Comparison tables: BBOB 2010 function testbed in 20-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: 20-D, running time excess ERT/ERT_{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
ERT_{best}/D	0.05	2.6	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	ERT_{best}/D
(1,2)-CMA-ES	**1**	6.7	6.7	11	15	19	23	27	31	40	(1,2)-CMA-ES [5, 3]
(1,2m)-CMA-ES	**1**	**2.7**	3.9	6.3	8.6	11	13	15	18	22	(1,2m)-CMA-ES [5]
(1,2ms)-CMA-ES	**1**	**2.7**	3.5	5.4	7.7	10	12	14	16	20	(1,2ms)-CMA-ES [5]
(1,2s)-CMA-ES	**1**	6.7	7.5	11	15	19	23	27	31	38	(1,2s)-CMA-ES [3]
(1,4)-CMA-ES	**1**	**1.9**	3.3	5.4	7.6	10	12	14	16	21	(1,4)-CMA-ES [6, 4]
(1,4m)-CMA-ES	**1**	**1.6**	**2.7**	4.6	6.4	8.4	10	12	14	18	(1,4m)-CMA-ES [6]
(1,4ms)-CMA-ES	**1**	**1.5**	**2.1**	**3.5**	**4.9**	**6.2**	**7.6**	**9.1**	**11**	**13**	(1,4ms)-CMA-ES [1, 6]
(1,4s)-CMA-ES	**1**	**1.8**	**2.7**	4.6	6.3	8.1	10	11	13	17	(1,4s)-CMA-ES [4]
(1+1)-CMA-ES	**1**	**1.2**	**2.4**	4.1	5.9	7.6	9.3	11	13	16	(1+1)-CMA-ES [7]
(1+2ms)-CMA-ES	**1**	**1.0**	**2.1**	**3.7**	**5.2**	**6.7**	**8.3**	**10**	**11**	**14**	(1+2ms)-CMA-ES [2]
Artif Bee Colony	**1**	5.3	16	29	41	59	76	105	126	161	Artif Bee Colony [8]
avg NEWUOA	**1**	**1.9**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	avg NEWUOA [23]
CMA-EGS (IPOP,r1)	47	4.4	5.5	8.3	11	14	17	20	23	29	CMA-EGS (IPOP,r1) [12]
Adap DE (F-AUC)	**1**	8.4	40	78	114	151	186	222	257	329	Adap DE (F-AUC) [10]
DE (Uniform)	**1**	9.5	64	129	191	254	317	380	443	569	DE (Uniform) [9]
IPOP-aCMA-ES	**1**	**1**	3.4	6.0	8.7	11	14	17	20	25	IPOP-aCMA-ES [16]
IPOP-CMA-ES	**1**	**1.1**	3.5	6.1	8.8	11	14	17	20	25	IPOP-CMA-ES [22]
CMA+DE-MOS	**1**	3.6	15	25	30	39	53	58	64	86	CMA+DE-MOS [18]
NBC-CMA	**1**	**1.9**	5.8	9.1	13	16	20	23	27	34	NBC-CMA [21]
POEMS	**1**	86	79	178	368	592	769	1006	1220	1615	POEMS [17]
PM-AdapSS-DE	**1**	7.4	44	85	126	163	201	240	279	357	PM-AdapSS-DE [9, 10]
pPOEMS	**1**	90	85	202	454	799	1108	1514	1942	3073	pPOEMS [17, 20]
Basic RCGA	**1**	3.9	24	58	374	1171	1650	2022	2345	2753	Basic RCGA [24]
SPSA	158	6.3	5.3	7.1	8.8	11	13	14	16	20	SPSA [13]

Table 2: 20-D, running time excess ERT/ERT_{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
ERT_{best}/D	65	153	232	318	454	582	605	622	637	666	ERT_{best}/D
(1,2)-CMA-ES	27	17	13	10	7.3	5.8	5.7	5.6	5.6	5.4	(1,2)-CMA-ES [5, 3]
(1,2m)-CMA-ES	11	7.2	5.9	4.9	3.5	**2.8**	**2.7**	**2.7**	**2.6**	**2.5**	(1,2m)-CMA-ES [5]
(1,2ms)-CMA-ES	9.3	6.2	5.0	4.1	**2.9**	**2.3**	**2.2**	**2.2**	**2.2**	**2.1**	(1,2ms)-CMA-ES [5]
(1,2s)-CMA-ES	27	18	14	11	8.0	6.4	6.3	6.2	6.2	6.0	(1,2s)-CMA-ES [3]
(1,4)-CMA-ES	6.8	5.1	4.5	3.8	**2.8**	**2.2**	**2.2**	**2.1**	**2.1**	**2.1**	(1,4)-CMA-ES [6, 4]
(1,4m)-CMA-ES	6.0	4.2	3.7	3.1	**2.3**	**1.8**	**1.8**	**1.8**	**1.8**	**1.7**	(1,4m)-CMA-ES [6]
(1,4ms)-CMA-ES	4.9	3.2	**2.8**	**2.4**	**1.7**	**1.4**	**1.3**	**1.3**	**1.3**	**1.3**	(1,4ms)-CMA-ES [1, 6]
(1,4s)-CMA-ES	5.7	4.1	3.6	3.1	**2.3**	**1.8**	**1.8**	**1.8**	**1.7**	**1.7**	(1,4s)-CMA-ES [4]
(1+1)-CMA-ES	3.5	**2.8**	**2.6**	**2.3**	**1.7**	**1.4**	**1.4**	**1.4**	**1.3**	**1.3**	(1+1)-CMA-ES [7]
(1+2ms)-CMA-ES	3.0	**2.6**	**2.4**	**2.0**	**1.5**	**1.2**	**1.2**	**1.1**	**1.1**	**1.1**	(1+2ms)-CMA-ES [2]
Artif Bee Colony	**1.8**	**1**	**1**	**1**	**1**	**1.0**	**1.3**	**1.5**	**1.7**	**2.1**	Artif Bee Colony [8]
avg NEWUOA	**1**	**1.3**	**1.8**	**2.6**	**2.7**	**2.9**	3.7	4.4	4.9	5.9	avg NEWUOA [23]
CMA-EGS (IPOP,r1)	14	8.2	6.1	4.8	3.5	**2.7**	**2.7**	**2.6**	**2.6**	**2.5**	CMA-EGS (IPOP,r1) [12]
Adap DE (F-AUC)	7.7	4.6	4.0	3.5	**2.9**	**2.6**	**2.8**	**3.0**	3.2	3.6	Adap DE (F-AUC) [10]
DE (Uniform)	13	7.6	6.3	5.6	4.6	4.1	4.5	4.9	5.3	6.0	DE (Uniform) [9]
IPOP-aCMA-ES	**2.9**	**2.1**	**1.9**	**1.7**	**1.2**	**1**	**1**	**1**	**1**	**1**	IPOP-aCMA-ES [16]
IPOP-CMA-ES	4.5	3.2	**2.9**	**2.5**	**1.8**	**1.5**	**1.5**	**1.5**	**1.5**	**1.4**	IPOP-CMA-ES [22]
CMA+DE-MOS	7.1	4.3	3.7	3.1	**2.4**	**2.0**	**2.1**	**2.2**	**2.3**	**2.4**	CMA+DE-MOS [18]
NBC-CMA	6.7	4.8	4.8	4.4	3.5	**2.9**	**2.9**	**2.9**	**2.9**	**2.9**	NBC-CMA [21]
POEMS	41	24	21	18	15	14	14	16	17	20	POEMS [17]
PM-AdapSS-DE	9.0	5.2	4.3	3.8	3.1	**2.8**	**3.0**	3.2	3.4	3.9	PM-AdapSS-DE [9, 10]
pPOEMS	43	27	25	26	22	22	24	28	37	41	pPOEMS [17, 20]
Basic RCGA	12	29	32	56	189	151	560	*51e-2/5e4*	.	.	Basic RCGA [24]
SPSA	22349	*18e+2/1e5*	.	.	.	.	.	.	.	.	SPSA [13]

Table 3: 20-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	0.93	80	369	1047	1164	1224	1361	1486	1581	1878	$\mathrm{ERT}_{\mathrm{best}}$/D
(1,2)-CMA-ES	14	1866	*14e+1/1e4*	.	.	.	.	.	.	.	(1,2)-CMA-ES [5, 3]
(1,2m)-CMA-ES	6.5	19	*63e+0/1e4*	.	.	.	.	.	.	.	(1,2m)-CMA-ES [5]
(1,2ms)-CMA-ES	4.8	21	*67e+0/1e4*	.	.	.	.	.	.	.	(1,2ms)-CMA-ES [5]
(1,2s)-CMA-ES	16	*16e+1/1e4*	.	.	.	.	.	.	.	.	(1,2s)-CMA-ES [3]
(1,4)-CMA-ES	4.1	19	*64e+0/1e4*	.	.	.	.	.	.	.	(1,4)-CMA-ES [6, 4]
(1,4m)-CMA-ES	**2.0**	6.5	*54e+0/1e4*	.	.	.	.	.	.	.	(1,4m)-CMA-ES [6]
(1,4ms)-CMA-ES	**2.2**	8.8	*61e+0/1e4*	.	.	.	.	.	.	.	(1,4ms)-CMA-ES [1, 6]
(1,4s)-CMA-ES	**2.8**	30	*73e+0/1e4*	.	.	.	.	.	.	.	(1,4s)-CMA-ES [4]
(1+1)-CMA-ES	**1.6**	75	*95e+0/1e4*	.	.	.	.	.	.	.	(1+1)-CMA-ES [7]
(1+2ms)-CMA-ES	**1.5**	60	*84e+0/1e4*	.	.	.	.	.	.	.	(1+2ms)-CMA-ES [2]
Artif Bee Colony	**1.7**	**1.2**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	Artif Bee Colony [8]
avg NEWUOA	4.8	165	*97e+0/1e4*	.	.	.	.	.	.	.	avg NEWUOA [23]
CMA-EGS (IPOP,r1)	9.5	**1.1**	834	*18e+0/1e5*	.	.	.	.	.	.	CMA-EGS (IPOP,r1) [12]
Adap DE (F-AUC)	**1.1**	55	*59e+0/1e5*	.	.	.	.	.	.	.	Adap DE (F-AUC) [10]
DE (Uniform)	**1.4**	58	*66e+0/1e5*	.	.	.	.	.	.	.	DE (Uniform) [9]
IPOP-aCMA-ES	**1.4**	**1**	**6.6**	*60e-1/1e5*	.	.	.	.	.	.	IPOP-aCMA-ES [16]
IPOP-CMA-ES	**1.4**	**1.0**	8.7	*50e-1/1e5*	.	.	.	.	.	.	IPOP-CMA-ES [22]
CMA+DE-MOS	**1**	**2.0**	**3.2**	**2.7**	**2.9**	**2.9**	**2.8**	**2.6**	**2.6**	**2.4**	CMA+DE-MOS [18]
NBC-CMA	**1.2**	**2.9**	577	*18e+0/2e4*	.	.	.	.	.	.	NBC-CMA [21]
POEMS	204	6.7	6.9	23	44	43	39	37	35	31	POEMS [17]
PM-AdapSS-DE	**1.4**	22	*56e+0/1e5*	.	.	.	.	.	.	.	PM-AdapSS-DE [9, 10]
pPOEMS	174	6.8	9.2	**21**	**34**	**33**	**31**	**29**	**29**	**27**	pPOEMS [17, 20]
Basic RCGA	**1.2**	5.8	19	680	*41e-1/5e4*	.	.	.	.	.	Basic RCGA [24]
SPSA	72029	*82e+1/1e5*	.	.	.	.	.	.	.	.	SPSA [13]

