

Comparison tables: BBOB 2010 noisy testbed with BBOB 2009 as reference in 5-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 [11, 7]. The experimental set-up is described in [10].

The performance measure provided in the following tables is the expected number of objective function evaluations to reach a given target function value (ERT, expected running time), divided by the respective value for the best algorithm in BBOB-2009 (see [6]) if an algorithm from BBOB-2009 reached the given target function value. The ERT value is given otherwise (ERT_{best} is noted as infinite). See [10] 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: 05-D, running time excess $ERT/ERT_{\text{best}} 2009$ on f_{101} , in italics is given the median final function value and the median number of function evaluations to reach this value divided by dimension

101 Sphere moderate Gauss											
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
	0.20	0.20	2.2	7.4	8.8	10	12	13	14	15	
(1,2)-CMA-ES	1	1.2	8.3	4.4	6.3	8.1	8.5	10	11	13	(1,2)-CMA-ES [4, 2]
(1,2m)-CMA-ES	1	3.1	4.3	3.3	4.9	6.0	5.8	6.6	7.4	8.9	(1,2m)-CMA-ES [4]
(1,2ms)-CMA-ES	1	1	3.8	2.9	4.1	5.0	5.1	5.8	6.7	7.7	(1,2ms)-CMA-ES [4]
(1,2s)-CMA-ES	1	1	7.0	4.7	6.7	8.0	7.6	8.7	10	12	(1,2s)-CMA-ES [2]
(1,4)-CMA-ES	1	1	2.8	2.8	3.6	4.5	4.6	5.5	6.1	7.1	(1,4)-CMA-ES [5, 3]
(1,4m)-CMA-ES	1	1.3	2.4	2.1	2.8	4.0	4.1	4.5	5.1	6.4	(1,4m)-CMA-ES [5]
(1,4ms)-CMA-ES	1	1.2	2.4	1.7	2.3	2.9	3.0	3.5	3.9	4.6	(1,4ms)-CMA-ES [1, 5]
(1,4s)-CMA-ES	1	3.3	2.7	2.1	2.7	3.5	3.5	4.0	4.4	5.3	(1,4s)-CMA-ES [3]
avg NEWUOA	1	2.6	2.9	1.5	1.6	1.7	1.5	1.5	1.5	1.5	avg NEWUOA [16]
CMA-EGS (IPOP,r1)	41	61	22	13	14	17	16	18	20	24	CMA-EGS (IPOP,r1) [8]
IPOP-aCMA-ES	1	1.2	3.0	3.0	4.2	5.8	5.8	6.7	7.6	9.3	IPOP-aCMA-ES [12]
IPOP-CMA-ES	1	1.2	3.3	3.4	4.7	6.0	6.0	6.9	7.8	9.3	IPOP-CMA-ES [15]
CMA+DE-MOS	1	1.1	7.3	12	19	23	24	27	31	37	CMA+DE-MOS [13]
NEWUOA	1	3.6	2.5	1.6	2.1	2.5	2.6	2.9	3.0	3.1	NEWUOA [16]
Basic RCGA	1	1.1	7.7	25	48	88	113	155	206	293	Basic RCGA [17]
SPSA	40	64	83	171	386	434	455	494	568	9667	SPSA [9]

Table 2: 05-D, running time excess ERT/ERT_{best} 2009 on f_{102} , in italics is given the median final function value and the median number of function evaluations to reach this value divided by dimension

102 Sphere moderate unif											
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	0.20	0.20	2.2	7.1	10	13	14	16	17	20	ERT_{best}/D
(1,2)-CMA-ES	1	1.4	9.2	5.8	6.2	6.5	7.7	9.1	10	11	(1,2)-CMA-ES [4, 2]
(1,2m)-CMA-ES	1	1.4	3.9	3.3	3.6	4.2	4.9	5.4	6.0	6.8	(1,2m)-CMA-ES [4]
(1,2ms)-CMA-ES	1	2.4	4.2	3.3	3.9	3.9	4.7	5.1	5.4	6.3	(1,2ms)-CMA-ES [4]
(1,2s)-CMA-ES	1	2.3	4.1	5.2	6.4	6.6	8.0	8.6	9.3	10	(1,2s)-CMA-ES [2]
(1,4)-CMA-ES	1	1	3.2	2.5	2.9	3.0	3.7	4.2	4.6	5.3	(1,4)-CMA-ES [5, 3]
(1,4m)-CMA-ES	1	1.7	2.4	2.4	2.7	2.7	3.4	3.9	4.1	4.5	(1,4m)-CMA-ES [5]
(1,4ms)-CMA-ES	1	1	2.3	1.7	2.1	2.3	2.7	3.0	3.2	3.7	(1,4ms)-CMA-ES [1, 5]
(1,4s)-CMA-ES	1	1.6	2.8	2.1	2.4	2.7	3.2	3.4	3.6	4.4	(1,4s)-CMA-ES [3]
avg NEWUOA	1	1.3	2.7	1.4	1.5	1.4	1.5	1.5	1.6	1.5	avg NEWUOA [16]
CMA-EGS (IPOP,r1)	45	79	21	14	14	14	16	18	18	20	CMA-EGS (IPOP,r1) [8]
IPOP-aCMA-ES	1	1.4	3.5	3.4	3.8	4.3	5.0	5.8	6.1	7.0	IPOP-aCMA-ES [12]
IPOP-CMA-ES	1	1.5	3.4	3.1	4.1	4.2	5.1	6.0	6.5	7.3	IPOP-CMA-ES [15]
CMA+DE-MOS	1	1.1	5.7	12	17	18	20	22	25	27	CMA+DE-MOS [13]
NEWUOA	1	3.9	6.3	6.0	7.0	15	20	27	33	41	NEWUOA [16]
Basic RCGA	1	1.2	10	29	39	57	88	123	155	209	Basic RCGA [17]
SPSA	41	60	1987	4868	9895	9681	9199	11030	24495	<i>31e-3/1e5</i>	SPSA [9]

Table 3: 05-D, running time excess ERT/ERT_{best} 2009 on f_{103} , in italics is given the median final function value and the median number of function evaluations to reach this value divided by dimension

