

Comparison tables: BBOB 2010 function testbed in 20-D

The BBOBies

August 30, 2010

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											
Δf_{target} ERT_{best}/D	1e+03	1e+02	1e+01	1e+00	1e-01	1e-02	1e-03	1e-04	1e-05	1e-07	Δf_{target} 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											
Δf_{target}	1e+03	1e+02	1e+01	1e+00	1e-01	1e-02	1e-03	1e-04	1e-05	1e-07	Δf_{target}
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	<i>51e-2/5e4</i>	.	.	Basic RCGA [24]
SPSA	22349	<i>18e+2/1e5</i>	.	.	.	.	.	.	.	.	SPSA [13]

Table 3: 20-D, running time excess ERT/ERT_{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											
Δf_{target} ERT_{best}/D	1e+03	1e+02	1e+01	1e+00	1e-01	1e-02	1e-03	1e-04	1e-05	1e-07	Δf_{target} ERT_{best}/D
(1,2)-CMA-ES	14	1866	<i>14e+1/1e4</i>	.	.	.	.	.	.	.	(1,2)-CMA-ES [5, 3]
(1,2m)-CMA-ES	6.5	19	<i>63e+0/1e4</i>	.	.	.	.	.	.	.	(1,2m)-CMA-ES [5]
(1,2ms)-CMA-ES	4.8	21	<i>67e+0/1e4</i>	.	.	.	.	.	.	.	(1,2ms)-CMA-ES [5]
(1,2s)-CMA-ES	16	<i>16e+1/1e4</i>	.	.	.	.	.	.	.	.	(1,2s)-CMA-ES [3]
(1,4)-CMA-ES	4.1	19	<i>64e+0/1e4</i>	.	.	.	.	.	.	.	(1,4)-CMA-ES [6, 4]
(1,4m)-CMA-ES	2.0	6.5	<i>54e+0/1e4</i>	.	.	.	.	.	.	.	(1,4m)-CMA-ES [6]
(1,4ms)-CMA-ES	2.2	8.8	<i>61e+0/1e4</i>	.	.	.	.	.	.	.	(1,4ms)-CMA-ES [1, 6]
(1,4s)-CMA-ES	2.8	30	<i>73e+0/1e4</i>	.	.	.	.	.	.	.	(1,4s)-CMA-ES [4]
(1+1)-CMA-ES	1.6	75	<i>95e+0/1e4</i>	.	.	.	.	.	.	.	(1+1)-CMA-ES [7]
(1+2ms)-CMA-ES	1.5	60	<i>84e+0/1e4</i>	.	.	.	.	.	.	.	(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	<i>97e+0/1e4</i>	.	.	.	.	.	.	.	avg NEWUOA [23]
CMA-EGS (IPOP,r1)	9.5	1.1	834	<i>18e+0/1e5</i>	.	.	.	.	.	.	CMA-EGS (IPOP,r1) [12]
Adap DE (F-AUC)	1.1	55	<i>59e+0/1e5</i>	.	.	.	.	.	.	.	Adap DE (F-AUC) [10]
DE (Uniform)	1.4	58	<i>66e+0/1e5</i>	.	.	.	.	.	.	.	DE (Uniform) [9]
IPOP-aCMA-ES	1.4	1	6.6	<i>60e-1/1e5</i>	.	.	.	.	.	.	IPOP-aCMA-ES [16]
IPOP-CMA-ES	1.4	1.0	8.7	<i>50e-1/1e5</i>	.	.	.	.	.	.	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	<i>18e+0/2e4</i>	.	.	.	.	.	.	NBC-CMA [21]
POEMS	204	6.7	6.9	23	44	43	39	37	35	31	POEMS [17]
PM-AdapSS-DE	1.4	22	<i>56e+0/1e5</i>	.	.	.	.	.	.	.	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	<i>41e-1/5e4</i>	.	.	.	.	.	Basic RCGA [24]
SPSA	72029	<i>82e+1/1e5</i>	.	.	.	.	.	.	.	.	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											
Δf_{target}	1e+03	1e+02	1e+01	1e+00	1e-01	1e-02	1e-03	1e-04	1e-05	1e-07	Δf_{target}
ERT_{best}/D	2.5	86	463	1609	2159	2297	2439	2672	2828	3168	ERT_{best}/D
(1,2)-CMA-ES	9.4	<i>17e+1/1e4</i>	.	.	.	.	.	.	.	.	(1,2)-CMA-ES [5, 3]
(1,2m)-CMA-ES	4.4	51	<i>79e+0/1e4</i>	.	.	.	.	.	.	.	(1,2m)-CMA-ES [5]
(1,2ms)-CMA-ES	4.0	65	<i>79e+0/1e4</i>	.	.	.	.	.	.	.	(1,2ms)-CMA-ES [5]
(1,2s)-CMA-ES	9.0	<i>15e+1/1e4</i>	.	.	.	.	.	.	.	.	(1,2s)-CMA-ES [3]
(1,4)-CMA-ES	3.0	74	<i>88e+0/1e4</i>	.	.	.	.	.	.	.	(1,4)-CMA-ES [6, 4]
(1,4m)-CMA-ES	2.0	23	<i>66e+0/1e4</i>	.	.	.	.	.	.	.	(1,4m)-CMA-ES [6]
(1,4ms)-CMA-ES	2.2	29	<i>69e+0/1e4</i>	.	.	.	.	.	.	.	(1,4ms)-CMA-ES [1, 6]
(1,4s)-CMA-ES	3.0	196	<i>10e+1/1e4</i>	.	.	.	.	.	.	.	(1,4s)-CMA-ES [4]
(1+1)-CMA-ES	1.0	1651	<i>14e+1/1e4</i>	.	.	.	.	.	.	.	(1+1)-CMA-ES [7]
(1+2ms)-CMA-ES	1.2	1630	<i>13e+1/1e4</i>	.	.	.	.	.	.	.	(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	<i>12e+1/2e4</i>	.	.	.	.	.	.	.	avg NEWUOA [23]
CMA-EGS (IPOP,r1)	6.0	1.1	<i>26e+0/1e5</i>	.	.	.	.	.	.	.	CMA-EGS (IPOP,r1) [12]
Adap DE (F-AUC)	1.9	103	<i>19e+0/1e5</i>	.	.	.	.	.	.	.	Adap DE (F-AUC) [10]
DE (Uniform)	2.2	108	<i>21e+0/1e5</i>	.	.	.	.	.	.	.	DE (Uniform) [9]
IPOP-aCMA-ES	1.1	1.0	<i>14e+0/1e5</i>	.	.	.	.	.	.	.	IPOP-aCMA-ES [16]
IPOP-CMA-ES	1.2	1	<i>13e+0/1e5</i>	.	.	.	.	.	.	.	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	<i>25e+0/1e4</i>	.	.	.	.	.	.	.	NBC-CMA [21]
POEMS	81	7.7	6.9	26	55	52	49	45	43	39	POEMS [17]
PM-AdapSS-DE	2.8	55	<i>20e+0/1e5</i>	.	.	.	.	.	.	.	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	<i>22e+0/5e4</i>	.	.	.	.	.	.	.	Basic RCGA [24]
SPSA	33	<i>24e+1/1e5</i>	.	.	.	.	.	.	.	.	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												
Δf_{target}	1e+03	1e+02	1e+01	1e+00	1e-01	1e-02	1e-03	1e-04	1e-05	1e-07	Δf_{target}	
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	<i>11e-3/1e4</i>	.	.	(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	<i>15e-2/1e4</i>	.	.	.	(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	<i>69e-2/1e4</i>	.	.	.	.	(1+1)-CMA-ES [7]
(1+2ms)-CMA-ES	1	1.6	12	144	1175	<i>74e-2/1e4</i>	.	.	.	.	(1+2ms)-CMA-ES [2]
Artif Bee Colony	6.4	7.3	46	608	3595	<i>54e-2/1e5</i>	.	.	.	.	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	<i>63e-6/5e4</i>	Basic RCGA [24]	
SPSA	1302	<i>40e+1/1e5</i>	.	.	.	.	.	.	.	.	SPSA [13]

