPOEMS	**1**	**1.4**	15	4.8	31	36	74	110	117	128	pPOEMS [17, 20]
Basic RCGA	**1**	**1**	**1.3**	5.5	16	38	88	107	132	213	Basic RCGA [24]
SPSA	**2.7**	107	89	99	573	*28e-2/1e5*	.	.	.	.	SPSA [13]

Table 17: 03-D, running time excess $\mathrm{ERT}/\mathrm{ERT}_{\mathrm{best}}$ 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

17 Schaffer F7, condition 10

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	0.33	0.38	2.3	33	102	270	353	433	848	1096	$\mathrm{ERT}_{\mathrm{best}}$/D
(1,2)-CMA-ES	**1**	**1.5**	3.3	8.2	23	83	*14e-3/1e4*		.	.	(1,2)-CMA-ES [5, 3]
(1,2m)-CMA-ES	**1**	**1.1**	**2.1**		3.6						

Table 18: 03-D, running time excess ERT/$\mathrm{ERT}_{\mathrm{best}}$ 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
$\mathrm{ERT}_{\mathrm{best}}$/D	0.33	0.62	18	61	262	568	779	994	1222	1559	$\mathrm{ERT}_{\mathrm{best}}$/D
(1,2)-CMA-ES	**1.2**	3.8	6.9	23	38	248	*69e-3/1e4*	.	.	.	(1,2)-CMA-ES [5, 3]
(1,2m)-CMA-ES	**1**	**2.3**	**1.0**	7.8	23	46	*42e-3/1e4*	.	.	.	(1,2m)-CMA-ES [5]
(1,2ms)-CMA-ES	**1**	3.5	**1.0**	3.4	10	37	*11e-3/1e4*	.	.	.	(1,2ms)-CMA-ES [5]
(1,2s)-CMA-ES	**1**	3.7	11	37	170	*24e-2/1e4*	.	.	.	.	(1,2s)-CMA-ES [3]
(1,4)-CMA-ES	**1.1**	**2.6**	4.1	5.7	9.1	30	180	*12e-3/1e4*	.	.	(1,4)-CMA-ES [6, 4]
(1,4m)-CMA-ES	**1.1**	31	3.5	4.0	5.1	11	27	*24e-4/1e4*	.	.	(1,4m)-CMA-ES [6]
(1,4ms)-CMA-ES	**1**	**2.7**	3.0	3.8	10	16	25	141	*15e-4/1e4*	.	(1,4ms)-CMA-ES [1, 6]
(1,4s)-CMA-ES	**1.2**	**3.0**	4.0	9.5	14	34	189	*15e-3/1e4*	.	.	(1,4s)-CMA-ES [4]
(1+1)-CMA-ES	**1**	**2.3**	4.5	16	18	63	*42e-3/1e4*	.	.	.	(1+1)-CMA-ES [7]
(1+2ms)-CMA-ES	**1**	39	4.4	9.1	16	47	192	*24e-3/1e4*	.	.	(1+2ms)-CMA-ES [2]
Artif Bee Colony	**1**	**2.0**	**2.5**	12	115	570	*23e-3/1e5*	.	.	.	Artif Bee Colony [8]
avg NEWUOA	**1.3**	3.1	8.5	24	24	160	*76e-3/6e3*	.	.	.	avg NEWUOA [23]
CMA-EGS (IPOP,r1)	12	25	10	50	467	*19e-2/1e5*	.	.	.	.	CMA-EGS (IPOP,r1) [12]
Adap DE (F-AUC)	**1.1**	**1.7**	**2.2**	**2.9**	**1.4**	**1.0**	**1.0**	**1**	**1.0**	**1.0**	Adap DE (F-AUC) [10]
DE (Uniform)	**1.5**	**1.8**	**2.6**	**2.9**	**1.4**	**1.0**	**1.0**	**1.0**	**1.0**	**1.0**	DE (Uniform) [9]
IPOP-aCMA-ES	**1**	4.8	**1**	**1**	**1**	**1.6**	**1.4**	**1.1**	**1.2**	**1.1**	IPOP-aCMA-ES [16]
IPOP-CMA-ES	**1.3**	4.1	**1.1**	**1.5**	**1.9**	**1.8**	**1.7**	**1.7**	**1.7**	**1.5**	IPOP-CMA-ES [22]
CMA+DE-MOS	**1.1**	**1.2**	**2.2**	6.2	3.4	3.1	**2.9**	**2.5**	**2.3**	**2.4**	CMA+DE-MOS [18]
NBC-CMA	**1.3**	**2.2**	**1.8**	3.8	31	15	11	8.7	7.5	6.3	NBC-CMA [21]
POEMS	43	167	18	21	15	91	166	142	204	267	POEMS [17]
PM-AdapSS-DE	**1.5**	**2.3**	**1.6**	**2.8**	**1.4**	**1**	**1**	**1.0**	**1**	**1**	PM-AdapSS-DE [9, 10]
pPOEMS	**1.1**	34	21	65	90	77	80	89	88	99	pPOEMS [17, 20]
Basic RCGA	**1**	**1**	18	68	101	592	*33e-3/5e4*	.	.	.	Basic RCGA [24]
SPSA	43	797	2877	2506	2541	*20e-1/1e5*	.	.	.	.	SPSA [13]