	103 Sphere moderate Cauchy										
Δf_{target} ERT_{best}/D	1e+03 0.20	1e+02 0.20	1e+01 2.2	1e+00 5.5	1e-01 6.0	1e-02 6.0	1e-03 6.3	1e-04 6.4	1e-05 7.0	1e-07 23	Δf_{target} ERT_{best}/D
(1,2)-CMA-ES	1	1.5	6.2	6.7	9.0	13	18	22	25	10	(1,2)-CMA-ES [4, 2]
(1,2m)-CMA-ES	1	2.5	3.4	3.8	5.5	8.4	10	13	15	6.1	(1,2m)-CMA-ES [4]
(1,2ms)-CMA-ES	1	1	3.8	3.6	5.4	7.5	9.4	12	13	5.4	(1,2ms)-CMA-ES [4]
(1,2s)-CMA-ES	1	2.1	8.2	7.0	10	12	16	20	22	9.2	(1,2s)-CMA-ES [2]
(1,4)-CMA-ES	1	1.6	2.1	3.0	4.4	6.5	8.5	10	12	5.0	(1,4)-CMA-ES [5, 3]
(1,4m)-CMA-ES	1	1.3	2.6	2.8	4.6	6.3	7.8	10	11	4.4	(1,4m)-CMA-ES [5]
(1,4ms)-CMA-ES	1	1.2	2.4	2.1	3.5	4.9	6.1	7.5	8.1	3.4	(1,4ms)-CMA-ES [1, 5]
(1,4s)-CMA-ES	1	1.6	2.9	2.9	4.8	6.7	8.0	10	10	4.2	(1,4s)-CMA-ES [3]
avg NEWUOA	1	2.5	2.5	1.6	3.6	5.4	13	26	42	34	avg NEWUOA [16]
CMA-EGS (IPOP,r1)	32	57	20	15	20	27	30	37	42	20	CMA-EGS (IPOP,r1) [8]
IPOP-aCMA-ES	1	1	2.9	4.1	6.3	8.8	11	14	16	6.5	IPOP-aCMA-ES [12]
IPOP-CMA-ES	1	1.4	3.6	4.0	6.6	9.4	12	15	17	7.1	IPOP-CMA-ES [15]
CMA+DE-MOS	1	1.1	7.6	13	28	38	48	60	72	30	CMA+DE-MOS [13]
NEWUOA	1	3.5	2.4	1.9	5.7	9.4	60	85	178	136	NEWUOA [16]
Basic RCGA	1	1.3	7.1	27	60	133	234	353	434	222	Basic RCGA [17]
SPSA	51	202	151	119	165	251	415	5261	93276	<i>42e-6/1e5</i>	SPSA [9]

Table 4: 05-D, running time excess $ERT/ERT_{\text{best}} 2009$ on f_{104} , in italics is given the median final function value and the median number of function evaluations to reach this value divided by dimension

104 Rosenbrock moderate Gauss											
	$1e+03$	$1e+02$	$1e+01$	$1e+00$	$1e-01$	$1e-02$	$1e-03$	$1e-04$	$1e-05$	$1e-07$	$\Delta\text{ftarget}$ ERT_{best}/D
	3.8	11	35	155	257	315	354	385	408	457	ERT_{best}/D
(1,2)-CMA-ES	7.1	7.7	3.9	13	54	222	<i>98e-3/1e4</i>	.	.	.	(1,2)-CMA-ES [4, 2]
(1,2m)-CMA-ES	2.9	8.2	3.3	4.3	13	14	13	13	12	11	(1,2m)-CMA-ES [4]
(1,2ms)-CMA-ES	3.2	2.9	1.6	9.3	14	24	24	22	21	18	(1,2ms)-CMA-ES [4]
(1,2s)-CMA-ES	4.0	8.0	3.5	13	50	98	410	<i>69e-3/1e4</i>	.	.	(1,2s)-CMA-ES [2]
(1,4)-CMA-ES	2.0	3.7	1.6	4.2	4.9	4.2	6.6	6.1	5.8	5.3	(1,4)-CMA-ES [5, 3]
(1,4m)-CMA-ES	2.3	3.4	1.5	5.0	3.3	3.9	3.6	3.3	3.2	2.9	(1,4m)-CMA-ES [5]
(1,4ms)-CMA-ES	2.1	3.1	1.3	4.3	5.0	4.2	3.8	3.5	3.3	3.0	(1,4ms)-CMA-ES [1, 5]
(1,4s)-CMA-ES	1.6	2.7	1.3	8.9	14	18	16	15	14	13	(1,4s)-CMA-ES [3]
avg NEWUOA	1.3	2.8	1.0	5.0	7.6	14	23	21	20	24	avg NEWUOA [16]
CMA-EGS (IPOP,r1)	22	13	5.5	583	448	367	327	300	284	254	CMA-EGS (IPOP,r1) [8]
IPOP-aCMA-ES	3.2	2.7	1.5	2.0	1.7	1.6	1.6	1.5	1.5	1.4	IPOP-aCMA-ES [12]
IPOP-CMA-ES	2.1	2.2	1.4	3.4	2.9	2.8	2.7	2.6	2.5	2.4	IPOP-CMA-ES [15]
CMA+DE-MOS	6.0	8.4	5.1	4.0	3.6	3.3	3.2	3.0	3.0	2.9	CMA+DE-MOS [13]
NEWUOA	1.1	2.8	1.2	3.4	6.0	14	24	100	<i>14e-4/5e3</i>	.	NEWUOA [16]
Basic RCGA	7.1	7.8	10	381	432	1080	963	1891	<i>12e-1/5e4</i>	.	Basic RCGA [17]
SPSA	189	148	<i>36e+0/1e5</i>	.	.	.	.	.	.	.	SPSA [9]

Table 5: 05-D, running time excess $\text{ERT}/\text{ERT}_{\text{best}}$ 2009 on f_{105} , in italics is given the median final function value and the median number of function evaluations to reach this value divided by dimension