Table 4: 20-D, running time excess ERT/ERT_{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
ERT_{best}/D	2.5	86	463	1609	2159	2297	2439	2672	2828	3168	ERT_{best}/D
(1,2)-CMA-ES	9.4	*17e+1/1e4*	.	.	.	.	.	.	.	.	(1,2)-CMA-ES [5, 3]
(1,2m)-CMA-ES	4.4	51	*79e+0/1e4*	.	.	.	.	.	.	.	(1,2m)-CMA-ES [5]
(1,2ms)-CMA-ES	4.0	65	*79e+0/1e4*	.	.	.	.	.	.	.	(1,2ms)-CMA-ES [5]
(1,2s)-CMA-ES	9.0	*15e+1/1e4*	.	.	.	.	.	.	.	.	(1,2s)-CMA-ES [3]
(1,4)-CMA-ES	3.0	74	*88e+0/1e4*	.	.	.	.	.	.	.	(1,4)-CMA-ES [6, 4]
(1,4m)-CMA-ES	**2.0**	23	*66e+0/1e4*	.	.	.	.	.	.	.	(1,4m)-CMA-ES [6]
(1,4ms)-CMA-ES	**2.2**	29	*69e+0/1e4*	.	.	.	.	.	.	.	(1,4ms)-CMA-ES [1, 6]
(1,4s)-CMA-ES	**3.0**	196	*10e+1/1e4*	.	.	.	.	.	.	.	(1,4s)-CMA-ES [4]
(1+1)-CMA-ES	**1.0**	1651	*14e+1/1e4*	.	.	.	.	.	.	.	(1+1)-CMA-ES [7]
(1+2ms)-CMA-ES	**1.2**	1630	*13e+1/1e4*	.	.	.	.	.	.	.	(1+2ms)-CMA-ES [2]
Artif Bee Colony	4.4	**1.2**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	Artif Bee Colony [8]
avg NEWUOA	**2.3**	624	*12e+1/2e4*	.	.	.	.	.	.	.	avg NEWUOA [23]
CMA-EGS (IPOP,r1)	6.0	**1.1**	*26e+0/1e5*	.	.	.	.	.	.	.	CMA-EGS (IPOP,r1) [12]
Adap DE (F-AUC)	**1.9**	103	*19e+0/1e5*	.	.	.	.	.	.	.	Adap DE (F-AUC) [10]
DE (Uniform)	**2.2**	108	*21e+0/1e5*	.	.	.	.	.	.	.	DE (Uniform) [9]
IPOP-aCMA-ES	**1.1**	**1.0**	*14e+0/1e5*	.	.	.	.	.	.	.	IPOP-aCMA-ES [16]
IPOP-CMA-ES	**1.2**	**1**	*13e+0/1e5*	.	.	.	.	.	.	.	IPOP-CMA-ES [22]
CMA+DE-MOS	**1.8**	**2.0**	**5.3**	**2.9**	**2.4**	**2.4**	**2.3**	**2.2**	**2.2**	**2.1**	CMA+DE-MOS [18]
NBC-CMA	**1**	**2.0**	*25e+0/1e4*	.	.	.	.	.	.	.	NBC-CMA [21]
POEMS	81	7.7	**6.9**	**26**	**55**	**52**	**49**	**45**	**43**	**39**	POEMS [17]
PM-AdapSS-DE	**2.8**	55	*20e+0/1e5*	.	.	.	.	.	.	.	PM-AdapSS-DE [9, 10]
pPOEMS	93	8.9	16	60	185	176	167	153	145	130	pPOEMS [17, 20]
Basic RCGA	**1.7**	29	*22e+0/5e4*	.	.	.	.	.	.	.	Basic RCGA [24]
SPSA	33	*24e+1/1e5*	.	.	.	.	.	.	.	.	SPSA [13]

Table 5: 20-D, running time excess ERT/ERT$_{\text{best}}$ 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
ERT$_{\text{best}}$/D	0.05	2.0	5.1	6.2	6.4	6.5	6.5	6.5	6.5	6.5	ERT$_{\text{best}}$/D
(1,2)-CMA-ES	**1**	**2.4**	**2.4**	**2.3**	**2.3**	**2.3**	**2.3**	**2.3**	**2.3**	**2.3**	(1,2)-CMA-ES [5, 3]
(1,2m)-CMA-ES	**1**	**1.4**	**1.4**	**1.4**	**1.4**	**1.4**	**1.4**	**1.4**	**1.4**	**1.4**	(1,2m)-CMA-ES [5]
(1,2ms)-CMA-ES	**1**	**1.4**	**1.3**	**1.3**	**1.3**	**1.3**	**1.3**	**1.3**	**1.3**	**1.3**	(1,2ms)-CMA-ES [5]
(1,2s)-CMA-ES	**1**	**2.9**	**2.6**	**2.5**	**2.5**	**2.6**	**2.6**	**2.6**	**2.6**	**2.6**	(1,2s)-CMA-ES [3]
(1,4)-CMA-ES	**1**	**2.1**	**2.0**	**2.0**	**2.0**	**2.0**	**2.0**	**2.0**	**2.0**	**2.0**	(1,4)-CMA-ES [6, 4]
(1,4m)-CMA-ES	**1**	**1.7**	**1.5**	**1.4**	**1.4**	**1.4**	**1.4**	**1.4**	**1.4**	**1.4**	(1,4m)-CMA-ES [6]
(1,4ms)-CMA-ES	**1**	**1.1**	**1.1**	**1.0**	**1.1**	**1.0**	**1.0**	**1.0**	**1.0**	**1.0**	(1,4ms)-CMA-ES [1, 6]
(1,4s)-CMA-ES	**1**	**1.6**	**1.6**	**1.6**	**1.7**	**1.7**	**1.7**	**1.7**	**1.7**	**1.7**	(1,4s)-CMA-ES [4]
(1+1)-CMA-ES	**1**	**1.5**	**1.3**	**1.2**	**1.2**	**1.2**	**1.2**	**1.2**	**1.2**	**1.2**	(1+1)-CMA-ES [7]
(1+2ms)-CMA-ES	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	(1+2ms)-CMA-ES [2]
Artif Bee Colony	**1**	35	27	29	29	29	29	29	29	29	Artif Bee Colony [8]
avg NEWUOA	**1**	**2.5**	**1.1**	**1.1**	**1.0**	**1.0**	**1.0**	**1.0**	**1.0**	**1.0**	avg NEWUOA [23]
CMA-EGS (IPOP,r1)	**1**	3.3	**2.1**	**1.9**	**1.9**	**1.9**	**1.9**	**1.9**	**1.9**	**1.9**	CMA-EGS (IPOP,r1) [12]
Adap DE (F-AUC)	**1**	14	17	17	17	17	17	17	17	17	Adap DE (F-AUC) [10]
DE (Uniform)	**1**	25	27	27	27	27	27	27	27	27	DE (Uniform) [9]
IPOP-aCMA-ES	**1**	**2.5**	**2.0**	**2.0**	**2.0**	**2.0**	**2.0**	**2.0**	**2.0**	**2.0**	IPOP-aCMA-ES [16]
IPOP-CMA-ES	**1**	**3.0**	**2.3**	**2.1**	**2.1**	**2.1**	**2.1**	**2.1**	**2.1**	**2.1**	IPOP-CMA-ES [22]
CMA+DE-MOS	**1**	21	20	17	17	17	17	17	17	17	CMA+DE-MOS [18]
NBC-CMA	**1**	11	2611	4380	4228	4208	4208	4208	4208	4208	NBC-CMA [21]
POEMS	**1**	167	101	101	104	108	109	110	111	111	POEMS [17]
PM-AdapSS-DE	**1**	32	33	30	30	30	30	30	30	30	PM-AdapSS-DE [9, 10]
pPOEMS	**1**	162	101	101	107	109	111	113	113	113	pPOEMS [17, 20]
Basic RCGA	**1**	128	221	1040	1650	2035	2278	2436	3103	*64e-7/5e4*	Basic RCGA [24]
SPSA	**1**	**2.8**	**2.5**	**2.6**	**2.6**	**2.6**	**2.6**	**2.6**	**2.6**	**2.6**	SPSA [13]

Table 6: 20-D, running time excess ERT/ERT_{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
ERT_{best}/D	7.0	30	65	87	123	152	184	219	248	309	ERT_{best}/D
(1,2)-CMA-ES	12	10	8.9	16	36	109	804	*11e-3/1e4*	.	.	(1,2)-CMA-ES [5, 3]
(1,2m)-CMA-ES	4.1	**2.7**	**2.2**	**2.4**	**2.5**	**3.0**	3.6	4.0	4.8	9.1	(1,2m)-CMA-ES [5]
(1,2ms)-CMA-ES	4.0	**2.4**	**1.9**	**2.1**	**2.0**	**2.1**	**2.4**	**2.5**	**2.9**	4.2	(1,2ms)-CMA-ES [5]
(1,2s)-CMA-ES	11	9.4	15	55	184	940	*15e-2/1e4*	.	.	.	(1,2s)-CMA-ES [3]
(1,4)-CMA-ES	**2.2**	**2.3**	**2.1**	**2.6**	**2.7**	3.1	3.6	4.2	4.9	10	(1,4)-CMA-ES [6, 4]
(1,4m)-CMA-ES	**2.7**	**2.3**	**2.0**	**2.2**	**2.2**	**2.2**	**2.2**	**2.3**	**2.4**	**3.0**	(1,4m)-CMA-ES [6]
(1,4ms)-CMA-ES	**1.8**	**1.4**	**1.3**	**1.5**	**1.4**	**1.6**	**1.8**	**2.1**	**2.3**	3.3	(1,4ms)-CMA-ES [1, 6]
(1,4s)-CMA-ES	**1.9**	**2.0**	**2.0**	**2.7**	3.3	4.3	6.8	13	30	466	(1,4s)-CMA-ES [4]
(1+1)-CMA-ES	**1.2**	**1.5**	13	124	1154	*69e-2/1e4*	.	.	.	.	(1+1)-CMA-ES [7]
(1+2ms)-CMA-ES	**1**	**1.6**	12	144	1175	*74e-2/1e4*	.	.	.	.	(1+2ms)-CMA-ES [2]
Artif Bee Colony	6.4	7.3	46	608	3595	*54e-2/1e5*	.	.	.	.	Artif Bee Colony [8]
avg NEWUOA	**1.3**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	avg NEWUOA [23]
CMA-EGS (IPOP,r1)	7.6	4.6	3.7	4.3	5.1	11	64	240	1187	1412	CMA-EGS (IPOP,r1) [12]
Adap DE (F-AUC)	13	22	19	21	19	19	19	19	19	19	Adap DE (F-AUC) [10]
DE (Uniform)	15	35	29	31	28	29	28	27	28	28	DE (Uniform) [9]
IPOP-aCMA-ES	**2.1**	**2.0**	**1.6**	**1.7**	**1.5**	**1.5**	**1.5**	**1.5**	**1.5**	**1.5**	IPOP-aCMA-ES [16]
IPOP-CMA-ES	**1.7**	**2.0**	**1.7**	**1.7**	**1.7**	**1.7**	**1.7**	**1.6**	**1.7**	**1.7**	IPOP-CMA-ES [22]
CMA+DE-MOS	11	7.8	5.6	5.2	4.7	4.5	4.3	4.0	4.0	3.8	CMA+DE-MOS [18]
NBC-CMA	30	94	50	38	27	22	19	16	14	12	NBC-CMA [21]
POEMS	52	26	32	38	36	37	36	36	37	37	POEMS [17]
PM-AdapSS-DE	13	24	20	22	20	20	20	19	20	20	PM-AdapSS-DE [9, 10]
pPOEMS	54	27	36	44	45	48	48	47	48	52	pPOEMS [17, 20]
Basic RCGA	23	13	52	80	78	76	73	266	2889	*63e-6/5e4*	Basic RCGA [24]
SPSA	1302	*40e+1/1e5*	.	.	.	.	.	.	.	.	SPSA [13]