Table 19: 03-D, running time excess $\mathrm{ERT}/\mathrm{ERT}_{\mathrm{best}}$ 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

Table 20: 03-D, running time excess ERT/$\mathrm{ERT}_{\mathrm{best}}$ 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
$\mathrm{ERT}_{\mathrm{best}}$/D	1.8	3.4	3.7	137	969	1461	3037	4119	4355	5005	$\mathrm{ERT}_{\mathrm{best}}$/D
(1,2)-CMA-ES	4.7	3.2	3.7	3.8	13	8.4	4.6	3.4	3.2	**2.8**	(1,2)-CMA-ES [5, 3]
(1,2m)-CMA-ES	**2.5**	**2.1**	**2.4**	7.6	32	21	10	7.5	7.1	6.2	(1,2m)-CMA-ES [5]
(1,2ms)-CMA-ES	**2.7**	**2.4**	**2.9**	7.4	72	48	23	17	16	14	(1,2ms)-CMA-ES [5]
(1,2s)-CMA-ES	4.5	5.9	5.8	10	25	18	8.5	6.3	5.9	5.2	(1,2s)-CMA-ES [3]
(1,4)-CMA-ES	**1.9**	**1.5**	**2.1**	3.8	8.7	5.8	**2.8**	**2.0**	**1.9**	**1.7**	(1,4)-CMA-ES [6, 4]
(1,4m)-CMA-ES	**1.4**	**1**	**1.5**	7.3	14	9.3	4.5	3.3	3.1	**2.7**	(1,4m)-CMA-ES [6]
(1,4ms)-CMA-ES	**1.3**	**1.2**	**1.3**	4.4	43	28	14	10	9.5	8.3	(1,4ms)-CMA-ES [1, 6]
(1,4s)-CMA-ES	**1**	**1.1**	**1.5**	5.6	16	11	5.3	3.9	3.7	3.2	(1,4s)-CMA-ES [4]
(1+1)-CMA-ES	**2.2**	**1.6**	**1.8**	**2.8**	8.1	5.3	**2.6**	**1.9**	**1.8**	**1.6**	(1+1)-CMA-ES [7]
(1+2ms)-CMA-ES	**1.3**	**1.1**	**1.3**	**1.9**	7.3	4.8	**2.3**	**1.7**	**1.6**	**1.4**	(1+2ms)-CMA-ES [2]
Artif Bee Colony	**2.7**	3.8	4.2	**1**	**1**	**1**	**1**	**1.2**	**1.4**	**1.7**	Artif Bee Colony [8]
avg NEWUOA	**1.6**	**1**	**1**	**2.1**	7.8	5.2	**2.5**	**1.8**	**1.7**	**1.5**	avg NEWUOA [23]
CMA-EGS (IPOP,r1)	11	8.7	10	147	*45e-2/1e5*	.	.	.	.	.	CMA-EGS (IPOP,r1) [12]
Adap DE (F-AUC)	**1.7**	**2.2**	3.4	3.5	27	18	8.6	6.4	6.0	5.3	Adap DE (F-AUC) [10]
DE (Uniform)	3.0	**2.6**	3.5	**2.6**	27	18	8.6	6.3	6.0	5.3	DE (Uniform) [9]
IPOP-aCMA-ES	**2.4**	**1.5**	**1.5**	4.7	4.5	3.2	**1.6**	**1.2**	**1.2**	**1.0**	IPOP-aCMA-ES [16]
IPOP-CMA-ES	**2.2**	**2.1**	**2.2**	4.2	**4.4**	**3.1**	**1.5**	**1.2**	**1.1**	**1**	IPOP-CMA-ES [22]
CMA+DE-MOS	3.1	**2.9**	3.4	4.0	**2.8**	**2.2**	**1.3**	**1**	**1**	**1.4**	CMA+DE-MOS [18]
NBC-CMA	**2.0**	3.1	3.7	3.6	10	6.8	3.3	**2.4**	**2.3**	**2.0**	NBC-CMA [21]
POEMS	116	63	60	7.6	115	77	37	28	27	24	POEMS [17]
PM-AdapSS-DE	**2.0**	**1.9**	**2.1**	**2.6**	17	11	5.4	4.0	3.8	3.3	PM-AdapSS-DE [9, 10]
pPOEMS	66	45	48	19	13	15	10	9.0	10	12	pPOEMS [17, 20]
Basic RCGA	**2.3**	**2.4**	3.5	60	171	501	242	*41e-2/5e4*	.	.	Basic RCGA [24]
SPSA	36	29	38	4736	*15e-1/1e5*	.	.	.	.	.	SPSA [13]