Table 7: 20-D, running time excess ERT/ERT_{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												
	Δf_{target} ERT_{best}/D	1e+03	1e+02	1e+01	1e+00	1e-01	1e-02	1e-03	1e-04	1e-05	1e-07	Δf_{target} ERT_{best}/D
	(1,2)-CMA-ES	22	29	<i>23e+0/1e4</i>	.	.	.	.	.	.	.	(1,2)-CMA-ES [5, 3]
	(1,2m)-CMA-ES	7.9	3.1	53	<i>67e-1/1e4</i>	.	.	.	.	.	.	(1,2m)-CMA-ES [5]
	(1,2ms)-CMA-ES	6.0	3.4	53	<i>72e-1/1e4</i>	.	.	.	.	.	.	(1,2ms)-CMA-ES [5]
	(1,2s)-CMA-ES	14	19	<i>29e+0/1e4</i>	.	.	.	.	.	.	.	(1,2s)-CMA-ES [3]
	(1,4)-CMA-ES	2.3	2.6	88	<i>78e-1/1e4</i>	.	.	.	.	.	.	(1,4)-CMA-ES [6, 4]
	(1,4m)-CMA-ES	1.8	2.2	17	<i>48e-1/1e4</i>	.	.	.	.	.	.	(1,4m)-CMA-ES [6]
	(1,4ms)-CMA-ES	1.7	3.2	28	<i>62e-1/1e4</i>	.	.	.	.	.	.	(1,4ms)-CMA-ES [1, 6]
	(1,4s)-CMA-ES	2.1	3.2	205	<i>12e+0/1e4</i>	.	.	.	.	.	.	(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	<i>60e-1/1e5</i>	.	.	.	.	.	.	Artif Bee Colony [8]
	avg NEWUOA	4.0	1	75	<i>51e-1/2e4</i>	.	.	.	.	.	.	avg NEWUOA [23]
	CMA-EGS (IPOP,r1)	12	3.7	16	<i>53e-1/1e5</i>	.	.	.	.	.	.	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	<i>55e-2/1e4</i>	.	.	.	.	NBC-CMA [21]
	POEMS	243	40	17	737	<i>11e-1/3e5</i>	.	.	.	.	.	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	<i>13e-1/5e4</i>	.	.	.	.	.	Basic RCGA [24]
	SPSA	59	701	<i>58e+0/1e5</i>	.	.	.	.	.	.	.	SPSA [13]