Table 7: 20-D, running time excess $\mathrm{ERT}/\mathrm{ERT}_{\mathrm{best}}$ 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	0.94	11	91	570	754	816	816	816	816	858	$\mathrm{ERT}_{\mathrm{best}}$/D
(1,2)-CMA-ES	22	29	*23e+0/1e4*	.	.	.	.	.	.	.	(1,2)-CMA-ES [5, 3]
(1,2m)-CMA-ES	7.9	3.1	53	*67e-1/1e4*	.	.	.	.	.	.	(1,2m)-CMA-ES [5]
(1,2ms)-CMA-ES	6.0	3.4	53	*72e-1/1e4*	.	.	.	.	.	.	(1,2ms)-CMA-ES [5]
(1,2s)-CMA-ES	14	19	*29e+0/1e4*	.	.	.	.	.	.	.	(1,2s)-CMA-ES [3]
(1,4)-CMA-ES	**2.3**	**2.6**	88	*78e-1/1e4*	.	.	.	.	.	.	(1,4)-CMA-ES [6, 4]
(1,4m)-CMA-ES	**1.8**	**2.2**	17	*48e-1/1e4*	.	.	.	.	.	.	(1,4m)-CMA-ES [6]
(1,4ms)-CMA-ES	**1.7**	3.2	28	*62e-1/1e4*	.	.	.	.	.	.	(1,4ms)-CMA-ES [1, 6]
(1,4s)-CMA-ES	**2.1**	3.2	205	*12e+0/1e4*	.	.	.	.	.	.	(1,4s)-CMA-ES [4]
(1+1)-CMA-ES	**1.7**	8.0	18	15	23	179	179	179	179	170	(1+1)-CMA-ES [7]
(1+2ms)-CMA-ES	**1**	**1.3**	18	20	61	183	183	183	183	174	(1+2ms)-CMA-ES [2]
Artif Bee Colony	3.1	13	187	*60e-1/1e5*	.	.	.	.	.	.	Artif Bee Colony [8]
avg NEWUOA	4.0	**1**	75	*51e-1/2e4*	.	.	.	.	.	.	avg NEWUOA [23]
CMA-EGS (IPOP,r1)	12	3.7	16	*53e-1/1e5*	.	.	.	.	.	.	CMA-EGS (IPOP,r1) [12]
Adap DE (F-AUC)	**1.7**	13	3.8	**1.2**	**1.2**	**1.6**	**1.6**	**1.6**	**1.6**	**1.6**	Adap DE (F-AUC) [10]
DE (Uniform)	**1.9**	21	6.2	**2.0**	**2.1**	**2.7**	**2.7**	**2.7**	**2.7**	**2.7**	DE (Uniform) [9]
IPOP-aCMA-ES	**1.5**	**1.8**	**1.2**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	IPOP-aCMA-ES [16]
IPOP-CMA-ES	**1.8**	**2.1**	**1.4**	**1.8**	**1.7**	**1.7**	**1.7**	**1.7**	**1.7**	**1.6**	IPOP-CMA-ES [22]
CMA+DE-MOS	**1.6**	8.8	**2.0**	**2.2**	**2.4**	**2.4**	**2.4**	**2.4**	**2.4**	**2.3**	CMA+DE-MOS [18]
NBC-CMA	**1.8**	**2.6**	**1**	12	142	*55e-2/1e4*	.	.	.	.	NBC-CMA [21]
POEMS	243	40	17	737	*11e-1/3e5*	.	.	.	.	.	POEMS [17]
PM-AdapSS-DE	**1.7**	15	4.4	**1.3**	**1.3**	**1.7**	**1.7**	**1.7**	**1.7**	**1.7**	PM-AdapSS-DE [9, 10]
pPOEMS	174	39	16	105	1120	2442	2442	2442	2442	2321	pPOEMS [17, 20]
Basic RCGA	**2.7**	8.7	10	416	*13e-1/5e4*	.	.	.	.	.	Basic RCGA [24]
SPSA	59	701	*58e+0/1e5*	.	.	.	.	.	.	.	SPSA [13]

Table 8: 20-D, running time excess 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	11	32	98	187	202	210	215	218	219	222	$\mathrm{ERT}_{\mathrm{best}}$/D
(1,2)-CMA-ES	5.7	3.2	10	20	20	20	20	20	20	20	(1,2)-CMA-ES [5, 3]
(1,2m)-CMA-ES	**2.7**	4.6	5.5	8.1	8.2	8.1	8.1	8.1	8.2	8.2	(1,2m)-CMA-ES [5]
(1,2ms)-CMA-ES	**2.3**	**1.4**	3.8	4.6	4.8	4.9	4.9	5.0	5.0	5.1	(1,2ms)-CMA-ES [5]
(1,2s)-CMA-ES	5.7	8.3	13	18	18	18	18	18	18	19	(1,2s)-CMA-ES [3]
(1,4)-CMA-ES	**2.1**	**1.5**	5.1	8.0	8.0	7.9	7.9	7.9	8.0	8.0	(1,4)-CMA-ES [6, 4]
(1,4m)-CMA-ES	**1.9**	**1.7**	3.8	6.0	6.0	6.0	6.0	6.0	6.0	6.1	(1,4m)-CMA-ES [6]
(1,4ms)-CMA-ES	**1.4**	**1.3**	3.5	6.0	5.9	5.8	5.8	5.8	5.8	5.8	(1,4ms)-CMA-ES [1, 6]
(1,4s)-CMA-ES	**2.4**	**2.1**	3.9	6.1	6.2	6.2	6.1	6.2	6.2	6.2	(1,4s)-CMA-ES [4]
(1+1)-CMA-ES	**1.3**	**1**	**3.3**	5.0	5.1	5.1	5.2	5.2	5.3	5.4	(1+1)-CMA-ES [7]
(1+2ms)-CMA-ES	**1.2**	**1.1**	**3.1**	5.6	5.6	5.6	5.6	5.6	5.7	5.8	(1+2ms)-CMA-ES [2]
Artif Bee Colony	7.0	4.1	4.1	6.1	10	37	347	1155	*24e-5/1e5*	.	Artif Bee Colony [8]
avg NEWUOA	**1**	**1.0**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	avg NEWUOA [23]
CMA-EGS (IPOP,r1)	3.2	**2.1**	5.5	6.7	6.9	7.0	7.0	7.1	7.3	7.5	CMA-EGS (IPOP,r1) [12]
Adap DE (F-AUC)	22	14	24	22	23	23	24	24	25	26	Adap DE (F-AUC) [10]
DE (Uniform)	37	24	35	32	33	34	35	35	37	39	DE (Uniform) [9]
IPOP-aCMA-ES	**2.1**	**1.7**	3.6	**3.6**	**3.7**	**3.8**	**3.8**	**3.9**	**3.9**	**4.0**	IPOP-aCMA-ES [16]
IPOP-CMA-ES	**2.0**	**2.1**	3.9	**4.0**	**4.2**	**4.3**	**4.3**	**4.4**	**4.4**	**4.5**	IPOP-CMA-ES [22]
CMA+DE-MOS	10	4.4	12	12	13	13	13	13	13	13	CMA+DE-MOS [18]
NBC-CMA	**2.9**	**2.2**	6.5	7.0	7.7	8.2	8.4	8.6	8.7	8.9	NBC-CMA [21]
POEMS	49	51	520	932	1628	21273	*15e-3/3e5*	.	.	.	POEMS [17]
PM-AdapSS-DE	24	16	36	36	38	38	39	39	40	41	PM-AdapSS-DE [9, 10]
pPOEMS	49	49	107	101	109	115	119	134	147	189	pPOEMS [17, 20]
Basic RCGA	12	16	*17e+0/5e4*	.	.	.	.	.	.	.	Basic RCGA [24]
SPSA	130	2584	*98e+0/1e5*	.	.	.	.	.	.	.	SPSA [13]

Table 9: 20-D, running time excess ERT/ERT$_{\text{best}}$ 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$_{\text{best}}$/D	11	25	89	190	204	213	217	220	222	225	ERT$_{\text{best}}$/D
(1,2)-CMA-ES	5.4	6.9	12	20	20	20	20	19	20	20	(1,2)-CMA-ES [5, 3]
(1,2m)-CMA-ES	3.8	4.8	5.6	6.6	6.8	6.8	6.8	6.8	6.9	6.9	(1,2m)-CMA-ES [5]
(1,2ms)-CMA-ES	**2.1**	**2.3**	4.3	5.3	5.5	5.5	5.5	5.5	5.6	5.6	(1,2ms)-CMA-ES [5]
(1,2s)-CMA-ES	4.8	8.0	15	18	19	18	18	19	19	19	(1,2s)-CMA-ES [3]
(1,4)-CMA-ES	**2.3**	**2.6**	5.0	4.9	5.2	5.2	5.2	5.3	5.3	5.4	(1,4)-CMA-ES [6, 4]
(1,4m)-CMA-ES	**1.8**	**1.7**	4.4	4.7	4.9	4.9	4.9	4.9	5.0	5.0	(1,4m)-CMA-ES [6]
(1,4ms)-CMA-ES	**1.2**	**1.5**	**3.2**	**4.3**	**4.4**	**4.3**	**4.3**	**4.3**	**4.3**	**4.4**	(1,4ms)-CMA-ES [1, 6]
(1,4s)-CMA-ES	**1.8**	**1.9**	4.9	5.9	6.0	5.9	5.9	5.9	6.0	6.0	(1,4s)-CMA-ES [4]
(1+1)-CMA-ES	**1.1**	**1**	3.5	5.1	5.2	5.2	5.2	5.2	5.3	5.4	(1+1)-CMA-ES [7]
(1+2ms)-CMA-ES	**1.0**	**1.3**	**3.3**	5.7	5.7	5.6	5.7	5.7	5.7	5.8	(1+2ms)-CMA-ES [2]
Artif Bee Colony	6.2	7.4	677	*92e-1/1e5*	.	.	.	.	.	.	Artif Bee Colony [8]
avg NEWUOA	**1**	**1.1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	avg NEWUOA [23]
CMA-EGS (IPOP,r1)	3.2	3.9	6.4	7.9	8.1	8.2	8.3	8.5	8.7	8.9	CMA-EGS (IPOP,r1) [12]
Adap DE (F-AUC)	16	15	25	21	22	23	23	24	24	26	Adap DE (F-AUC) [10]
DE (Uniform)	33	29	40	32	33	33	34	35	36	38	DE (Uniform) [9]
IPOP-aCMA-ES	**1.6**	**1.5**	4.0	**3.8**	**3.9**	**3.9**	**4.0**	**4.0**	**4.0**	**4.1**	IPOP-aCMA-ES [16]
IPOP-CMA-ES	**1.7**	**1.6**	4.4	4.6	4.8	4.8	4.8	4.9	4.9	5.0	IPOP-CMA-ES [22]
CMA+DE-MOS	6.7	3.7	9.3	10	12	12	12	12	12	12	CMA+DE-MOS [18]
NBC-CMA	**2.7**	**2.1**	6.8	7.5	8.2	8.6	8.8	8.9	9.0	9.2	NBC-CMA [21]
POEMS	46	119	1063	*22e-1/3e5*	.	.	.	.	.	.	POEMS [17]
PM-AdapSS-DE	20	18	36	33	35	36	36	37	37	39	PM-AdapSS-DE [9, 10]
pPOEMS	43	62	208	268	356	540	773	1027	2053	19955	pPOEMS [17, 20]
Basic RCGA	**3.0**	12	*17e+0/5e4*	.	.	.	.	.	.	.	Basic RCGA [24]
SPSA	259	11760	*14e+1/1e5*	.	.	.	.	.	.	.	SPSA [13]

Table 10: 20-D, running time excess ERT/ERT$_{\text{best}}$ 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
ERT$_{\text{best}}$/D	94	272	440	516	552	579	595	610	624	654	ERT$_{\text{best}}$/D
(1,2)-CMA-ES	16	8.8	6.6	6.2	6.2	6.1	6.1	6.0	6.0	5.8	(1,2)-CMA-ES [5, 3]
(1,2m)-CMA-ES	8.3	4.1	**3.0**	**2.9**	**2.9**	**2.8**	**2.8**	**2.7**	**2.7**	**2.6**	(1,2m)-CMA-ES [5]
(1,2ms)-CMA-ES	6.8	3.7	**2.7**	**2.5**	**2.4**	**2.3**	**2.3**	**2.3**	**2.2**	**2.2**	(1,2ms)-CMA-ES [5]
(1,2s)-CMA-ES	20	11	7.6	6.9	6.7	6.5	6.4	6.4	6.3	6.2	(1,2s)-CMA-ES [3]
(1,4)-CMA-ES	5.2	**3.0**	**2.3**	**2.3**	**2.3**	**2.2**	**2.2**	**2.2**	**2.2**	**2.1**	(1,4)-CMA-ES [6, 4]
(1,4m)-CMA-ES	4.3	**2.5**	**2.0**	**1.9**	**1.9**	**1.9**	**1.8**	**1.8**	**1.8**	**1.7**	(1,4m)-CMA-ES [6]
(1,4ms)-CMA-ES	3.7	**1.9**	**1.5**	**1.5**	**1.4**	**1.4**	**1.4**	**1.4**	**1.3**	**1.3**	(1,4ms)-CMA-ES [1, 6]
(1,4s)-CMA-ES	4.2	**2.5**	**2.0**	**1.9**	**1.9**	**1.8**	**1.8**	**1.8**	**1.8**	**1.7**	(1,4s)-CMA-ES [4]
(1+1)-CMA-ES	**2.8**	**1.7**	**1.4**	**1.4**	**1.4**	**1.4**	**1.4**	**1.4**	**1.4**	**1.3**	(1+1)-CMA-ES [7]
(1+2ms)-CMA-ES	**2.0**	**1.2**	**1.1**	**1.1**	**1.2**	**1.2**	**1.1**	**1.1**	**1.1**	**1.1**	(1+2ms)-CMA-ES [2]
Artif Bee Colony	*50e+2/1e5*	.	.	.	.	.	.	.	.	.	Artif Bee Colony [8]
avg NEWUOA	**1**	**1**	**1.2**	**2.2**	**3.0**	3.6	4.5	5.2	5.7	6.6	avg NEWUOA [23]
CMA-EGS (IPOP,r1)	10	4.5	3.2	**3.0**	**2.8**	**2.8**	**2.7**	**2.7**	**2.6**	**2.6**	CMA-EGS (IPOP,r1) [12]
Adap DE (F-AUC)	5.3	**2.6**	**2.1**	**2.2**	**2.3**	**2.5**	**2.8**	3.0	3.3	3.7	Adap DE (F-AUC) [10]
DE (Uniform)	8.8	4.2	3.3	3.4	3.8	4.1	4.6	5.0	5.4	6.1	DE (Uniform) [9]
IPOP-aCMA-ES	**2.1**	**1.2**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	IPOP-aCMA-ES [16]
IPOP-CMA-ES	**2.9**	**1.7**	**1.5**	**1.5**	**1.5**	**1.5**	**1.5**	**1.5**	**1.5**	**1.5**	IPOP-CMA-ES [22]
CMA+DE-MOS	6.1	3.3	**2.8**	**2.8**	**2.9**	**2.9**	**2.9**	**3.0**	**2.9**	**2.9**	CMA+DE-MOS [18]
NBC-CMA	5.0	**2.8**	**2.7**	**2.8**	**2.9**	3.0	3.1	3.1	3.1	3.1	NBC-CMA [21]
POEMS	1276	*35e+1/3e5*	.	.	.	.	.	.	.	.	POEMS [17]
PM-AdapSS-DE	6.3	**2.9**	**2.3**	**2.3**	**2.5**	**2.8**	3.0	3.3	3.5	3.9	PM-AdapSS-DE [9, 10]
pPOEMS	225	1268	*97e+0/3e5*	.	.	.	.	.	.	.	pPOEMS [17, 20]
Basic RCGA	*48e+2/5e4*	.	.	.	.	.	.	.	.	.	Basic RCGA [24]
SPSA	*30e+2/1e5*	.	.	.	.	.	.	.	.	.	SPSA [13]