	105 Rosenbrock moderate unif										
$\Delta\text{ftarget}$	1e+03	1e+02	1e+01	1e+00	1e-01	1e-02	1e-03	1e-04	1e-05	1e-07	$\Delta\text{ftarget}$
$\text{ERT}_{\text{best}}/D$	3.6	12	33	287	1035	2000	2078	2129	2165	2240	$\text{ERT}_{\text{best}}/D$
(1,2)-CMA-ES	8.3	4.9	3.1	7.8	19	35	70	69	<i>18e-2/1e4</i>	.	(1,2)-CMA-ES [4, 2]
(1,2m)-CMA-ES	4.5	3.8	2.1	6.0	10	10	20	<i>88e-3/1e4</i>	.	.	(1,2m)-CMA-ES [4]
(1,2ms)-CMA-ES	3.4	4.4	2.1	3.5	5.0	23	<i>38e-3/1e4</i>	.	.	.	(1,2ms)-CMA-ES [4]
(1,2s)-CMA-ES	6.6	3.5	4.9	10	19	<i>14e-2/1e4</i>	.	.	.	.	(1,2s)-CMA-ES [2]
(1,4)-CMA-ES	3.6	6.0	2.8	12	14	16	34	70	<i>14e-2/1e4</i>	.	(1,4)-CMA-ES [5, 3]
(1,4m)-CMA-ES	2.4	6.0	2.6	5.9	12	21	34	33	67	64	(1,4m)-CMA-ES [5]
(1,4ms)-CMA-ES	1.5	1.8	1.0	4.3	8.7	23	69	67	66	64	(1,4ms)-CMA-ES [1, 5]
(1,4s)-CMA-ES	1.7	1.5	1.6	6.6	16	22	70	68	<i>12e-2/1e4</i>	.	(1,4s)-CMA-ES [3]
avg NEWUOA	1.3	3.7	1.7	2.4	1.9	4.4	14	47	46	<i>45e-4/7e3</i>	avg NEWUOA [16]
CMA-EGS (IPOP,r1)	20	12	5.7	989	1355	702	675	659	648	626	CMA-EGS (IPOP,r1) [8]
IPOP-aCMA-ES	1.8	5.3	2.8	3.0	1.3	0.71	0.70	0.70	0.70	0.70	IPOP-aCMA-ES [12]
IPOP-CMA-ES	2.3	2.7	1.6	3.8	1.6	0.89	0.90	0.90	0.90	0.90	IPOP-CMA-ES [15]
CMA+DE-MOS	6.3	6.9	4.8	5.9	2.2	1.3	1.5	1.6	1.6	1.6	CMA+DE-MOS [13]
NEWUOA	0.91	2.8	1.7	2.7	3.3	5.0	<i>38e-3/5e3</i>	.	.	.	NEWUOA [16]
Basic RCGA	8.4	11	13	106	121	183	177	<i>51e-2/5e4</i>	.	.	Basic RCGA [17]
SPSA	499	250	<i>36e+0/1e5</i>	.	.	.	.	.	.	.	SPSA [9]

Table 8: 05-D, running time excess ERT/ERT_{best} 2009 on f_{108} , in italics is given the median final function value and the median number of function evaluations to reach this value divided by dimension

	108 Sphere unif										
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	0.20	0.20	17	1029	2894	4930	6187	8237	11726	16133	ERT_{best}/D
(1,2)-CMA-ES	1	1.7	43	<i>23e-1/1e4</i>	.	.	.	.	.	.	(1,2)-CMA-ES [4, 2]
(1,2m)-CMA-ES	1	2.7	27	22	<i>18e-1/1e4</i>	.	.	.	.	.	(1,2m)-CMA-ES [4]
(1,2ms)-CMA-ES	1	1.1	32	44	<i>19e-1/1e4</i>	.	.	.	.	.	(1,2ms)-CMA-ES [4]
(1,2s)-CMA-ES	1	2.8	90	69	<i>22e-1/1e4</i>	.	.	.	.	.	(1,2s)-CMA-ES [2]
(1,4)-CMA-ES	1	1.7	5.9	15	51	<i>11e-1/1e4</i>	.	.	.	.	(1,4)-CMA-ES [5, 3]
(1,4m)-CMA-ES	1	1.4	25	7.7	<i>84e-2/1e4</i>	.	.	.	.	.	(1,4m)-CMA-ES [5]
(1,4ms)-CMA-ES	1	3.7	15	13	<i>94e-2/1e4</i>	.	.	.	.	.	(1,4ms)-CMA-ES [1, 5]
(1,4s)-CMA-ES	1	2.7	25	69	<i>15e-1/1e4</i>	.	.	.	.	.	(1,4s)-CMA-ES [3]
avg NEWUOA	1	3.0	155	44	<i>27e-1/6e3</i>	.	.	.	.	.	avg NEWUOA [16]
CMA-EGS (IPOP,r1)	5825	9728	290	14	7.8	7.2	8.6	10	13	46	CMA-EGS (IPOP,r1) [8]
IPOP-aCMA-ES	1	12	11	0.68	0.64	0.64	0.64	0.75	0.66	0.94	IPOP-aCMA-ES [12]
IPOP-CMA-ES	1	1.7	9.1	0.80	0.67	0.64	0.77	0.70	0.62	0.69	IPOP-CMA-ES [15]
CMA+DE-MOS	1	1.1	2.5	95	125	157	267	201	141	<i>89e-2/1e5</i>	CMA+DE-MOS [13]
NEWUOA	1	48	77	64	<i>41e-1/5e3</i>	.	.	.	.	.	NEWUOA [16]
Basic RCGA	1	1	0.79	13	30	70	<i>16e-2/5e4</i>	.	.	.	Basic RCGA [17]
SPSA	436	1305	89	10	242	<i>15e-2/1e5</i>	.	.	.	.	SPSA [9]

Table 9: 05-D, running time excess $ERT/ERT_{\text{best}} 2009$ on f_{109} , in italics is given the median final function value and the median number of function evaluations to reach this value divided by dimension