∞

Table 8: 20-D, running time excess ERT/ERT_{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											
Δf_{target} ERT_{best}/D	1e+03	1e+02	1e+01	1e+00	1e-01	1e-02	1e-03	1e-04	1e-05	1e-07	Δf_{target} ERT_{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	<i>24e-5/1e5</i>	.	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	<i>15e-3/3e5</i>	.	.	.	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	<i>17e+0/5e4</i>	.	.	.	.	.	.	.	Basic RCGA [24]
SPSA	130	2584	<i>98e+0/1e5</i>	.	.	.	.	.	.	.	SPSA [13]

Table 12: 20-D, running time excess ERT/ERT_{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											
Δf_{target}	1e+03	1e+02	1e+01	1e+00	1e-01	1e-02	1e-03	1e-04	1e-05	1e-07	Δf_{target}	
ERT_{best}/D	35	38	133	289	440	539	639	747	830	954	ERT_{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	<i>18e-3/1e5</i>	.	.	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	<i>12e-1/3e5</i>	.	.	.	.	.	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	<i>17e-1/3e5</i>	.	.	.	.	pPOEMS [17, 20]	
Basic RCGA	237	267	87	81	161	398	<i>12e-2/5e4</i>	.	.	.	Basic RCGA [24]	
SPSA	5890	7325	<i>20e+5/1e5</i>	.	.	.	.	.	.	.	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											
Δf_{target} ERT_{best}/D	1e+03	1e+02	1e+01	1e+00	1e-01	1e-02	1e-03	1e-04	1e-05	1e-07	Δf_{target} 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	<i>10e-4/1e5</i>	.	.	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	<i>27e-6/3e5</i>	.	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	<i>78e-7/3e5</i>	pPOEMS [17, 20]
Basic RCGA	1	1.4	6.6	17	36	187	1136	<i>11e-4/5e4</i>	.	.	Basic RCGA [24]
SPSA	59	246	42	33	28	24	42	87	313	<i>85e-7/1e5</i>	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											
Δf_{target} ERT_{best}/D	1e+03	1e+02	1e+01	1e+00	1e-01	1e-02	1e-03	1e-04	1e-05	1e-07	Δf_{target} 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	<i>47e-1/3e5</i>	.	.	.	.	.	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	<i>18e-1/1e5</i>	.	.	.	.	.	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											
Δf_{target} ERT_{best}/D	1e+03	1e+02	1e+01	1e+00	1e-01	1e-02	1e-03	1e-04	1e-05	1e-07	Δf_{target} 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	<i>44e-3/1e5</i>	.	.	.	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	<i>20e-1/1e5</i>	.	.	.	.	.	CMA-EGS (IPOP,r1) [12]
Adap DE (F-AUC)	1	1	339	327	<i>26e-1/1e5</i>	.	.	.	.	.	Adap DE (F-AUC) [10]
DE (Uniform)	1	1	793	225	<i>20e-1/1e5</i>	.	.	.	.	.	DE (Uniform) [9]
IPOP-aCMA-ES	1	1	232	60	<i>20e-1/6e4</i>	.	.	.	.	.	IPOP-aCMA-ES [16]
IPOP-CMA-ES	1	1	223	65	<i>20e-1/6e4</i>	.	.	.	.	.	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	<i>73e-1/1e4</i>	.	.	.	.	.	NBC-CMA [21]
POEMS	1	1	3240	1593	<i>73e-1/3e5</i>	.	.	.	.	.	POEMS [17]
PM-AdapSS-DE	1	1	789	531	<i>51e-1/1e5</i>	.	.	.	.	.	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	<i>73e-1/5e4</i>	.	.	.	.	.	Basic RCGA [24]
SPSA	7.6	240	538	328	<i>26e-1/1e5</i>	.	.	.	.	.	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 Kubařík. 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 Kubařík. 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.