Table 11: 20-D, running time excess ERT/ERT$_{\text{best}}$ 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
ERT$_{\text{best}}$/D	2.7	116	228	253	274	293	310	326	343	372	ERT$_{\text{best}}$/D
(1,2)-CMA-ES	237	9.1	5.4	5.5	5.5	5.6	5.7	5.7	5.7	5.7	(1,2)-CMA-ES [5, 3]
(1,2m)-CMA-ES	177	6.9	3.9	3.8	3.7	3.7	3.6	3.6	3.5	3.4	(1,2m)-CMA-ES [5]
(1,2ms)-CMA-ES	171	6.0	3.4	3.4	3.3	3.2	3.2	3.1	3.1	**2.9**	(1,2ms)-CMA-ES [5]
(1,2s)-CMA-ES	253	8.2	4.9	5.1	5.1	5.4	5.5	5.6	5.7	5.8	(1,2s)-CMA-ES [3]
(1,4)-CMA-ES	115	5.9	3.5	3.5	3.5	3.5	3.5	3.5	3.4	3.3	(1,4)-CMA-ES [6, 4]
(1,4m)-CMA-ES	68	6.0	3.5	3.4	3.4	3.3	3.3	3.2	3.2	3.1	(1,4m)-CMA-ES [6]
(1,4ms)-CMA-ES	97	4.7	**2.8**	**2.7**	**2.6**	**2.6**	**2.6**	**2.5**	**2.4**	**2.3**	(1,4ms)-CMA-ES [1, 6]
(1,4s)-CMA-ES	62	4.7	**2.8**	**2.8**	**2.8**	**2.8**	**2.8**	**2.8**	**2.7**	**2.6**	(1,4s)-CMA-ES [4]
(1+1)-CMA-ES	**1.5**	**1.4**	**1.7**	**2.6**	3.1	3.7	4.1	4.3	4.3	4.2	(1+1)-CMA-ES [7]
(1+2ms)-CMA-ES	3.4	**1**	**1.3**	**1.9**	**2.4**	**2.8**	3.1	3.4	3.4	3.4	(1+2ms)-CMA-ES [2]
Artif Bee Colony	**1**	452	*92e+0/1e5*	.	.	.	.	.	.	.	Artif Bee Colony [8]
avg NEWUOA	**2.9**	**2.4**	3.2	4.9	6.5	7.5	8.8	9.3	10	12	avg NEWUOA [23]
CMA-EGS (IPOP,r1)	449	28	26	42	67	88	85	82	80	100	CMA-EGS (IPOP,r1) [12]
Adap DE (F-AUC)	3.8	**1.6**	**1.6**	**2.2**	**2.7**	3.2	3.6	4.0	4.3	5.0	Adap DE (F-AUC) [10]
DE (Uniform)	**2.5**	**2.2**	**2.5**	3.6	4.4	5.2	5.9	6.6	7.2	8.3	DE (Uniform) [9]
IPOP-aCMA-ES	6.3	**1.6**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	IPOP-aCMA-ES [16]
IPOP-CMA-ES	**1.2**	3.9	**2.4**	**2.4**	**2.4**	**2.3**	**2.3**	**2.2**	**2.2**	**2.1**	IPOP-CMA-ES [22]
CMA+DE-MOS	**1.9**	3.1	4.5	4.6	4.6	4.6	4.5	4.5	4.4	4.3	CMA+DE-MOS [18]
NBC-CMA	**2.1**	42	*85e+0/1e4*	.	.	.	.	.	.	.	NBC-CMA [21]
POEMS	62	11	106	176	250	303	346	390	429	515	POEMS [17]
PM-AdapSS-DE	4.2	**2.0**	**1.9**	**2.5**	3.0	3.5	3.9	4.4	4.7	5.4	PM-AdapSS-DE [9, 10]
pPOEMS	65	11	24	47	96	208	563	1707	12627	*18e-5/3e5*	pPOEMS [17, 20]
Basic RCGA	**2.4**	8.3	*51e+0/5e4*	.	.	.	.	.	.	.	Basic RCGA [24]
SPSA	36876	*97e+1/1e5*	.	.	.	.	.	.	.	.	SPSA [13]

Table 12: 20-D, running time excess ERT/ERT$_{\text{best}}$ 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
ERT$_{\text{best}}$/D	35	38	133	289	440	539	639	747	830	954	ERT$_{\text{best}}$/D
(1,2)-CMA-ES	4.2	15	9.5	7.1	5.9	5.6	5.2	4.9	4.8	4.9	(1,2)-CMA-ES [5, 3]
(1,2m)-CMA-ES	**2.1**	6.8	5.8	4.3	3.6	3.3	3.0	**2.8**	**2.7**	**2.6**	(1,2m)-CMA-ES [5]
(1,2ms)-CMA-ES	**1.8**	**2.9**	**2.9**	**2.7**	**2.4**	**2.2**	**2.1**	**2.0**	**1.9**	**1.9**	(1,2ms)-CMA-ES [5]
(1,2s)-CMA-ES	3.8	8.2	8.9	7.8	6.7	6.2	5.9	5.5	5.3	5.4	(1,2s)-CMA-ES [3]
(1,4)-CMA-ES	**1.9**	4.1	3.4	**3.0**	**2.7**	**2.5**	**2.3**	**2.2**	**2.2**	**2.1**	(1,4)-CMA-ES [6, 4]
(1,4m)-CMA-ES	**1.6**	**2.8**	**2.4**	**2.3**	**2.0**	**2.0**	**1.8**	**1.8**	**1.7**	**1.7**	(1,4m)-CMA-ES [6]
(1,4ms)-CMA-ES	**1.2**	**2.4**	**1.9**	**1.7**	**1.6**	**1.5**	**1.4**	**1.3**	**1.3**	**1.3**	(1,4ms)-CMA-ES [1, 6]
(1,4s)-CMA-ES	**1.6**	**2.9**	**2.8**	**2.3**	**2.1**	**2.0**	**1.9**	**1.8**	**1.7**	**1.7**	(1,4s)-CMA-ES [4]
(1+1)-CMA-ES	**1.3**	**2.0**	**2.6**	3.3	3.2	3.1	**2.9**	**2.7**	**2.7**	**2.7**	(1+1)-CMA-ES [7]
(1+2ms)-CMA-ES	**1.2**	**1.8**	**2.5**	**2.8**	**2.6**	**2.4**	**2.2**	**2.1**	**2.2**	**2.3**	(1+2ms)-CMA-ES [2]
Artif Bee Colony	9.2	16	10	22	134	640	2346	*18e-3/1e5*	.	.	Artif Bee Colony [8]
avg NEWUOA	**1**	**1**	4.5	5.2	5.6	7.0	7.8	8.5	9.0	15	avg NEWUOA [23]
CMA-EGS (IPOP,r1)	3.1	12	12	12	12	11	11	10	10	10	CMA-EGS (IPOP,r1) [12]
Adap DE (F-AUC)	27	30	10	6.5	6.0	6.2	6.5	6.8	7.0	7.4	Adap DE (F-AUC) [10]
DE (Uniform)	46	51	17	9.1	7.7	7.9	8.4	8.9	9.2	10	DE (Uniform) [9]
IPOP-aCMA-ES	**2.1**	**2.3**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	IPOP-aCMA-ES [16]
IPOP-CMA-ES	**2.1**	**2.4**	**1.9**	**1.8**	**1.7**	**1.7**	**1.7**	**1.6**	**1.6**	**1.6**	IPOP-CMA-ES [22]
CMA+DE-MOS	7.6	7.6	**2.8**	**3.0**	4.2	4.2	3.9	3.7	3.5	3.4	CMA+DE-MOS [18]
NBC-CMA	**2.8**	3.1	**2.4**	4.2	4.4	4.3	4.1	3.9	3.9	3.8	NBC-CMA [21]
POEMS	112	133	608	1583	*12e-1/3e5*	.	.	.	.	.	POEMS [17]
PM-AdapSS-DE	31	34	11	6.1	6.3	7.0	7.8	8.5	9.1	10	PM-AdapSS-DE [9, 10]
pPOEMS	3697	3460	1319	1306	2882	*17e-1/3e5*	.	.	.	.	pPOEMS [17, 20]
Basic RCGA	237	267	87	81	161	398	*12e-2/5e4*	.	.	.	Basic RCGA [24]
SPSA	5890	7325	*20e+5/1e5*	.	.	.	.	.	.	.	SPSA [13]

Table 13: 20-D, running time excess ERT/ERT$_{\text{best}}$ 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
ERT$_{\text{best}}$/D	6.7	15	48	346	511	602	754	1059	1557	1904	ERT$_{\text{best}}$/D
(1,2)-CMA-ES	5.1	5.6	13	7.3	11	25	58	65	*13e-3/1e4*	.	(1,2)-CMA-ES [5, 3]
(1,2m)-CMA-ES	**2.3**	**2.9**	8.6	3.6	6.5	10	41	64	44	74	(1,2m)-CMA-ES [5]
(1,2ms)-CMA-ES	**2.2**	**2.6**	3.1	**2.0**	6.3	11	60	133	91	74	(1,2ms)-CMA-ES [5]
(1,2s)-CMA-ES	4.8	5.2	9.1	8.5	11	33	45	*27e-3/1e4*	.	.	(1,2s)-CMA-ES [3]
(1,4)-CMA-ES	**2.0**	**2.8**	5.6	4.4	6.8	12	26	66	95	*46e-4/1e4*	(1,4)-CMA-ES [6, 4]
(1,4m)-CMA-ES	**1.6**	**2.2**	4.3	**2.9**	4.2	8.1	10	18	29	*32e-5/1e4*	(1,4m)-CMA-ES [6]
(1,4ms)-CMA-ES	**1.2**	**1.7**	**3.1**	**1.9**	**2.9**	7.6	26	31	44	*18e-4/1e4*	(1,4ms)-CMA-ES [1, 6]
(1,4s)-CMA-ES	**1.7**	**2.2**	5.2	**1.4**	3.9	6.6	21	31	45	*10e-4/1e4*	(1,4s)-CMA-ES [4]
(1+1)-CMA-ES	**1.2**	**1.8**	4.4	**1.4**	**2.7**	4.7	5.1	5.5	6.0	10	(1+1)-CMA-ES [7]
(1+2ms)-CMA-ES	**1.1**	**1.6**	3.3	**1.8**	**2.1**	3.7	4.1	3.7	4.1	14	(1+2ms)-CMA-ES [2]
Artif Bee Colony	12	23	17	21	169	1145	1933	*60e-3/1e5*	.	.	Artif Bee Colony [8]
avg NEWUOA	**1**	**1**	**1**	**1.6**	3.8	8.8	17	58	135	*67e-5/2e4*	avg NEWUOA [23]
CMA-EGS (IPOP,r1)	3.0	3.6	4.6	**2.2**	10	37	134	262	436	*90e-5/1e5*	CMA-EGS (IPOP,r1) [12]
Adap DE (F-AUC)	16	30	17	3.4	3.0	**3.2**	**3.0**	**2.5**	**1.9**	**2.0**	Adap DE (F-AUC) [10]
DE (Uniform)	27	50	29	5.8	5.1	5.4	5.1	4.2	3.3	3.3	DE (Uniform) [9]
IPOP-aCMA-ES	**1.8**	**2.9**	**2.5**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	IPOP-aCMA-ES [16]
IPOP-CMA-ES	**1.7**	**2.9**	4.4	**1.4**	**1.7**	**1.5**	**1.7**	**1.7**	**1.3**	**1.8**	IPOP-CMA-ES [22]
CMA+DE-MOS	7.8	10	6.6	**2.7**	3.1	3.4	3.4	**3.0**	**2.5**	**2.4**	CMA+DE-MOS [18]
NBC-CMA	**2.9**	4.2	3.2	4.4	7.8	7.0	7.1	7.6	7.3	36	NBC-CMA [21]
POEMS	47	111	4245	12173	*90e-1/3e5*	.	.	.	.	.	POEMS [17]
PM-AdapSS-DE	19	35	19	3.7	3.3	3.4	3.3	**2.7**	**2.1**	**2.1**	PM-AdapSS-DE [9, 10]
pPOEMS	49	123	634	656	1672	7094	5672	*57e-2/3e5*	.	.	pPOEMS [17, 20]
Basic RCGA	9.0	62	157	87	222	358	*28e-2/5e4*	.	.	.	Basic RCGA [24]
SPSA	36	1599	*29e+0/1e5*	.	.	.	.	.	.	.	SPSA [13]