109 Sphere Cauchy											
Δf_{target} ERT_{best}/D	1e+03 0.20	1e+02 0.20	1e+01 2.2	1e+00 11	1e-01 43	1e-02 75	1e-03 114	1e-04 139	1e-05 175	1e-07 189	Δf_{target} ERT_{best}/D
(1,2)-CMA-ES	1	2.7	5.5	2.8	1.8	1.9	1.9	2.5	2.5	3.4	(1,2)-CMA-ES [4, 2]
(1,2m)-CMA-ES	1	3.3	4.1	2.5	1.2	1.1	1.0	1.1	1.0	1.3	(1,2m)-CMA-ES [4]
(1,2ms)-CMA-ES	1	1.3	3.4	2.1	1.0	0.86	0.77	0.89	0.89	1.1	(1,2ms)-CMA-ES [4]
(1,2s)-CMA-ES	1	1	5.8	3.5	2.0	2.0	2.2	2.4	2.4	3.4	(1,2s)-CMA-ES [2]
(1,4)-CMA-ES	1	1.1	3.4	2.2	1.0	0.98	1.0	1.1	1.1	1.4	(1,4)-CMA-ES [5, 3]
(1,4m)-CMA-ES	1	1	2.9	1.4	0.79	0.82	0.81	0.88	0.93	1.2	(1,4m)-CMA-ES [5]
(1,4ms)-CMA-ES	1	1.6	1.9	1.1	0.57	0.52	0.50	0.53	0.52	0.67	(1,4ms)-CMA-ES [1, 5]
(1,4s)-CMA-ES	1	1.2	3.0	1.3	0.79	0.76	0.68	0.68	0.66	0.88	(1,4s)-CMA-ES [3]
avg NEWUOA	1	1.5	4.3	3.6	26	47	<i>67e-4/6e3</i>	.	.	.	avg NEWUOA [16]
CMA-EGS (IPOP,r1)	41	62	21	8.3	3.1	110	2422	<i>17e-4/1e5</i>	.	.	CMA-EGS (IPOP,r1) [8]
IPOP-aCMA-ES	1	1.1	3.1	1.9	1.1	1.0	0.92	1.1	1.2	1.5	IPOP-aCMA-ES [12]
IPOP-CMA-ES	1	1	2.9	2.2	1.2	1.1	1.0	1.1	1.1	1.5	IPOP-CMA-ES [15]
CMA+DE-MOS	1	1.1	6.1	8.7	4.9	4.9	4.7	5.2	5.3	7.4	CMA+DE-MOS [13]
NEWUOA	1	1.7	4.8	13	83	885	<i>41e-3/5e3</i>	.	.	.	NEWUOA [16]
Basic RCGA	1	1.3	9.0	20	12	14	16	20	25	53	Basic RCGA [17]
SPSA	50	101	138	953	3515	<i>13e-2/1e5</i>	.	.	.	.	SPSA [9]

Table 14: 05-D, running time excess $ERT/ERT_{\text{best}}^{2009}$ on f_{114} , in italics is given the median final function value and the median number of function evaluations to reach this value divided by dimension

	114 Step-ellipsoid unif										
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
	0.20	2.3	153	2944	11262	15778	16654	16654	16654	16990	
(1,2)-CMA-ES	1.3	144	101	<i>11e+0/1e4</i>	.	.	.	.	.	.	(1,2)-CMA-ES [4, 2]
(1,2m)-CMA-ES	1.5	87	25	<i>63e-1/1e4</i>	.	.	.	.	.	.	(1,2m)-CMA-ES [4]
(1,2ms)-CMA-ES	1.3	139	54	<i>79e-1/1e4</i>	.	.	.	.	.	.	(1,2ms)-CMA-ES [4]
(1,2s)-CMA-ES	38	56	56	<i>73e-1/1e4</i>	.	.	.	.	.	.	(1,2s)-CMA-ES [2]
(1,4)-CMA-ES	2.3	55	18	<i>46e-1/1e4</i>	.	.	.	.	.	.	(1,4)-CMA-ES [5, 3]
(1,4m)-CMA-ES	2.3	17	14	<i>30e-1/1e4</i>	.	.	.	.	.	.	(1,4m)-CMA-ES [5]
(1,4ms)-CMA-ES	53	26	19	50	<i>21e-1/1e4</i>	.	.	.	.	.	(1,4ms)-CMA-ES [1, 5]
(1,4s)-CMA-ES	1.4	23	21	<i>53e-1/1e4</i>	.	.	.	.	.	.	(1,4s)-CMA-ES [3]
avg NEWUOA	1.3	112	74	<i>11e+0/6e3</i>	.	.	.	.	.	.	avg NEWUOA [16]
CMA-EGS (IPOP,r1)	1787	721	152	61	<i>19e-1/1e5</i>	.	.	.	.	.	CMA-EGS (IPOP,r1) [8]
IPOP-aCMA-ES	1.3	35	3.3	0.61	0.49	0.62	0.60	0.60	0.60	0.61	IPOP-aCMA-ES [12]
IPOP-CMA-ES	1.3	41	3.2	0.45	0.48	0.80	0.79	0.79	0.79	0.80	IPOP-CMA-ES [15]
CMA+DE-MOS	1.5	2.5	60	130	34	33	48	48	48	47	CMA+DE-MOS [13]
NEWUOA	1	150	43	<i>89e-1/5e3</i>	.	.	.	.	.	.	NEWUOA [16]
Basic RCGA	1.2	1.2	12	16	31	<i>41e-2/5e4</i>	.	.	.	.	Basic RCGA [17]
SPSA	1025	531	181	245	<i>29e-1/1e5</i>	.	.	.	.	.	SPSA [9]

Table 15: 05-D, running time excess $ERT/ERT_{\text{best}}^{2009}$ on f_{115} , in italics is given the median final function value and the median number of function evaluations to reach this value divided by dimension

	115 Step-ellipsoid Cauchy										
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	2.2	3.8	5.3	5.7	66	<i>13e-2/1e4</i>	.	.	.	.	(1,2)-CMA-ES [4, 2]
(1,2m)-CMA-ES	1.7	2.5	1.9	2.4	6.6	54	137	137	137	240	(1,2m)-CMA-ES [4]
(1,2ms)-CMA-ES	2.9	3.0	2.3	1.6	7.5	44	88	88	88	247	(1,2ms)-CMA-ES [4]
(1,2s)-CMA-ES	1.3	3.1	4.7	11	50	<i>17e-2/1e4</i>	.	.	.	.	(1,2s)-CMA-ES [2]
(1,4)-CMA-ES	1.9	1.7	1.7	1.7	5.5	23	134	134	134	119	(1,4)-CMA-ES [5, 3]
(1,4m)-CMA-ES	1.6	1.4	1.2	1.3	2.6	13	26	26	26	70	(1,4m)-CMA-ES [5]
(1,4ms)-CMA-ES	1.7	1.4	2.9	1.7	4.6	26	49	49	49	55	(1,4ms)-CMA-ES [1, 5]
(1,4s)-CMA-ES	1.7	1.6	1.9	1.8	6.9	45	89	89	89	<i>11e-3/1e4</i>	(1,4s)-CMA-ES [3]
avg NEWUOA	1.1	1.6	1.1	4.2	28	<i>10e-2/6e3</i>	.	.	.	.	avg NEWUOA [16]
CMA-EGS (IPOP,r1)	63	13	8.6	422	1803	3116	2779	2779	2779	<i>31e-2/1e5</i>	CMA-EGS (IPOP,r1) [8]
IPOP-aCMA-ES	1.2	2.0	1.8	0.81	1.1	1.1	1.4	1.4	1.4	1.5	IPOP-aCMA-ES [12]
IPOP-CMA-ES	1.3	1.2	1.7	2.4	2.7	2.9	3.1	3.1	3.1	2.7	IPOP-CMA-ES [15]
CMA+DE-MOS	1.5	2.5	5.3	18	31	25	23	23	23	20	CMA+DE-MOS [13]
NEWUOA	2.1	1.2	2.9	14	42	<i>34e-2/4e3</i>	.	.	.	.	NEWUOA [16]
Basic RCGA	1.4	1.7	74	68	108	769	703	703	703	604	Basic RCGA [17]
SPSA	58	64	222	1640	3866	<i>12e-1/1e5</i>	.	.	.	.	SPSA [9]