Table 21: 03-D, running time excess ERT/$\mathrm{ERT}_{\mathrm{best}}$ 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
$\mathrm{ERT}_{\mathrm{best}}$/D	0.33	0.33	2.2	101	232	285	301	307	310	319	$\mathrm{ERT}_{\mathrm{best}}$/D
(1,2)-CMA-ES	**1**	**1**	6.2	6.4	15	14	14	13	13	13	(1,2)-CMA-ES [5, 3]
(1,2m)-CMA-ES	**1**	**1**	**1.4**	4.7	4.7	5.8	5.6	5.5	5.5	5.4	(1,2m)-CMA-ES [5]
(1,2ms)-CMA-ES	**1**	**1**	**1.7**	4.9	7.1	6.4	8.9	8.8	8.7	8.6	(1,2ms)-CMA-ES [5]
(1,2s)-CMA-ES	**1**	**1**	3.8	13	24	22	21	20	20	20	(1,2s)-CMA-ES [3]
(1,4)-CMA-ES	**1**	**1**	**1.3**	4.5	8.0	6.5	6.2	6.1	6.1	6.0	(1,4)-CMA-ES [6, 4]
(1,4m)-CMA-ES	**1**	**1**	**1**	3.3	13	13	14	14	13	13	(1,4m)-CMA-ES [6]
(1,4ms)-CMA-ES	**1**	**1**	**2.4**	3.1	4.5	3.7	3.5	3.5	3.5	3.4	(1,4ms)-CMA-ES [1, 6]
(1,4s)-CMA-ES	**1**	**1**	**2.2**	4.9	7.0	5.7	5.5	5.4	5.4	5.3	(1,4s)-CMA-ES [4]
(1+1)-CMA-ES	**1**	**1**	**2.3**	3.2	6.1	5.0	4.8	4.7	4.6	4.5	(1+1)-CMA-ES [7]
(1+2ms)-CMA-ES	**1**	**1**	**1.5**	4.5	5.5	4.5	4.3	4.2	4.2	4.1	(1+2ms)-CMA-ES [2]
Artif Bee Colony	**1**	**1**	**2.2**	**1.5**	**2.2**	3.0	5.2	13	30	73	Artif Bee Colony [8]
avg NEWUOA	**1**	**1**	3.7	**1.5**	**1.3**	**1.0**	**1**	**1**	**1**	**1**	avg NEWUOA [23]
CMA-EGS (IPOP,r1)	**1**	19	9.2	21	135	157	149	292	289	282	CMA-EGS (IPOP,r1) [12]
Adap DE (F-AUC)	**1**	**1**	**1.8**	**1.3**	**1**	**1**	**1.2**	**1.3**	**1.4**	**1.6**	Adap DE (F-AUC) [10]
DE (Uniform)	**1**	**1**	**1.2**	**1.2**	**1.1**	**1.2**	**1.3**	**1.4**	**1.5**	**1.7**	DE (Uniform) [9]
IPOP-aCMA-ES	**1**	**1**	**1.6**	4.0	6.3	5.3	5.2	5.1	5.7	5.7	IPOP-aCMA-ES [16]
IPOP-CMA-ES	**1**	**1**	**1.4**	6.6	6.2	5.5	5.5	5.5	5.5	5.6	IPOP-CMA-ES [22]
CMA+DE-MOS	**1**	**1**	**1.5**	8.1	14	55	248	377	376	434	CMA+DE-MOS [18]
NBC-CMA	**1**	**1**	**1.2**	3.1	19	28	27	26	26	25	NBC-CMA [21]
POEMS	**1**	**1**	83	606	490	398	379	373	371	364	POEMS [17]
PM-AdapSS-DE	**1**	**1**	**1.0**	**1**	32	26	25	24	24	24	PM-AdapSS-DE [9, 10]
pPOEMS	**1**	**1**	29	7.0	6.6	12	20	29	46	73	pPOEMS [17, 20]
Basic RCGA	**1**	**1**	**1.7**	13	36	83	83	109	136	148	Basic RCGA [24]
SPSA	**1**	30	28	266	748	609	578	573	583	1470	SPSA [13]