Table 14: 20-D, running time excess ERT/ERT_{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
ERT_{best}/D	0.05	0.17	8.8	18	24	36	62	179	318	522	ERT_{best}/D
(1,2)-CMA-ES	**1**	45	6.8	5.4	5.2	5.2	5.9	3.7	3.6	7.2	(1,2)-CMA-ES [5, 3]
(1,2m)-CMA-ES	**1**	18	3.3	**2.5**	**2.6**	**2.6**	3.2	**2.1**	**2.1**	**2.9**	(1,2m)-CMA-ES [5]
(1,2ms)-CMA-ES	**1**	12	**2.6**	**2.1**	**2.1**	**2.2**	**2.7**	**1.8**	**1.7**	**2.4**	(1,2ms)-CMA-ES [5]
(1,2s)-CMA-ES	**1**	41	6.1	4.6	4.6	4.7	5.2	3.4	3.3	8.5	(1,2s)-CMA-ES [3]
(1,4)-CMA-ES	**1**	4.6	**2.4**	**2.0**	**2.2**	**2.5**	**3.0**	**1.9**	**1.9**	**2.4**	(1,4)-CMA-ES [6, 4]
(1,4m)-CMA-ES	**1**	5.4	**2.1**	**1.8**	**2.0**	**2.1**	**2.4**	**1.7**	**1.6**	**2.1**	(1,4m)-CMA-ES [6]
(1,4ms)-CMA-ES	**1**	4.6	**1.6**	**1.4**	**1.5**	**1.6**	**2.0**	**1.3**	**1.3**	**1.6**	(1,4ms)-CMA-ES [1, 6]
(1,4s)-CMA-ES	**1**	4.8	**2.0**	**1.7**	**1.8**	**2.1**	**2.4**	**1.5**	**1.4**	**1.9**	(1,4s)-CMA-ES [4]
(1+1)-CMA-ES	**1**	3.5	**1.2**	**1.2**	**1.4**	**1.6**	**1.6**	**1.2**	**1.4**	**1.7**	(1+1)-CMA-ES [7]
(1+2ms)-CMA-ES	**1**	3.7	**1**	**1.1**	**1.2**	**1.3**	**1.4**	**1.0**	**1.2**	**1.5**	(1+2ms)-CMA-ES [2]
Artif Bee Colony	**1.1**	**1.2**	7.6	12	18	33	2554	*10e-4/1e5*	.	.	Artif Bee Colony [8]
avg NEWUOA	**1**	11	**1.2**	**1**	**1**	**1**	**1**	**1**	**2.4**	39	avg NEWUOA [23]
CMA-EGS (IPOP,r1)	26	46	4.1	3.1	3.2	3.6	4.7	4.3	5.7	7.2	CMA-EGS (IPOP,r1) [12]
Adap DE (F-AUC)	**1**	**1.3**	14	20	24	23	17	7.5	5.0	4.2	Adap DE (F-AUC) [10]
DE (Uniform)	**1**	**1.6**	23	33	40	38	28	12	8.0	6.3	DE (Uniform) [9]
IPOP-aCMA-ES	**1**	**2.8**	**1.5**	**1.8**	**2.2**	**2.5**	**2.4**	**1.3**	**1**	**1**	IPOP-aCMA-ES [16]
IPOP-CMA-ES	**1**	3.7	**1.6**	**1.9**	**2.2**	**2.7**	**3.0**	**1.8**	**1.5**	**1.7**	IPOP-CMA-ES [22]
CMA+DE-MOS	**1**	**1.5**	8.4	6.8	6.6	8.0	9.0	4.7	3.6	3.5	CMA+DE-MOS [18]
NBC-CMA	**1.1**	**1**	**2.3**	**2.5**	**2.9**	3.3	3.8	**2.6**	**2.3**	**2.5**	NBC-CMA [21]
POEMS	**1**	909	42	43	78	103	99	429	*27e-6/3e5*	.	POEMS [17]
PM-AdapSS-DE	**1**	**1.5**	18	23	27	25	19	7.8	5.2	4.2	PM-AdapSS-DE [9, 10]
pPOEMS	**1**	214	44	47	90	266	267	164	1174	*78e-7/3e5*	pPOEMS [17, 20]
Basic RCGA	**1**	**1.4**	6.6	17	36	187	1136	*11e-4/5e4*	.	.	Basic RCGA [24]
SPSA	59	246	42	33	28	24	42	87	313	*85e-7/1e5*	SPSA [13]

Table 15: 20-D, running time excess ERT/ERT$_{\text{best}}$ 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
ERT$_{\text{best}}$/D	0.70	105	1246	7711	10744	10967	11206	11422	11656	12106	ERT$_{\text{best}}$/D
(1,2)-CMA-ES	20	426	*15e+1/1e4*	.	.	.	.	.	.	.	(1,2)-CMA-ES [5, 3]
(1,2m)-CMA-ES	10	11	*55e+0/1e4*	.	.	.	.	.	.	.	(1,2m)-CMA-ES [5]
(1,2ms)-CMA-ES	6.8	10	*54e+0/1e4*	.	.	.	.	.	.	.	(1,2ms)-CMA-ES [5]
(1,2s)-CMA-ES	22	1388	*15e+1/1e4*	.	.	.	.	.	.	.	(1,2s)-CMA-ES [3]
(1,4)-CMA-ES	3.7	19	*65e+0/1e4*	.	.	.	.	.	.	.	(1,4)-CMA-ES [6, 4]
(1,4m)-CMA-ES	**2.4**	6.8	*50e+0/1e4*	.	.	.	.	.	.	.	(1,4m)-CMA-ES [6]
(1,4ms)-CMA-ES	**2.6**	4.9	*53e+0/1e4*	.	.	.	.	.	.	.	(1,4ms)-CMA-ES [1, 6]
(1,4s)-CMA-ES	5.0	22	*76e+0/1e4*	.	.	.	.	.	.	.	(1,4s)-CMA-ES [4]
(1+1)-CMA-ES	**2.1**	59	*83e+0/1e4*	.	.	.	.	.	.	.	(1+1)-CMA-ES [7]
(1+2ms)-CMA-ES	**1.7**	42	*81e+0/1e4*	.	.	.	.	.	.	.	(1+2ms)-CMA-ES [2]
Artif Bee Colony	6.0	462	*84e+0/1e5*	.	.	.	.	.	.	.	Artif Bee Colony [8]
avg NEWUOA	4.8	92	*95e+0/1e4*	.	.	.	.	.	.	.	avg NEWUOA [23]
CMA-EGS (IPOP,r1)	16	**1.0**	341	*14e+0/1e5*	.	.	.	.	.	.	CMA-EGS (IPOP,r1) [12]
Adap DE (F-AUC)	**1.5**	34	578	*30e+0/1e5*	.	.	.	.	.	.	Adap DE (F-AUC) [10]
DE (Uniform)	**1**	43	1193	*38e+0/1e5*	.	.	.	.	.	.	DE (Uniform) [9]
IPOP-aCMA-ES	**1.8**	**1**	**1**	**1**	**1.0**	**1.0**	**1.0**	**1.0**	**1.0**	**1.0**	IPOP-aCMA-ES [16]
IPOP-CMA-ES	**2.2**	**1.1**	**1.3**	**1.0**	**1**	**1**	**1**	**1**	**1**	**1**	IPOP-CMA-ES [22]
CMA+DE-MOS	**3.0**	**2.3**	**1.8**	**1.5**	**1.4**	**1.4**	**1.4**	**1.4**	**1.4**	**1.4**	CMA+DE-MOS [18]
NBC-CMA	**1.8**	13	*20e+0/1e4*	.	.	.	.	.	.	.	NBC-CMA [21]
POEMS	221	17	*33e+0/3e5*	.	.	.	.	.	.	.	POEMS [17]
PM-AdapSS-DE	**1.3**	15	*59e+0/1e5*	.	.	.	.	.	.	.	PM-AdapSS-DE [9, 10]
pPOEMS	169	55	*20e+0/3e5*	.	.	.	.	.	.	.	pPOEMS [17, 20]
Basic RCGA	**1.1**	11	7.7	92	*50e-1/5e4*	.	.	.	.	.	Basic RCGA [24]
SPSA	76768	13393	*16e+1/1e5*	.	.	.	.	.	.	.	SPSA [13]

Table 16: 20-D, running time excess ERT/ERT$_{\text{best}}$ 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
ERT$_{\text{best}}$/D	0.05	0.05	118	366	1912	5307	7509	7923	8089	8397	ERT$_{\text{best}}$/D
(1,2)-CMA-ES	**1**	**1.1**	*31e+0/1e4*	.	.	.	.	.	.	.	(1,2)-CMA-ES [5, 3]
(1,2m)-CMA-ES	**1**	**1.3**	89	*94e-1/1e4*	.	.	.	.	.	.	(1,2m)-CMA-ES [5]
(1,2ms)-CMA-ES	**1**	**1.5**	112	*97e-1/1e4*	.	.	.	.	.	.	(1,2ms)-CMA-ES [5]
(1,2s)-CMA-ES	**1**	**1**	*33e+0/1e4*	.	.	.	.	.	.	.	(1,2s)-CMA-ES [3]
(1,4)-CMA-ES	**1**	**1.1**	83	*88e-1/1e4*	.	.	.	.	.	.	(1,4)-CMA-ES [6, 4]
(1,4m)-CMA-ES	**1**	**1.3**	20	*61e-1/1e4*	.	.	.	.	.	.	(1,4m)-CMA-ES [6]
(1,4ms)-CMA-ES	**1**	**1.4**	29	*55e-1/1e4*	.	.	.	.	.	.	(1,4ms)-CMA-ES [1, 6]
(1,4s)-CMA-ES	**1**	**1.3**	72	*86e-1/1e4*	.	.	.	.	.	.	(1,4s)-CMA-ES [4]
(1+1)-CMA-ES	**1**	**1.2**	18	*57e-1/1e4*	.	.	.	.	.	.	(1+1)-CMA-ES [7]
(1+2ms)-CMA-ES	**1**	**1.3**	8.5	*51e-1/1e4*	.	.	.	.	.	.	(1+2ms)-CMA-ES [2]
Artif Bee Colony	**1**	**1.4**	7.3	*39e-1/1e5*	.	.	.	.	.	.	Artif Bee Colony [8]
avg NEWUOA	**1**	**1.5**	**2.1**	*31e-1/2e4*	.	.	.	.	.	.	avg NEWUOA [23]
CMA-EGS (IPOP,r1)	**1**	88	**2.7**	152	360	*55e-2/1e5*	.	.	.	.	CMA-EGS (IPOP,r1) [12]
Adap DE (F-AUC)	**1**	**1.2**	*15e+0/1e5*	.	.	.	.	.	.	.	Adap DE (F-AUC) [10]
DE (Uniform)	**1**	**1.1**	12590	*15e+0/1e5*	.	.	.	.	.	.	DE (Uniform) [9]
IPOP-aCMA-ES	**1**	**1.5**	**1.6**	**4.0**	**1.8**	**1**	**1**	**1**	**1**	**1**	IPOP-aCMA-ES [16]
IPOP-CMA-ES	**1**	**1.2**	**1**	**3.0**	**1.8**	**1.1**	**1.0**	**1.2**	**1.3**	**1.4**	IPOP-CMA-ES [22]
CMA+DE-MOS	**1**	**1.1**	**1.0**	**1**	**1**	**3.8**	**6.8**	**6.9**	**6.9**	**8.3**	CMA+DE-MOS [18]
NBC-CMA	**1**	**1.1**	11	6.6	14	*15e-2/1e4*	.	.	.	.	NBC-CMA [21]
POEMS	**1**	69	8.4	10	1022	*33e-2/3e5*	.	.	.	.	POEMS [17]
PM-AdapSS-DE	**1**	**1.3**	12696	*14e+0/1e5*	.	.	.	.	.	.	PM-AdapSS-DE [9, 10]
pPOEMS	**1**	**1.3**	15	91	2211	*29e-2/3e5*	.	.	.	.	pPOEMS [17, 20]
Basic RCGA	**1**	**1.1**	4.8	17	36	134	*12e-2/5e4*	.	.	.	Basic RCGA [24]
SPSA	**1**	8885	2614	*13e+0/1e5*	.	.	.	.	.	.	SPSA [13]