Table 20: 05-D, running time excess $ERT/ERT_{\text{best}}^{2009}$ on f_{120} , in italics is given the median final function value and the median number of function evaluations to reach this value divided by dimension

	120 Sum of diff powers unif										
Δf_{target} ERT_{best}/D	1e+03 0.20	1e+02 0.20	1e+01 3.2	1e+00 580	1e-01 3740	1e-02 6898	1e-03 14488	1e-04 35436	1e-05 66660	1e-07 1.10e5	Δf_{target} ERT_{best}/D
(1,2)-CMA-ES	1	1.5	77	33	<i>14e-1/1e4</i>	.	.	.	.	.	(1,2)-CMA-ES [4, 2]
(1,2m)-CMA-ES	1	34	46	79	40	<i>11e-1/1e4</i>	.	.	.	.	(1,2m)-CMA-ES [4]
(1,2ms)-CMA-ES	1	1.7	34	26	<i>10e-1/1e4</i>	.	.	.	.	.	(1,2ms)-CMA-ES [4]
(1,2s)-CMA-ES	1	63	51	34	<i>14e-1/1e4</i>	.	.	.	.	.	(1,2s)-CMA-ES [2]
(1,4)-CMA-ES	1	11	36	16	<i>77e-2/1e4</i>	.	.	.	.	.	(1,4)-CMA-ES [5, 3]
(1,4m)-CMA-ES	1	2.9	13	6.6	<i>66e-2/1e4</i>	.	.	.	.	.	(1,4m)-CMA-ES [5]
(1,4ms)-CMA-ES	1	56	64	10	<i>69e-2/1e4</i>	.	.	.	.	.	(1,4ms)-CMA-ES [1, 5]
(1,4s)-CMA-ES	1	1.9	38	15	<i>83e-2/1e4</i>	.	.	.	.	.	(1,4s)-CMA-ES [3]
avg NEWUOA	1	42	94	49	<i>15e-1/6e3</i>	.	.	.	.	.	avg NEWUOA [16]
CMA-EGS (IPOP,r1)	1223	2182	675	85	33	24	49	<i>13e-3/1e5</i>	.	.	CMA-EGS (IPOP,r1) [8]
IPOP-aCMA-ES	1	2.3	18	0.76	0.65	0.82	0.83	0.53	0.43	0.66	IPOP-aCMA-ES [12]
IPOP-CMA-ES	1	1.1	6.0	1.6	0.68	0.73	0.69	0.46	0.55	0.83	IPOP-CMA-ES [15]
CMA+DE-MOS	1	1.2	2.5	63	130	71	34	22	24	15	CMA+DE-MOS [13]
NEWUOA	1	34	130	55	<i>24e-1/5e3</i>	.	.	.	.	.	NEWUOA [16]
Basic RCGA	1	1.3	0.87	17	12	23	<i>50e-3/5e4</i>	.	.	.	Basic RCGA [17]
SPSA	194	1082	276	165	<i>84e-2/1e5</i>	.	.	.	.	.	SPSA [9]

Table 21: 05-D, running time excess $ERT/ERT_{\text{best}} 2009$ on f_{121} , in italics is given the median final function value and the median number of function evaluations to reach this value divided by dimension

	121 Sum of diff powers Cauchy										
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	0.20	0.20	1.7	22	55	107	317	525	774	1239	ERT_{best}/D
(1,2)-CMA-ES	1	1.3	4.5	2.9	1.9	3.3	2.9	3.8	4.5	9.0	(1,2)-CMA-ES [4, 2]
(1,2m)-CMA-ES	1	1.6	2.4	1.2	0.94	1.2	1.1	1.7	1.9	2.8	(1,2m)-CMA-ES [4]
(1,2ms)-CMA-ES	1	1.1	2.7	1.1	0.87	0.84	0.90	1.0	1.2	1.3	(1,2ms)-CMA-ES [4]
(1,2s)-CMA-ES	1	4.4	5.3	2.9	2.2	2.8	5.7	5.5	9.4	27	(1,2s)-CMA-ES [2]
(1,4)-CMA-ES	1	2.1	1.7	1.2	0.91	1.1	0.96	1.1	1.2	1.3	(1,4)-CMA-ES [5, 3]
(1,4m)-CMA-ES	1	1.7	3.4	1.2	0.86	1.1	0.91	0.93	1.0	1.2	(1,4m)-CMA-ES [5]
(1,4ms)-CMA-ES	1	1.2	2.0	0.72	0.57	0.70	0.51	0.58	0.60	0.56	(1,4ms)-CMA-ES [1, 5]
(1,4s)-CMA-ES	1	3.1	2.6	0.98	0.75	0.86	0.62	0.70	0.77	0.80	(1,4s)-CMA-ES [3]
avg NEWUOA	1	3.3	4.3	3.3	45	788	<i>38e-3/6e3</i>	.	.	.	avg NEWUOA [16]
CMA-EGS (IPOP,r1)	46	62	16	4.3	2.9	482	4519	<i>55e-4/1e5</i>	.	.	CMA-EGS (IPOP,r1) [8]
IPOP-aCMA-ES	1	3.3	3.0	1.1	1.1	1.1	0.78	0.79	0.84	0.82	IPOP-aCMA-ES [12]
IPOP-CMA-ES	1	1.6	1.9	1.1	1.0	1.1	1.1	1.7	2.1	2.3	IPOP-CMA-ES [15]
CMA+DE-MOS	1	1.2	3.5	4.9	4.0	4.0	2.3	2.4	2.3	2.5	CMA+DE-MOS [13]
NEWUOA	1	3.9	4.8	15	76	<i>86e-3/4e3</i>	.	.	.	.	NEWUOA [16]
Basic RCGA	1	1.3	2.1	11	11	11	30	1408	<i>22e-5/5e4</i>	.	Basic RCGA [17]
SPSA	42	74	119	6850	<i>11e-1/1e5</i>	.	.	.	.	.	SPSA [9]