Table 22: 03-D, running time excess ERT/$\mathrm{ERT}_{\mathrm{best}}$ 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
$\mathrm{ERT}_{\mathrm{best}}$/D	0.33	0.33	7.0	85	338	344	357	375	387	423	$\mathrm{ERT}_{\mathrm{best}}$/D
(1,2)-CMA-ES	**1**	**1**	3.4	11	10	12	12	12	11	10	(1,2)-CMA-ES [5, 3]
(1,2m)-CMA-ES	**1**	**1**	13	7.3	7.8	8.9	9.1	8.8	8.6	8.0	(1,2m)-CMA-ES [5]
(1,2ms)-CMA-ES	**1**	**1**	6.1	5.1	7.2	11	11	12	12	11	(1,2ms)-CMA-ES [5]
(1,2s)-CMA-ES	**1**	**1**	16	10	9.2	9.2	10	10	9.3	8.7	(1,2s)-CMA-ES [3]
(1,4)-CMA-ES	**1**	**1**	3.4	5.2	**2.7**	**2.8**	**2.7**	**2.6**	**2.6**	**2.4**	(1,4)-CMA-ES [6, 4]
(1,4m)-CMA-ES	**1**	**1**	3.1	4.6	**2.5**	**2.6**	**2.6**	**2.5**	**2.5**	**2.3**	(1,4m)-CMA-ES [6]
(1,4ms)-CMA-ES	**1**	**1**	**2.4**	6.7	5.3	5.6	5.4	5.2	5.1	4.7	(1,4ms)-CMA-ES [1, 6]
(1,4s)-CMA-ES	**1**	**1**	7.8	4.7	3.5	3.5	3.4	3.3	3.2	**3.0**	(1,4s)-CMA-ES [4]
(1+1)-CMA-ES	**1**	**1**	5.5	5.8	**2.5**	**2.5**	**2.5**	**2.4**	**2.3**	**2.1**	(1+1)-CMA-ES [7]
(1+2ms)-CMA-ES	**1**	**1**	**2.7**	**1.8**	**1.2**	**1.2**	**1.2**	**1.2**	**1.1**	**1.1**	(1+2ms)-CMA-ES [2]
Artif Bee Colony	**1**	**1**	**2.2**	**1.2**	**1.5**	10	38	85	114	1588	Artif Bee Colony [8]
avg NEWUOA	**1**	**1**	**2.4**	**1.3**	**1**	**1**	**1**	**1**	**1**	**1**	avg NEWUOA [23]
CMA-EGS (IPOP,r1)	**1**	16	3.1	29	83	184	286	411	399	365	CMA-EGS (IPOP,r1) [12]
Adap DE (F-AUC)	**1**	**1**	**1.8**	**1.4**	46	46	44	42	41	38	Adap DE (F-AUC) [10]
DE (Uniform)	**1**	**1**	**1.1**	**1**	46	46	44	42	41	38	DE (Uniform) [9]
IPOP-aCMA-ES	**1**	**1**	5.7	4.7	9.3	29	82	79	77	71	IPOP-aCMA-ES [16]
IPOP-CMA-ES	**1**	**1**	**1**	3.3	7.2	32	89	102	99	92	IPOP-CMA-ES [22]
CMA+DE-MOS	**1**	**1**	**1.3**	11	7.7	10	11	15	15	63	CMA+DE-MOS [18]
NBC-CMA	**1**	**1**	**1.2**	73	61	79	76	73	71	65	NBC-CMA [21]
POEMS	**1**	**1**	1844	416	346	342	330	316	308	283	POEMS [17]
PM-AdapSS-DE	**1**	**1**	**1.1**	85	75	73	71	68	66	60	PM-AdapSS-DE [9, 10]
pPOEMS	**1**	**1**	25	7.9	74	80	84	93	103	118	pPOEMS [17, 20]
Basic RCGA	**1**	**1**	**1.1**	21	39	136	185	211	421	1760	Basic RCGA [24]
SPSA	**1**	28	27	214	2063	4287	*40e-2/1e5*	.	.	.	SPSA [13]