Table 17: 20-D, running time excess ERT/ERT_{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
ERT_{best}/D	0.05	0.05	6.8	46	101	625	1163	1594	2330	3516	ERT_{best}/D
(1,2)-CMA-ES	**1**	**1**	188	*53e-1/1e4*	.	.	.	.	.	.	(1,2)-CMA-ES [5, 3]
(1,2m)-CMA-ES	**1**	13	4.0	3123	*19e-1/1e4*	.	.	.	.	.	(1,2m)-CMA-ES [5]
(1,2ms)-CMA-ES	**1**	10	3.1	3252	*20e-1/1e4*	.	.	.	.	.	(1,2ms)-CMA-ES [5]
(1,2s)-CMA-ES	**1**	15	216	*64e-1/1e4*	.	.	.	.	.	.	(1,2s)-CMA-ES [3]
(1,4)-CMA-ES	**1**	**1**	34	3129	*26e-1/1e4*	.	.	.	.	.	(1,4)-CMA-ES [6, 4]
(1,4m)-CMA-ES	**1**	**1.1**	**2.4**	723	*22e-1/1e4*	.	.	.	.	.	(1,4m)-CMA-ES [6]
(1,4ms)-CMA-ES	**1**	7.1	**2.8**	1552	*16e-1/1e4*	.	.	.	.	.	(1,4ms)-CMA-ES [1, 6]
(1,4s)-CMA-ES	**1**	3.3	28	*30e-1/1e4*	.	.	.	.	.	.	(1,4s)-CMA-ES [4]
(1+1)-CMA-ES	**1**	**1.3**	25	*48e-1/1e4*	.	.	.	.	.	.	(1+1)-CMA-ES [7]
(1+2ms)-CMA-ES	**1**	**1.2**	19	*46e-1/1e4*	.	.	.	.	.	.	(1+2ms)-CMA-ES [2]
Artif Bee Colony	**1**	**1.1**	16	*40e-1/1e5*	.	.	.	.	.	.	Artif Bee Colony [8]
avg NEWUOA	**1**	**2.1**	**1.1**	*29e-1/4e4*	.	.	.	.	.	.	avg NEWUOA [23]
CMA-EGS (IPOP,r1)	72	141	3.4	**1.4**	**2.2**	**1.2**	**1.4**	**2.9**	4.5	14	CMA-EGS (IPOP,r1) [12]
Adap DE (F-AUC)	**1**	**1.4**	11	14	13	3.3	**2.5**	**2.4**	**2.3**	6.3	Adap DE (F-AUC) [10]
DE (Uniform)	**1**	**1.3**	18	22	21	5.3	4.0	3.9	3.8	3.2	DE (Uniform) [9]
IPOP-aCMA-ES	**1**	**1.3**	**1.1**	**1**	**1**	**1.3**	**1.1**	**1**	**1**	**1**	IPOP-aCMA-ES [16]
IPOP-CMA-ES	**1**	**1**	**1**	**1.1**	**2.3**	**1**	**1**	**1.3**	**1.2**	**1.1**	IPOP-CMA-ES [22]
CMA+DE-MOS	**1**	**1.1**	5.1	9.3	5.6	**1.5**	**1.5**	**1.4**	**1.5**	**1.2**	CMA+DE-MOS [18]
NBC-CMA	**1**	**1.1**	**1.6**	**1.4**	**2.2**	**1.3**	20	*10e-4/2e4*	.	.	NBC-CMA [21]
POEMS	**1**	691	46	30	251	184	394	2641	*21e-4/3e5*	.	POEMS [17]
PM-AdapSS-DE	**1**	**1.4**	11	15	13	3.4	**2.5**	**2.4**	**2.2**	21	PM-AdapSS-DE [9, 10]
pPOEMS	**1**	**1.3**	46	35	108	113	413	2675	*11e-4/3e5*	.	pPOEMS [17, 20]
Basic RCGA	**1.1**	**1.5**	**2.9**	14	61	23	22	45	*12e-5/5e4*	.	Basic RCGA [24]
SPSA	3.00e6	3.00e6	40764	*23e+2/1e5*	.	.	.	.	.	.	SPSA [13]

Table 18: 20-D, running time excess ERT/ERT$_{\text{best}}$ 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
ERT$_{\text{best}}$/D	0.05	0.43	35	151	731	1621	3074	4293	5114	6058	ERT$_{\text{best}}$/D
(1,2)-CMA-ES	**1.1**	34	*18e+0/1e4*	.	.	.	.	.	.	.	(1,2)-CMA-ES [5, 3]
(1,2m)-CMA-ES	**1**	15	128	*64e-1/1e4*	.	.	.	.	.	.	(1,2m)-CMA-ES [5]
(1,2ms)-CMA-ES	**1.1**	10	117	*73e-1/1e4*	.	.	.	.	.	.	(1,2ms)-CMA-ES [5]
(1,2s)-CMA-ES	6.4	38	*19e+0/1e4*	.	.	.	.	.	.	.	(1,2s)-CMA-ES [3]
(1,4)-CMA-ES	**1**	5.3	230	*82e-1/1e4*	.	.	.	.	.	.	(1,4)-CMA-ES [6, 4]
(1,4m)-CMA-ES	**1.1**	3.2	60	*40e-1/1e4*	.	.	.	.	.	.	(1,4m)-CMA-ES [6]
(1,4ms)-CMA-ES	**1**	3.6	30	*54e-1/1e4*	.	.	.	.	.	.	(1,4ms)-CMA-ES [1, 6]
(1,4s)-CMA-ES	**1**	6.6	270	*91e-1/1e4*	.	.	.	.	.	.	(1,4s)-CMA-ES [4]
(1+1)-CMA-ES	**1**	3.1	*15e+0/1e4*	.	.	.	.	.	.	.	(1+1)-CMA-ES [7]
(1+2ms)-CMA-ES	**1**	**1.2**	4205	*14e+0/1e4*	.	.	.	.	.	.	(1+2ms)-CMA-ES [2]
Artif Bee Colony	**1.1**	6.8	40972	*13e+0/1e5*	.	.	.	.	.	.	Artif Bee Colony [8]
avg NEWUOA	**1.3**	6.3	2879	*10e+0/6e4*	.	.	.	.	.	.	avg NEWUOA [23]
CMA-EGS (IPOP,r1)	74	21	**1.2**	**1.3**	**1.5**	**1.8**	**2.5**	12	40	243	CMA-EGS (IPOP,r1) [12]
Adap DE (F-AUC)	**1.1**	**1.9**	10	6.1	**2.3**	**1.6**	3.5	6.9	14	34	Adap DE (F-AUC) [10]
DE (Uniform)	**1**	**2.1**	16	10	3.8	**2.6**	**1.8**	**1.7**	**1.9**	**2.0**	DE (Uniform) [9]
IPOP-aCMA-ES	**1.3**	**2.4**	**1.1**	**1.9**	**1**	**1**	**1**	**1**	**1**	**1**	IPOP-aCMA-ES [16]
IPOP-CMA-ES	**1**	**2.3**	**1**	**2.4**	**1.5**	**1.4**	**1.1**	**1.3**	**1.3**	**1.3**	IPOP-CMA-ES [22]
CMA+DE-MOS	**1.1**	**1.6**	3.6	**2.1**	**1.5**	**1.6**	**1.4**	**1.5**	**1.6**	**1.4**	CMA+DE-MOS [18]
NBC-CMA	**1.1**	**1**	**1.4**	**1**	**1.5**	31	*16e-3/2e4*	.	.	.	NBC-CMA [21]
POEMS	**2.4**	298	19	164	367	2596	*92e-3/3e5*	.	.	.	POEMS [17]
PM-AdapSS-DE	**1**	**1.4**	11	7.1	**2.5**	**1.7**	9.3	6.9	8.3	9.5	PM-AdapSS-DE [9, 10]
pPOEMS	**1.1**	158	19	68	142	1228	*33e-3/3e5*	.	.	.	pPOEMS [17, 20]
Basic RCGA	**1**	**2.2**	6.7	26	31	55	*16e-3/5e4*	.	.	.	Basic RCGA [24]
SPSA	5.50e6	9.31e5	*46e+2/1e5*	.	.	.	.	.	.	.	SPSA [13]

Table 19: 20-D, running time excess ERT/ERT_{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

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_{best}/D	0.05	0.05	8.0	1028	10741	1.06e5	1.18e5	1.36e5	1.37e5	1.39e5	ERT_{best}/D
(1,2)-CMA-ES	**1**	**1**	14	*62e-1/1e4*	.	.	.	.	.	.	(1,2)-CMA-ES [5, 3]
(1,2m)-CMA-ES	**1**	**1**	4.1	*27e-1/1e4*	.	.	.	.	.	.	(1,2m)-CMA-ES [5]
(1,2ms)-CMA-ES	**1**	**1**	**2.5**	*31e-1/1e4*	.	.	.	.	.	.	(1,2ms)-CMA-ES [5]
(1,2s)-CMA-ES	**1**	**1**	22	*66e-1/1e4*	.	.	.	.	.	.	(1,2s)-CMA-ES [3]
(1,4)-CMA-ES	**1**	**1**	**2.7**	*24e-1/1e4*	.	.	.	.	.	.	(1,4)-CMA-ES [6, 4]
(1,4m)-CMA-ES	**1**	**1**	**1.6**	69	*19e-1/1e4*	.	.	.	.	.	(1,4m)-CMA-ES [6]
(1,4ms)-CMA-ES	**1**	**1**	**1.4**	138	*16e-1/1e4*	.	.	.	.	.	(1,4ms)-CMA-ES [1, 6]
(1,4s)-CMA-ES	**1**	**1**	**2.1**	137	*36e-1/1e4*	.	.	.	.	.	(1,4s)-CMA-ES [4]
(1+1)-CMA-ES	**1**	**1**	**1.8**	143	*18e-1/1e4*	.	.	.	.	.	(1+1)-CMA-ES [7]
(1+2ms)-CMA-ES	**1**	**1**	5.3	*16e-1/1e4*	.	.	.	.	.	.	(1+2ms)-CMA-ES [2]
Artif Bee Colony	**1**	**1**	14	*37e-1/1e5*	.	.	.	.	.	.	Artif Bee Colony [8]
avg NEWUOA	**1**	**2.9**	**1.3**	391	*20e-1/1e5*	.	.	.	.	.	avg NEWUOA [23]
CMA-EGS (IPOP,r1)	37	118	**2.6**	**2.1**	*33e-2/1e5*	.	.	.	.	.	CMA-EGS (IPOP,r1) [12]
Adap DE (F-AUC)	**1**	**1.2**	8.2	464	*31e-1/1e5*	.	.	.	.	.	Adap DE (F-AUC) [10]
DE (Uniform)	**1**	**1.1**	18	462	*29e-1/1e5*	.	.	.	.	.	DE (Uniform) [9]
IPOP-aCMA-ES	**1**	**1**	**1.0**	**1.4**	**1**	**1.0**	**1.1**	**1.1**	**1.1**	**1.1**	IPOP-aCMA-ES [16]
IPOP-CMA-ES	**1**	**1**	**1**	**1.3**	**1.1**	**1**	**1**	**1**	**1**	**1**	IPOP-CMA-ES [22]
CMA+DE-MOS	**1**	**1.1**	7.7	**1**	**4.7**	**7.1**	*47e-3/1e5*	.	.	.	CMA+DE-MOS [18]
NBC-CMA	**1**	**1.1**	**1.6**	*41e-1/2e4*	.	.	.	.	.	.	NBC-CMA [21]
POEMS	**1**	701	38	299	*98e-2/3e5*	.	.	.	.	.	POEMS [17]
PM-AdapSS-DE	**1**	**1.1**	11	*26e-1/1e5*	.	.	.	.	.	.	PM-AdapSS-DE [9, 10]
pPOEMS	**1**	**1.2**	39	70	*45e-2/3e5*	.	.	.	.	.	pPOEMS [17, 20]
Basic RCGA	**1**	**1.2**	**1.9**	20	11	*23e-2/5e4*	.	.	.	.	Basic RCGA [24]
SPSA	116	413	32	*39e-1/1e5*	.	.	.	.	.	.	SPSA [13]