Table 24: 05-D, running time excess $ERT/ERT_{\text{best}}^{2009}$ on f_{124} , in italics is given the median final function value and the median number of function evaluations to reach this value divided by dimension

	124 Schaffer F7 Cauchy										
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
	0.20	0.20	1.9	40	208	1795	4096	5279	9067	19040	
(1,2)-CMA-ES	1	1.1	11	127	700	<i>52e-2/1e4</i>	.	.	.	.	(1,2)-CMA-ES [4, 2]
(1,2m)-CMA-ES	1	1.1	3.4	2.7	30	83	<i>65e-3/1e4</i>	.	.	.	(1,2m)-CMA-ES [4]
(1,2ms)-CMA-ES	1	1.3	4.3	5.5	22	<i>60e-3/1e4</i>	.	.	.	.	(1,2ms)-CMA-ES [4]
(1,2s)-CMA-ES	1	1.8	96	277	<i>88e-2/1e4</i>	.	.	.	.	.	(1,2s)-CMA-ES [2]
(1,4)-CMA-ES	1	3.1	2.8	21	119	<i>13e-2/1e4</i>	.	.	.	.	(1,4)-CMA-ES [5, 3]
(1,4m)-CMA-ES	1	1.1	2.4	2.5	15	39	<i>41e-3/1e4</i>	.	.	.	(1,4m)-CMA-ES [5]
(1,4ms)-CMA-ES	1	1.3	1.8	7.6	18	79	<i>46e-3/1e4</i>	.	.	.	(1,4ms)-CMA-ES [1, 5]
(1,4s)-CMA-ES	1	1.7	17	19	72	<i>10e-2/1e4</i>	.	.	.	.	(1,4s)-CMA-ES [3]
avg NEWUOA	1	2.1	6.1	89	<i>63e-2/6e3</i>	.	.	.	.	.	avg NEWUOA [16]
CMA-EGS (IPOP,r1)	54	76	19	5.7	80	<i>44e-3/6e4</i>	.	.	.	.	CMA-EGS (IPOP,r1) [8]
IPOP-aCMA-ES	1	1.3	2.6	1.2	2.1	0.85	0.93	0.93	0.94	0.59	IPOP-aCMA-ES [12]
IPOP-CMA-ES	1	1.8	2.8	1.3	4.0	1.0	1.2	1.1	0.93	0.65	IPOP-CMA-ES [15]
CMA+DE-MOS	1	1.1	1.7	5.9	15	3.5	2.4	2.2	3.3	1.9	CMA+DE-MOS [13]
NEWUOA	1	1.1	3.0	158	<i>11e-1/4e3</i>	.	.	.	.	.	NEWUOA [16]
Basic RCGA	1	1.1	2.4	63	41	10	11	66	<i>55e-5/5e4</i>	.	Basic RCGA [17]
SPSA	59	96	516	16583	<i>39e-1/1e5</i>	.	.	.	.	.	SPSA [9]

Table 25: 05-D, running time excess $ERT/ERT_{\text{best } 2009}$ on f_{125} , in italics is given the median final function value and the median number of function evaluations to reach this value divided by dimension

125 Griewank-Rosenbrock Gauss											
$\Delta\text{ftarget}$ ERT_{best}/D	1e+03 0.20	1e+02 0.20	1e+01 0.20	1e+00 0.20	1e-01 0.20	1e-02 25031	1e-03 47750	1e-04 48260	1e-05 48600	1e-07 49199	$\Delta\text{ftarget}$ ERT_{best}/D
(1,2)-CMA-ES	1	1	1	120	59424	<i>92e-3/1e4</i>	.	.	.	.	(1,2)-CMA-ES [4, 2]
(1,2m)-CMA-ES	1	1	1.3	69	14809	<i>69e-3/1e4</i>	.	.	.	.	(1,2m)-CMA-ES [4]
(1,2ms)-CMA-ES	1	1	1	36	32993	<i>81e-3/1e4</i>	.	.	.	.	(1,2ms)-CMA-ES [4]
(1,2s)-CMA-ES	1	1	1	247	1.04e5	<i>11e-2/1e4</i>	.	.	.	.	(1,2s)-CMA-ES [2]
(1,4)-CMA-ES	1	1	1	21	12610	<i>58e-3/1e4</i>	.	.	.	.	(1,4)-CMA-ES [5, 3]
(1,4m)-CMA-ES	1	1	1	24	12571	<i>58e-3/1e4</i>	.	.	.	.	(1,4m)-CMA-ES [5]
(1,4ms)-CMA-ES	1	1	1	20	12034	<i>54e-3/1e4</i>	.	.	.	.	(1,4ms)-CMA-ES [1, 5]
(1,4s)-CMA-ES	1	1	1	48	23166	<i>82e-3/1e4</i>	.	.	.	.	(1,4s)-CMA-ES [3]
avg NEWUOA	1	1	2.0	81	9966	<i>36e-3/6e3</i>	.	.	.	.	avg NEWUOA [16]
CMA-EGS (IPOP,r1)	49	65	70	153	3423	5.7	<i>10e-3/1e5</i>	.	.	.	CMA-EGS (IPOP,r1) [8]
IPOP-aCMA-ES	1	1	1	26	3142	0.75	0.53	0.56	0.57	0.57	IPOP-aCMA-ES [12]
IPOP-CMA-ES	1	1	1	27	2599	0.79	0.78	1.3	1.3	1.3	IPOP-CMA-ES [15]
CMA+DE-MOS	1	1	1.2	34	810	5.0	16	16	16	16	CMA+DE-MOS [13]
NEWUOA	1	1	3.9	15	6088	2.8	<i>40e-3/5e3</i>	.	.	.	NEWUOA [16]
Basic RCGA	1	1	1.1	26	1574	1.3	<i>82e-4/5e4</i>	.	.	.	Basic RCGA [17]
SPSA	41	60	35786	35837	52690	56	<i>51e-3/1e5</i>	.	.	.	SPSA [9]