Table 23: 03-D, running time excess ERT/$\mathrm{ERT_{best}}$ 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

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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
$\mathrm{ERT_{best}}$/D	0.33	0.33	2.2	328	1526	2661	3203	3933	4046	4294	$\mathrm{ERT_{best}}$/D
(1,2)-CMA-ES	**1**	**1**	**2.9**	15	47	27	45	37	36	*68e-2/1e4*	(1,2)-CMA-ES [5, 3]
(1,2m)-CMA-ES	**1**	**1**	**2.6**	5.2	9.4	16	13	17	17	*22e-2/1e4*	(1,2m)-CMA-ES [5]
(1,2ms)-CMA-ES	**1**	**1**	**2.1**	7.6	14	12	10	12	12	11	(1,2ms)-CMA-ES [5]
(1,2s)-CMA-ES	**1**	**1**	3.9	22	46	27	46	*66e-2/1e4*	.	.	(1,2s)-CMA-ES [3]
(1,4)-CMA-ES	**1**	**1**	**1**	3.0	3.9	**2.4**	**2.3**	**1.9**	**1.8**	**2.1**	(1,4)-CMA-ES [6, 4]
(1,4m)-CMA-ES	**1**	**1**	**1.2**	**2.6**	3.8	3.2	3.2	**2.7**	**2.6**	**2.4**	(1,4m)-CMA-ES [6]
(1,4ms)-CMA-ES	**1**	**1**	**2.4**	3.4	5.9	4.0	3.4	**2.7**	**2.7**	**2.5**	(1,4ms)-CMA-ES [1, 6]
(1,4s)-CMA-ES	**1**	**1**	3.8	6.8	7.9	6.2	7.8	8.3	8.1	10	(1,4s)-CMA-ES [4]
(1+1)-CMA-ES	**1**	**1**	**2.2**	**1.4**	**2.5**	**2.8**	**3.0**	**2.9**	3.8	5.3	(1+1)-CMA-ES [7]
(1+2ms)-CMA-ES	**1**	**1**	**2.0**	**1.5**	**2.0**	3.1	3.8	4.7	4.6	4.3	(1+2ms)-CMA-ES [2]
Artif Bee Colony	**1**	**1**	**1.7**	4.0	*24e-2/1e5*	.	.	.	.	.	Artif Bee Colony [8]
avg NEWUOA	**1**	**1**	4.3	**1.0**	4.5	13	34	*46e-3/7e3*	.	.	avg NEWUOA [23]
CMA-EGS (IPOP,r1)	**1**	7.1	6.3	4.6	*29e-2/1e5*	.	.	.	.	.	CMA-EGS (IPOP,r1) [12]
Adap DE (F-AUC)	**1**	**1**	**1.2**	**1.3**	**1**	**1**	**1.2**	**1.2**	**1.5**	**1.8**	Adap DE (F-AUC) [10]
DE (Uniform)	**1**	**1**	**1.6**	**1**	**1.0**	**1.1**	**1.3**	**1.3**	**1.6**	**2.0**	DE (Uniform) [9]
IPOP-aCMA-ES	**1**	**1**	**2.9**	**2.2**	**2.0**	**1.2**	**1**	**1.0**	**1.0**	**1**	IPOP-aCMA-ES [16]
IPOP-CMA-ES	**1**	**1**	**2.0**	**2.2**	16	9.1	7.6	6.2	6.0	5.7	IPOP-CMA-ES [22]
CMA+DE-MOS	**1**	**1**	**1.6**	3.1	**2.0**	**1.3**	**1.2**	**1**	**1**	**1.0**	CMA+DE-MOS [18]
NBC-CMA	**1**	**1**	**1.1**	6.3	70	40	33	27	26	25	NBC-CMA [21]
POEMS	**1**	**1**	8.0	8.6	21	22	19	16	16	16	POEMS [17]
PM-AdapSS-DE	**1**	**1**	**1.6**	**1.1**	**1.1**	3.9	3.6	3.3	3.5	3.8	PM-AdapSS-DE [9, 10]
pPOEMS	**1**	**1**	5.8	27	52	42	44	43	48	61	pPOEMS [17, 20]
Basic RCGA	**1**	**1**	**2.2**	6.8	54	127	*15e-2/5e4*	.	.	.	Basic RCGA [24]
SPSA	**1**	26	45	390	*99e-2/1e5*	.	.	.	.	.	SPSA [13]