Table 20: 20-D, running time excess ERT/$\mathrm{ERT_{best}}$ 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
$\mathrm{ERT_{best}}$/D	4.9	5.1	5.2	269	12060	14366	16107	17231	18022	20754	$\mathrm{ERT_{best}}$/D
(1,2)-CMA-ES	8.5	9.0	10	261	*12e-1/1e4*	.	.	.	.	.	(1,2)-CMA-ES [5, 3]
(1,2m)-CMA-ES	4.2	4.7	5.1	257	*11e-1/1e4*	.	.	.	.	.	(1,2m)-CMA-ES [5]
(1,2ms)-CMA-ES	3.4	3.9	4.1	*11e-1/1e4*	.	.	.	.	.	.	(1,2ms)-CMA-ES [5]
(1,2s)-CMA-ES	7.8	8.5	8.8	125	*12e-1/1e4*	.	.	.	.	.	(1,2s)-CMA-ES [3]
(1,4)-CMA-ES	3.3	3.8	4.0	525	*12e-1/1e4*	.	.	.	.	.	(1,4)-CMA-ES [6, 4]
(1,4m)-CMA-ES	**2.8**	3.2	3.6	270	*11e-1/1e4*	.	.	.	.	.	(1,4m)-CMA-ES [6]
(1,4ms)-CMA-ES	**2.2**	**2.5**	**2.7**	98	*11e-1/1e4*	.	.	.	.	.	(1,4ms)-CMA-ES [1, 6]
(1,4s)-CMA-ES	**2.7**	3.0	3.4	62	*10e-1/1e4*	.	.	.	.	.	(1,4s)-CMA-ES [4]
(1+1)-CMA-ES	**2.0**	**2.4**	**2.6**	172	*12e-1/1e4*	.	.	.	.	.	(1+1)-CMA-ES [7]
(1+2ms)-CMA-ES	**1.8**	**2.1**	**2.3**	156	*11e-1/1e4*	.	.	.	.	.	(1+2ms)-CMA-ES [2]
Artif Bee Colony	12	12	13	**1**	*23e-2/1e5*	.	.	.	.	.	Artif Bee Colony [8]
avg NEWUOA	**1**	**1**	**1**	915	*12e-1/2e4*	.	.	.	.	.	avg NEWUOA [23]
CMA-EGS (IPOP,r1)	5.8	6.0	6.2	*20e-1/1e5*	.	.	.	.	.	.	CMA-EGS (IPOP,r1) [12]
Adap DE (F-AUC)	24	29	32	5527	*15e-1/1e5*	.	.	.	.	.	Adap DE (F-AUC) [10]
DE (Uniform)	43	53	59	*17e-1/1e5*	.	.	.	.	.	.	DE (Uniform) [9]
IPOP-aCMA-ES	**2.5**	3.2	3.7	27	**11**	**11**	**10**	**9.5**	**9.1**	**8.1**	IPOP-aCMA-ES [16]
IPOP-CMA-ES	**2.8**	3.3	3.6	55	**8.3**	**11**	**10**	**9.3**	**9.0**	**7.9**	IPOP-CMA-ES [22]
CMA+DE-MOS	13	16	16	**8.3**	**1**	**1**	**1**	**1**	**1**	**1**	CMA+DE-MOS [18]
NBC-CMA	4.6	5.5	5.7	784	*12e-1/1e4*	.	.	.	.	.	NBC-CMA [21]
POEMS	73	86	92	21	110	*30e-2/3e5*	.	.	.	.	POEMS [17]
PM-AdapSS-DE	29	36	36	*22e-1/1e5*	.	.	.	.	.	.	PM-AdapSS-DE [9, 10]
pPOEMS	72	88	105	**16**	*24e-2/3e5*	.	.	.	.	.	pPOEMS [17, 20]
Basic RCGA	5.7	7.0	7.9	*22e-1/5e4*	.	.	.	.	.	.	Basic RCGA [24]
SPSA	7.8	10	13	*22e-1/1e5*	.	.	.	.	.	.	SPSA [13]

Table 21: 20-D, running time excess ERT/ERT_{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
ERT_{best}/D	0.05	0.05	52	570	1254	1262	1267	1274	1279	1291	ERT_{best}/D
(1,2)-CMA-ES	**1**	**1**	6.9	4.7	5.8	5.8	6.3	6.3	6.2	6.2	(1,2)-CMA-ES [5, 3]
(1,2m)-CMA-ES	**1**	**1**	3.2	**1.9**	**2.0**	**2.0**	**2.0**	**2.0**	**2.0**	**2.0**	(1,2m)-CMA-ES [5]
(1,2ms)-CMA-ES	**1**	**1**	3.9	**2.8**	**2.3**	**2.3**	**2.3**	**2.2**	**2.2**	**2.2**	(1,2ms)-CMA-ES [5]
(1,2s)-CMA-ES	**1**	**1**	3.7	5.3	5.1	5.1	5.1	5.1	5.1	5.1	(1,2s)-CMA-ES [3]
(1,4)-CMA-ES	**1**	**1**	**1.1**	**2.1**	**2.6**	**2.6**	**2.6**	**2.6**	**2.6**	**2.6**	(1,4)-CMA-ES [6, 4]
(1,4m)-CMA-ES	**1**	**1**	**2.1**	**2.7**	**2.7**	**2.7**	**2.7**	**2.7**	**2.7**	**2.7**	(1,4m)-CMA-ES [6]
(1,4ms)-CMA-ES	**1**	**1**	**1.3**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	(1,4ms)-CMA-ES [1, 6]
(1,4s)-CMA-ES	**1**	**1**	**2.1**	**1.3**	**1.5**	**1.4**	**1.4**	**1.4**	**1.4**	**1.4**	(1,4s)-CMA-ES [4]
(1+1)-CMA-ES	**1**	**1**	**1.9**	3.2	3.0	3.0	3.0	3.0	3.0	**3.0**	(1+1)-CMA-ES [7]
(1+2ms)-CMA-ES	**1**	**1**	**1.8**	**2.6**	**2.2**	**2.2**	**2.2**	**2.2**	**2.2**	**2.2**	(1+2ms)-CMA-ES [2]
Artif Bee Colony	**1**	**1**	**2.7**	13	14	15	15	18	21	58	Artif Bee Colony [8]
avg NEWUOA	**1**	**1**	**1.7**	3.2	**2.0**	**2.0**	**2.0**	**2.0**	**2.0**	**2.0**	avg NEWUOA [23]
CMA-EGS (IPOP,r1)	**2.7**	106	**1**	121	122	122	121	121	120	119	CMA-EGS (IPOP,r1) [12]
Adap DE (F-AUC)	**1**	**1**	6.3	352	319	318	316	315	313	311	Adap DE (F-AUC) [10]
DE (Uniform)	**1**	**1**	11	265	320	318	316	315	314	311	DE (Uniform) [9]
IPOP-aCMA-ES	**1**	**1**	**1.0**	46	37	37	37	37	37	36	IPOP-aCMA-ES [16]
IPOP-CMA-ES	**1**	**1**	**2.0**	80	62	61	61	61	61	60	IPOP-CMA-ES [22]
CMA+DE-MOS	**1**	**1**	5.8	151	160	159	159	158	158	157	CMA+DE-MOS [18]
NBC-CMA	**1**	**1**	45	40	33	33	33	32	32	32	NBC-CMA [21]
POEMS	**1**	**1**	5941	3426	*47e-1/3e5*	.	.	.	.	.	POEMS [17]
PM-AdapSS-DE	**1**	**1**	6.4	202	319	318	316	315	313	311	PM-AdapSS-DE [9, 10]
pPOEMS	**1**	**1**	74	673	537	673	670	667	665	664	pPOEMS [17, 20]
Basic RCGA	**1**	**1**	64	59	48	48	50	58	59	60	Basic RCGA [24]
SPSA	3.5	251	321	712	*18e-1/1e5*	.	.	.	.	.	SPSA [13]

Table 22: 20-D, running time excess ERT/ERT_{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
ERT_{best}/D	0.05	0.05	46	1225	11465	11487	11506	11522	11537	11567	ERT_{best}/D
(1,2)-CMA-ES	**1**	**1**	5.1	6.1	13	13	13	13	13	13	(1,2)-CMA-ES [5, 3]
(1,2m)-CMA-ES	**1**	**1**	4.4	**2.9**	**2.1**	**2.1**	**2.1**	**2.1**	**2.1**	**2.1**	(1,2m)-CMA-ES [5]
(1,2ms)-CMA-ES	**1**	**1**	4.1	**2.9**	**1.7**	**1.7**	**1.7**	**1.7**	**1.7**	**1.7**	(1,2ms)-CMA-ES [5]
(1,2s)-CMA-ES	**1**	**1**	18	5.0	3.8	3.8	3.8	3.8	3.8	3.8	(1,2s)-CMA-ES [3]
(1,4)-CMA-ES	**1**	**1**	9.0	**1.5**	**1.2**	**1.2**	**1.2**	**1.2**	**1.2**	**1.2**	(1,4)-CMA-ES [6, 4]
(1,4m)-CMA-ES	**1**	**1**	**2.8**	**1.8**	**1.7**	**1.7**	**1.7**	**1.7**	**1.7**	**1.7**	(1,4m)-CMA-ES [6]
(1,4ms)-CMA-ES	**1**	**1**	4.5	**1.1**	**2.9**	**2.8**	**2.8**	**2.8**	**2.8**	**2.8**	(1,4ms)-CMA-ES [1, 6]
(1,4s)-CMA-ES	**1**	**1**	**2.4**	3.1	**2.7**	**2.7**	**2.7**	**2.7**	**2.7**	**2.7**	(1,4s)-CMA-ES [4]
(1+1)-CMA-ES	**1**	**1**	8.5	**2.1**	**1.5**	**1.5**	**1.5**	**1.5**	**1.5**	**1.5**	(1+1)-CMA-ES [7]
(1+2ms)-CMA-ES	**1**	**1**	5.2	**1**	**1**	**1**	**1**	**1**	**1**	**1**	(1+2ms)-CMA-ES [2]
Artif Bee Colony	**1**	**1**	5.3	11	7.9	61	*44e-3/1e5*	.	.	.	Artif Bee Colony [8]
avg NEWUOA	**1**	**1**	**1**	**1.3**	**1.4**	**1.4**	**1.4**	**1.4**	**1.4**	**1.4**	avg NEWUOA [23]
CMA-EGS (IPOP,r1)	**1.9**	104	339	124	*20e-1/1e5*	.	.	.	.	.	CMA-EGS (IPOP,r1) [12]
Adap DE (F-AUC)	**1**	**1**	339	327	*26e-1/1e5*	.	.	.	.	.	Adap DE (F-AUC) [10]
DE (Uniform)	**1**	**1**	793	225	*20e-1/1e5*	.	.	.	.	.	DE (Uniform) [9]
IPOP-aCMA-ES	**1**	**1**	232	60	*20e-1/6e4*	.	.	.	.	.	IPOP-aCMA-ES [16]
IPOP-CMA-ES	**1**	**1**	223	65	*20e-1/6e4*	.	.	.	.	.	IPOP-CMA-ES [22]
CMA+DE-MOS	**1**	**1**	269	182	69	69	69	69	69	69	CMA+DE-MOS [18]
NBC-CMA	**1**	**1**	162	80	*73e-1/1e4*	.	.	.	.	.	NBC-CMA [21]
POEMS	**1**	**1**	3240	1593	*73e-1/3e5*	.	.	.	.	.	POEMS [17]
PM-AdapSS-DE	**1**	**1**	789	531	*51e-1/1e5*	.	.	.	.	.	PM-AdapSS-DE [9, 10]
pPOEMS	**1**	**1**	1015	328	172	172	172	172	172	171	pPOEMS [17, 20]
Basic RCGA	**1**	**1**	595	273	*73e-1/5e4*	.	.	.	.	.	Basic RCGA [24]
SPSA	7.6	240	538	328	*26e-1/1e5*	.	.	.	.	.	SPSA [13]