Table 26: 05-D, running time excess $ERT/ERT_{\text{best}}^{2009}$ on f_{126} , in italics is given the median final function value and the median number of function evaluations to reach this value divided by dimension

	126 Griewank-Rosenbrock unif											
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	
	0.20	0.20	0.20	0.20	0.20	<i>1.75e5</i>	∞	∞	∞	∞		
(1,2)-CMA-ES	1	1	1.1	2015	7.40e5	<i>25e-2/1e4</i>	.	.	.	.	(1,2)-CMA-ES [4, 2]
(1,2m)-CMA-ES	1	1	1	618	<i>22e-2/1e4</i>	.	.	.	.	.	(1,2m)-CMA-ES [4]
(1,2ms)-CMA-ES	1	1	1	719	<i>20e-2/1e4</i>	.	.	.	.	.	(1,2ms)-CMA-ES [4]
(1,2s)-CMA-ES	1	1	32	585	7.17e5	<i>26e-2/1e4</i>	.	.	.	.	(1,2s)-CMA-ES [2]
(1,4)-CMA-ES	1	1	1	532	<i>15e-2/1e4</i>	.	.	.	.	.	(1,4)-CMA-ES [5, 3]
(1,4m)-CMA-ES	1	1	1	356	2.33e5	<i>12e-2/1e4</i>	.	.	.	.	(1,4m)-CMA-ES [5]
(1,4ms)-CMA-ES	1	1	1	82	1.14e5	<i>12e-2/1e4</i>	.	.	.	.	(1,4ms)-CMA-ES [1, 5]
(1,4s)-CMA-ES	1	1	1.2	282	3.57e5	<i>18e-2/1e4</i>	.	.	.	.	(1,4s)-CMA-ES [3]
avg NEWUOA	1	1	22	1636	4.54e5	<i>26e-2/6e3</i>	.	.	.	.	avg NEWUOA [16]
CMA-EGS (IPOP,r1)	1548	1777	5228	7914	99874	8.3	<i>23e-3/1e5</i>	.	.	.	CMA-EGS (IPOP,r1) [8]	
IPOP-aCMA-ES	1	1	1	62	7882	1.4	<i>51e-4/4e5</i>	.	.	.	IPOP-aCMA-ES [12]	
IPOP-CMA-ES	1	1	1	63	10254	1.2	1.21e7	1.87e7	1.88e7	1.89e7	IPOP-CMA-ES [15]	
CMA+DE-MOS	1	1	1.2	34	568	<i>23e-3/1e5</i>	.	.	.	.	CMA+DE-MOS [13]
NEWUOA	1	1	1.2	1053	3.47e5	<i>26e-2/5e3</i>	.	.	.	.	NEWUOA [16]
Basic RCGA	1	1	1.1	33	1409	0.59	<i>11e-3/5e4</i>	.	.	.	Basic RCGA [17]	
SPSA	1.00e6	2.00e6	3.25e6	3.25e6	7.17e6	<i>16e+2/1e5</i>	.	.	.	.	SPSA [9]

Table 27: 05-D, running time excess $ERT/ERT_{\text{best}} 2009$ on f_{127} , in italics is given the median final function value and the median number of function evaluations to reach this value divided by dimension

127 Griewank-Rosenbrock Cauchy											
$\Delta\text{ftarget}$ ERT_{best}/D	1e+03 0.20	1e+02 0.20	1e+01 0.20	1e+00 0.20	1e-01 0.20	1e-02 25716	1e-03 68336	1e-04 77023	1e-05 77898	1e-07 79070	$\Delta\text{ftarget}$ ERT_{best}/D
(1,2)-CMA-ES	1	1	1	85	13853	5.8	<i>55e-3/1e4</i>	.	.	.	(1,2)-CMA-ES [4, 2]
(1,2m)-CMA-ES	1	1	1	31	5212	2.7	<i>44e-3/1e4</i>	.	.	.	(1,2m)-CMA-ES [4]
(1,2ms)-CMA-ES	1	1	1	27	4508	5.8	<i>29e-3/1e4</i>	.	.	.	(1,2ms)-CMA-ES [4]
(1,2s)-CMA-ES	1	1	1.3	60	37537	<i>64e-3/1e4</i>	.	.	.	.	(1,2s)-CMA-ES [2]
(1,4)-CMA-ES	1	1	1	18	7947	<i>32e-3/1e4</i>	.	.	.	.	(1,4)-CMA-ES [5, 3]
(1,4m)-CMA-ES	1	1	1	17	3986	5.6	<i>24e-3/1e4</i>	.	.	.	(1,4m)-CMA-ES [5]
(1,4ms)-CMA-ES	1	1	1	24	7806	<i>42e-3/1e4</i>	.	.	.	.	(1,4ms)-CMA-ES [1, 5]
(1,4s)-CMA-ES	1	1	1	17	9717	5.7	<i>29e-3/1e4</i>	.	.	.	(1,4s)-CMA-ES [3]
avg NEWUOA	1	1	2.0	18	5233	<i>53e-3/6e3</i>	.	.	.	.	avg NEWUOA [16]
CMA-EGS (IPOP,r1)	44	62	77	181	1992	3.6	<i>92e-4/1e5</i>	.	.	.	CMA-EGS (IPOP,r1) [8]
IPOP-aCMA-ES	1	1	1.1	30	3085	0.65	0.50	0.45	0.46	0.46	IPOP-aCMA-ES [12]
IPOP-CMA-ES	1	1	1	15	1542	0.69	0.58	0.63	0.64	0.65	IPOP-CMA-ES [15]
CMA+DE-MOS	1	1	1.2	35	656	0.96	4.6	20	20	19	CMA+DE-MOS [13]
NEWUOA	1	1	2.5	14	7248	<i>62e-3/4e3</i>	.	.	.	.	NEWUOA [16]
Basic RCGA	1	1	1.1	41	991	1.8	<i>95e-4/5e4</i>	.	.	.	Basic RCGA [17]
SPSA	45	56	122	21588	3.40e6	<i>15e-2/1e5</i>	.	.	.	.	SPSA [9]