Table 24: 03-D, running time excess ERT/$\mathrm{ERT}_{\mathrm{best}}$ 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
$\mathrm{ERT}_{\mathrm{best}}$/D	0.33	0.33	45	4197	70760	1.44e5	1.44e5	1.44e5	1.44e5	1.44e5	$\mathrm{ERT}_{\mathrm{best}}$/D
(1,2)-CMA-ES	**1**	**1**	4.9	36	*18e-1/1e4*	.	.	.	.	.	(1,2)-CMA-ES [5, 3]
(1,2m)-CMA-ES	**1**	**1**	**1.4**	16	*14e-1/1e4*	.	.	.	.	.	(1,2m)-CMA-ES [5]
(1,2ms)-CMA-ES	**1**	**1**	**2.4**	6.2	*19e-1/1e4*	.	.	.	.	.	(1,2ms)-CMA-ES [5]
(1,2s)-CMA-ES	**1**	**1**	8.9	*31e-1/1e4*	.	.	.	.	.	.	(1,2s)-CMA-ES [3]
(1,4)-CMA-ES	**1**	**1**	**2.3**	11	*14e-1/1e4*	.	.	.	.	.	(1,4)-CMA-ES [6, 4]
(1,4m)-CMA-ES	**1**	**1**	**1.1**	**2.0**	*85e-2/1e4*	.	.	.	.	.	(1,4m)-CMA-ES [6]
(1,4ms)-CMA-ES	**1**	**1.1**	**1**	3.4	**1**	**1**	**1**	**1**	**1**	**1**	(1,4ms)-CMA-ES [1, 6]
(1,4s)-CMA-ES	**1**	**1**	3.8	3.2	*86e-2/1e4*	.	.	.	.	.	(1,4s)-CMA-ES [4]
(1+1)-CMA-ES	**1**	**1.1**	4.7	**2.8**	*97e-2/1e4*	.	.	.	.	.	(1+1)-CMA-ES [7]
(1+2ms)-CMA-ES	**1**	**1**	**1.5**	3.8	*10e-1/1e4*	.	.	.	.	.	(1+2ms)-CMA-ES [2]
Artif Bee Colony	**1**	**1.4**	3.4	7.0	*54e-2/1e5*	.	.	.	.	.	Artif Bee Colony [8]
avg NEWUOA	**1**	**2.6**	**2.7**	**1**	**1.2**	*64e-2/6e3*	.	.	.	.	avg NEWUOA [23]
CMA-EGS (IPOP,r1)	27	31	**2.9**	12	*40e-2/1e5*	.	.	.	.	.	CMA-EGS (IPOP,r1) [12]
Adap DE (F-AUC)	**1**	**1**	**2.2**	66	3.9	**2.8**	**2.8**	**2.8**	**2.8**	**2.8**	Adap DE (F-AUC) [10]
DE (Uniform)	**1**	**1.1**	**2.7**	48	**2.9**	**1.4**	**1.4**	**1.4**	**1.4**	**1.4**	DE (Uniform) [9]
IPOP-aCMA-ES	**1**	**1**	**1.9**	121	31	33	33	33	33	33	IPOP-aCMA-ES [16]
IPOP-CMA-ES	**1**	**1.1**	**1.3**	224	*30e-1/3e5*	.	.	.	.	.	IPOP-CMA-ES [22]
CMA+DE-MOS	**1**	**1.2**	4.6	6.5	**1.7**	**1.3**	**1.6**	**1.6**	**1.6**	**1.6**	CMA+DE-MOS [18]
NBC-CMA	**1**	**1.1**	**2.0**	20	21	*51e-2/1e5*	.	.	.	.	NBC-CMA [21]
POEMS	**1**	44	12	465	*31e-1/3e5*	.	.	.	.	.	POEMS [17]
PM-AdapSS-DE	**1**	**1.7**	**2.9**	48	5.7	**2.9**	4.7	4.7	4.7	4.7	PM-AdapSS-DE [9, 10]
pPOEMS	**1**	**1.3**	13	53	5.6	3.6	3.6	3.7	3.8	3.9	pPOEMS [17, 20]
Basic RCGA	**1**	**1.3**	3.6	37	10	5.1	*17e-1/5e4*	.	.	.	Basic RCGA [24]
SPSA	59	528	10749	*14e+0/1e5*	.	.	.	.	.	.	SPSA [13]

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