Table 23: 20-D, running time excess ERT/ERT$_{\text{best}}$ 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

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	0.05	0.05	0.18	383	30011	2.50e5	∞	∞	∞	∞	ERT$_{\text{best}}$/D
(1,2)-CMA-ES	**1**	**1**	304	386	*27e-1/1e4*	.	.	.	.	.	(1,2)-CMA-ES [5, 3]
(1,2m)-CMA-ES	**1**	**1**	28	29	*97e-2/1e4*	.	.	.	.	.	(1,2m)-CMA-ES [5]
(1,2ms)-CMA-ES	**1**	**1**	44	81	*14e-1/1e4*	.	.	.	.	.	(1,2ms)-CMA-ES [5]
(1,2s)-CMA-ES	**1**	**1**	171	*34e-1/1e4*	.	.	.	.	.	.	(1,2s)-CMA-ES [3]
(1,4)-CMA-ES	**1**	**1**	40	22	*86e-2/1e4*	.	.	.	.	.	(1,4)-CMA-ES [6, 4]
(1,4m)-CMA-ES	**1**	**1**	17	9.5	*38e-2/1e4*	.	.	.	.	.	(1,4m)-CMA-ES [6]
(1,4ms)-CMA-ES	**1**	**1**	15	26	*66e-2/1e4*	.	.	.	.	.	(1,4ms)-CMA-ES [1, 6]
(1,4s)-CMA-ES	**1**	**1**	20	29	*81e-2/1e4*	.	.	.	.	.	(1,4s)-CMA-ES [4]
(1+1)-CMA-ES	**1**	**1**	16	**1.7**	*40e-2/1e4*	.	.	.	.	.	(1+1)-CMA-ES [7]
(1+2ms)-CMA-ES	**1**	**1**	7.0	**1.3**	*38e-2/1e4*	.	.	.	.	.	(1+2ms)-CMA-ES [2]
Artif Bee Colony	**1**	**1**	**1**	16	*64e-2/1e5*	.	.	.	.	.	Artif Bee Colony [8]
avg NEWUOA	**1**	**1**	13	**1**	*20e-2/2e4*	.	.	.	.	.	avg NEWUOA [23]
CMA-EGS (IPOP,r1)	**1.4**	66	49	*15e-1/1e5*	.	.	.	.	.	.	CMA-EGS (IPOP,r1) [12]
Adap DE (F-AUC)	**1**	**1**	**1.4**	502	49	*11e-1/1e5*	.	.	.	.	Adap DE (F-AUC) [10]
DE (Uniform)	**1**	**1**	**2.7**	1265	*13e-1/1e5*	.	.	.	.	.	DE (Uniform) [9]
IPOP-aCMA-ES	**1**	**1**	3.6	4802	*15e-1/1e5*	.	.	.	.	.	IPOP-aCMA-ES [16]
IPOP-CMA-ES	**1**	**1**	3.8	4860	*14e-1/1e5*	.	.	.	.	.	IPOP-CMA-ES [22]
CMA+DE-MOS	**1**	**1**	**1.9**	12	**1**	**1**	*29e-3/1e5*	.	.	.	CMA+DE-MOS [18]
NBC-CMA	**1**	**1**	**1.7**	*18e-1/1e4*	.	.	.	.	.	.	NBC-CMA [21]
POEMS	**1**	**1**	26	10	**5.2**	*90e-3/3e5*	.	.	.	.	POEMS [17]
PM-AdapSS-DE	**1**	**1**	**1.4**	1788	*13e-1/1e5*	.	.	.	.	.	PM-AdapSS-DE [9, 10]
pPOEMS	**1**	**1**	4.4	67	**4.0**	*60e-3/3e5*	.	.	.	.	pPOEMS [17, 20]
Basic RCGA	**1**	**1**	**2.4**	120	12	*26e-2/5e4*	.	.	.	.	Basic RCGA [24]
SPSA	4.7	868	2062	*16e-1/1e5*	.	.	.	.	.	.	SPSA [13]

Table 24: 20-D, running time excess ERT/ERT$_{\text{best}}$ 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

24 Lunacek bi-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	0.05	629	1.13e5	1.68e6	∞	∞	∞	∞	∞	∞	ERT$_{\text{best}}$/D
(1,2)-CMA-ES	**1**	*19e+1/1e4*	.	.	.	.	.	.	.	.	(1,2)-CMA-ES [5, 3]
(1,2m)-CMA-ES	**1**	6.0	*77e+0/1e4*	.	.	.	.	.	.	.	(1,2m)-CMA-ES [5]
(1,2ms)-CMA-ES	**1**	8.7	*90e+0/1e4*	.	.	.	.	.	.	.	(1,2ms)-CMA-ES [5]
(1,2s)-CMA-ES	**1**	237	*19e+1/1e4*	.	.	.	.	.	.	.	(1,2s)-CMA-ES [3]
(1,4)-CMA-ES	**1**	7.6	*85e+0/1e4*	.	.	.	.	.	.	.	(1,4)-CMA-ES [6, 4]
(1,4m)-CMA-ES	**1**	**1.1**	*62e+0/1e4*	.	.	.	.	.	.	.	(1,4m)-CMA-ES [6]
(1,4ms)-CMA-ES	**1**	**1.5**	*60e+0/1e4*	.	.	.	.	.	.	.	(1,4ms)-CMA-ES [1, 6]
(1,4s)-CMA-ES	**1**	7.2	*81e+0/1e4*	.	.	.	.	.	.	.	(1,4s)-CMA-ES [4]
(1+1)-CMA-ES	**1**	19	*97e+0/1e4*	.	.	.	.	.	.	.	(1+1)-CMA-ES [7]
(1+2ms)-CMA-ES	**1**	8.0	*83e+0/1e4*	.	.	.	.	.	.	.	(1+2ms)-CMA-ES [2]
Artif Bee Colony	**1.1**	1095	*12e+1/1e5*	.	.	.	.	.	.	.	Artif Bee Colony [8]
avg NEWUOA	14	**1.7**	*74e+0/1e4*	.	.	.	.	.	.	.	avg NEWUOA [23]
CMA-EGS (IPOP,r1)	184	3.8	**2.5**	*25e+0/1e5*	.	.	.	.	.	.	CMA-EGS (IPOP,r1) [12]
Adap DE (F-AUC)	**1**	27	*83e+0/1e5*	.	.	.	.	.	.	.	Adap DE (F-AUC) [10]
DE (Uniform)	**1.2**	39	*81e+0/1e5*	.	.	.	.	.	.	.	DE (Uniform) [9]
IPOP-aCMA-ES	**1**	3.2	15	**1**	*20e+0/3e5*	.	.	.	.	.	IPOP-aCMA-ES [16]
IPOP-CMA-ES	**1**	**2.9**	*20e+0/3e5*	.	.	.	.	.	.	.	IPOP-CMA-ES [22]
CMA+DE-MOS	**1.1**	**1**	**1.0**	*89e-1/1e5*	.	.	.	.	.	.	CMA+DE-MOS [18]
NBC-CMA	**1.1**	*12e+1/1e4*	.	.	.	.	.	.	.	.	NBC-CMA [21]
POEMS	39	5.1	*42e+0/3e5*	.	.	.	.	.	.	.	POEMS [17]
PM-AdapSS-DE	**1**	11	*70e+0/1e5*	.	.	.	.	.	.	.	PM-AdapSS-DE [9, 10]
pPOEMS	**1.3**	29	38	*17e+0/3e5*	.	.	.	.	.	.	pPOEMS [17, 20]
Basic RCGA	**1**	25	**1**	*25e+0/5e4*	.	.	.	.	.	.	Basic RCGA [24]
SPSA	2.52e5	*86e+1/1e5*	.	.	.	.	.	.	.	.	SPSA [13]

References

[1] Anne Auger, Dimo Brockhoff, and Nikolaus Hansen. Benchmarking the (1, 4)-CMA-ES with mirrored sampling and sequential selection on the noiseless BBOB-2010 testbed. In Pelikan and Branke [19], pages 1617–1624.

[2] Anne Auger, Dimo Brockhoff, and Nikolaus Hansen. Comparing the (1+1)-CMA-ES with a mirrored (1+2)-CMA-ES with sequential selection on the noiseless BBOB-2010 testbed. In Pelikan and Branke [19], pages 1543–1550.

[3] Anne Auger, Dimo Brockhoff, and Nikolaus Hansen. Investigating the impact of sequential selection in the (1, 2)-CMA-ES on the noiseless BBOB-2010 testbed. In Pelikan and Branke [19], pages 1591–1596.

[4] Anne Auger, Dimo Brockhoff, and Nikolaus Hansen. Investigating the impact of sequential selection in the (1, 4)-CMA-ES on the noiseless BBOB-2010 testbed. In Pelikan and Branke [19], pages 1597–1604.

[5] Anne Auger, Dimo Brockhoff, and Nikolaus Hansen. Mirrored variants of the (1, 2)-CMA-ES compared on the noiseless BBOB-2010 testbed. In Pelikan and Branke [19], pages 1551–1558.

[6] Anne Auger, Dimo Brockhoff, and Nikolaus Hansen. Mirrored variants of the (1, 4)-CMA-ES compared on the noiseless BBOB-2010 testbed. In Pelikan and Branke [19], pages 1559–1566.

[7] Anne Auger and Nikolaus Hansen. Benchmarking the (1+1)-CMA-ES on the BBOB-2009 function testbed. In Franz Rothlauf, editor, *GECCO (Companion)*, pages 2459–2466. ACM, 2009.

[8] Mohammed El-Abd. Black-box optimization benchmarking for noiseless function testbed using artificial bee colony algorithm. In Pelikan and Branke [19], pages 1719–1724.

[9] Álvaro Fialho, Wenyin Gong, and Zhihua Cai. Probability matching-based adaptive strategy selection vs. uniform strategy selection within differential evolution: an empirical comparison on the BBOB-2010 noiseless testbed. In Pelikan and Branke [19], pages 1527–1534.

[10] Álvaro Fialho, Marc Schoenauer, and Michèle Sebag. Fitness-AUC bandit adaptive strategy selection vs. the probability matching one within differential evolution: an empirical comparison on the BBOB-2010 noiseless testbed. In Pelikan and Branke [19], pages 1535–1542.

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

[12] Steffen Finck and Hans-Georg Beyer. Benchmarking CMA-EGS on the BBOB 2010 noiseless function testbed. In Pelikan and Branke [19], pages 1633–1640.

[13] Steffen Finck and Hans-Georg Beyer. Benchmarking SPSA on BBOB-2010 noiseless function testbed. In Pelikan and Branke [19], pages 1657–1664.

[14] N. Hansen, A. Auger, S. Finck, and R. Ros. Real-parameter black-box optimization benchmarking 2010: Experimental setup. Technical Report RR-7215, INRIA, 2010.

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

[16] Nikolaus Hansen and Raymond Ros. Benchmarking a weighted negative covariance matrix update on the BBOB-2010 noiseless testbed. In Pelikan and Branke [19], pages 1673–1680.

[17] Jirí Kubalík. Black-box optimization benchmarking of two variants of the POEMS algorithm on the noiseless testbed. In Pelikan and Branke [19], pages 1567–1574.

[18] Antonio LaTorre, Santiago Muelas, and José María Peña. Benchmarking a MOS-based algorithm on the BBOB-2010 noiseless function testbed. In Pelikan and Branke [19], pages 1649–1656.

[19] Martin Pelikan and Jürgen Branke, editors. *Genetic and Evolutionary Computation Conference, GECCO 2010, Proceedings, Portland, Oregon, USA, July 7-11, 2010, Companion Material.* ACM, 2010.

[20] Petr Posík and Jirí Kubalík. Comparison of Cauchy EDA and pPOEMS algorithms on the BBOB noiseless testbed. In Pelikan and Branke [19], pages 1703–1710.

[21] Mike Preuss. Niching the CMA-ES via nearest-better clustering. In Pelikan and Branke [19], pages 1711–1718.

[22] Raymond Ros. Black-box optimization benchmarking the IPOP-CMA-ES on the noiseless testbed: comparison to the BIPOP-CMA-ES. In Pelikan and Branke [19], pages 1503–1510.

[23] Raymond Ros. Comparison of NEWUOA with different numbers of interpolation points on the BBOB noiseless testbed. In Pelikan and Branke [19], pages 1487–1494.

[24] Thanh-Do Tran and Gang-Gyoo Jin. Real-coded genetic algorithm benchmarked on noiseless black-box optimization testbed. In Pelikan and Branke [19], pages 1731–1738.