Table 30: 05-D, running time excess $ERT/ERT_{\text{best}}^{2009}$ on f_{130} , in italics is given the median final function value and the median number of function evaluations to reach this value divided by dimension

130 Gallagher Cauchy											
Δf_{target} ERT_{best}/D	1e+03 0.20	1e+02 0.20	1e+01 11	1e+00 162	1e-01 607	1e-02 1640	1e-03 6565	1e-04 6746	1e-05 6778	1e-07 6906	Δf_{target} ERT_{best}/D
(1,2)-CMA-ES	1	1	14	48	23	10	2.9	2.8	2.8	3.6	(1,2)-CMA-ES [4, 2]
(1,2m)-CMA-ES	1	1	7.2	17	8.7	3.3	0.82	0.80	0.80	0.79	(1,2m)-CMA-ES [4]
(1,2ms)-CMA-ES	1	1	5.3	14	5.1	1.9	0.47	0.46	0.46	0.46	(1,2ms)-CMA-ES [4]
(1,2s)-CMA-ES	1	1	37	58	41	15	3.8	3.7	3.8	3.8	(1,2s)-CMA-ES [2]
(1,4)-CMA-ES	1	1	5.4	25	12	4.5	1.1	1.1	1.2	1.2	(1,4)-CMA-ES [5, 3]
(1,4m)-CMA-ES	1	1	1.0	15	10	3.8	0.95	0.93	0.93	0.92	(1,4m)-CMA-ES [5]
(1,4ms)-CMA-ES	1	1	6.8	4.2	3.5	1.3	0.33	0.32	0.32	0.32	(1,4ms)-CMA-ES [1, 5]
(1,4s)-CMA-ES	1	1	3.3	14	15	5.5	1.4	1.3	1.3	1.3	(1,4s)-CMA-ES [3]
avg NEWUOA	1	1	1.3	6.4	5.9	6.0	3.0	13	<i>14e-3/6e3</i>	.	avg NEWUOA [16]
CMA-EGS (IPOP,r1)	35	57	5.2	203	146	124	104	102	<i>31e-3/1e5</i>	.	CMA-EGS (IPOP,r1) [8]
IPOP-aCMA-ES	1	1	1.4	143	391	145	36	35	35	35	IPOP-aCMA-ES [12]
IPOP-CMA-ES	1	1	1.2	59	321	147	37	36	36	35	IPOP-CMA-ES [15]
CMA+DE-MOS	1	1	2.4	295	221	121	30	29	29	29	CMA+DE-MOS [13]
NEWUOA	1	1	2.3	11	10	19	<i>62e-3/4e3</i>	.	.	.	NEWUOA [16]
Basic RCGA	1	1	2.5	250	74	29	7.5	9.2	9.3	10	Basic RCGA [17]
SPSA	40	62	142	1955	<i>19e-1/1e5</i>	.	.	.	.	.	SPSA [9]

References

- [1] Anne Auger, Dimo Brockhoff, and Nikolaus Hansen. Benchmarking the (1, 4)-CMA-ES with mirrored sampling and sequential selection on the noisy BBOB-2010 testbed. In Pelikan and Branke [14], pages 1625–1632.
- [2] Anne Auger, Dimo Brockhoff, and Nikolaus Hansen. Investigating the impact of sequential selection in the (1, 2)-CMA-ES on the noisy BBOB-2010 testbed. In Pelikan and Branke [14], pages 1605–1610.
- [3] Anne Auger, Dimo Brockhoff, and Nikolaus Hansen. Investigating the impact of sequential selection in the (1, 4)-CMA-ES on the noisy BBOB-2010 testbed. In Pelikan and Branke [14], pages 1611–1616.
- [4] Anne Auger, Dimo Brockhoff, and Nikolaus Hansen. Mirrored variants of the (1, 2)-CMA-ES compared on the noisy BBOB-2010 testbed. In Pelikan and Branke [14], pages 1575–1582.
- [5] Anne Auger, Dimo Brockhoff, and Nikolaus Hansen. Mirrored variants of the (1, 4)-CMA-ES compared on the noisy BBOB-2010 testbed. In Pelikan and Branke [14], pages 1583–1590.
- [6] Anne Auger, Steffen Finck, Nikolaus Hansen, and Raymond Ros. BBOB 2009: Comparison tables of all algorithms on all noisy functions. Technical Report RT-0384, INRIA, 04 2010.
- [7] S. Finck, N. Hansen, R. Ros, and A. Auger. Real-parameter black-box optimization benchmarking 2010: Presentation of the noisy functions. Technical Report 2009/21, Research Center PPE, 2010.
- [8] Steffen Finck and Hans-Georg Beyer. Benchmarking CMA-EGS on the BBOB 2010 noisy function testbed. In Pelikan and Branke [14], pages 1641–1648.
- [9] Steffen Finck and Hans-Georg Beyer. Benchmarking SPSA on BBOB-2010 noisy function testbed. In Pelikan and Branke [14], pages 1665–1672.
- [10] N. Hansen, A. Auger, S. Finck, and R. Ros. Real-parameter black-box optimization benchmarking 2010: Experimental setup. Technical Report RR-7215, INRIA, 2010.
- [11] N. Hansen, S. Finck, R. Ros, and A. Auger. Real-parameter black-box optimization benchmarking 2009: Noisy functions definitions. Technical Report RR-6869, INRIA, 2009. Updated February 2010.
- [12] Nikolaus Hansen and Raymond Ros. Benchmarking a weighted negative covariance matrix update on the BBOB-2010 noisy testbed. In Pelikan and Branke [14], pages 1681–1688.
- [13] Antonio LaTorre, Santiago Muelas, and José María Peña. Benchmarking a MOS-based algorithm on the BBOB-2010 noisy function testbed. In Pelikan and Branke [14], pages 1725–1730.

- [14] 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.
- [15] Raymond Ros. Black-box optimization benchmarking the IPOP-CMA-ES on the noisy testbed: comparison to the BIPOP-CMA-ES. In Pelikan and Branke [14], pages 1511–1518.
- [16] Raymond Ros. Comparison of NEWUOA with different numbers of interpolation points on the BBOB noisy testbed. In Pelikan and Branke [14], pages 1495–1502.
- [17] Thanh-Do Tran and Gang-Gyoo Jin. Benchmarking real-coded genetic algorithm on noisy black-box optimization testbed. In Pelikan and Branke [14], pages 1739–1744.