# Comparison tables: BBOB 2010 function testbed with BBOB 2009 as reference in 2-D

The BBOBies

August 31, 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 [16, 12]. The experimental set-up is described in [15].

The performance measure provided in the following tables is the expected number of objective function evaluations to reach a given target function value (ERT, expected running time), divided by the respective value for the best algorithm in BBOB-2009 (see [7]) if an algorithm from BBOB-2009 reached the given target function value. The ERT value is given otherwise ($\mathrm{ERT}_{\mathrm{best}}$ is noted as infinite). See [15] for details on how ERT is obtained. Bold entries in the table correspond to values below 3 or the top-three best values.

Table 1: 02-D, running time excess ERT/ERT$_{\text{best 2009}}$ on $f_1$, in italics is given the median final function value and the median number of function evaluations to reach this value divided by dimension

**1 Sphere**

| Δftarget | 1e+03 | 1e+02 | 1e+01 | 1e+00 | 1e-01 | 1e-02 | 1e-03 | 1e-04 | 1e-05 | 1e-07 | Δftarget |
|---|---|---|---|---|---|---|---|---|---|---|---|
| ERT$_{\text{best}}$/D | 0.50 | 0.50 | 0.90 | 2.8 | 2.8 | 3.1 | 3.1 | 3.1 | 3.1 | 3.1 | ERT$_{\text{best}}$/D |
| (1,2)-CMA-ES | **1** | **1** | 4.9 | 7.8 | 14 | 19 | 24 | 32 | 38 | 53 | (1,2)-CMA-ES [5, 3] |
| (1,2m)-CMA-ES | **1** | **1** | **2.1** | **2.3** | 8.4 | 15 | 19 | 28 | 34 | 48 | (1,2m)-CMA-ES [5] |
| (1,2ms)-CMA-ES | **1** | **1** | **2.8** | **2.9** | 6.5 | 11 | 17 | 24 | 29 | 39 | (1,2ms)-CMA-ES [5] |
| (1,2s)-CMA-ES | **1** | **1** | 5.2 | 3.4 | 8.2 | 11 | 20 | 28 | 36 | 49 | (1,2s)-CMA-ES [3] |
| (1,4)-CMA-ES | **1** | **1** | 3.8 | 3.4 | 6.4 | 9.4 | 14 | 20 | 24 | 32 | (1,4)-CMA-ES [6, 4] |
| (1,4m)-CMA-ES | **1** | **1** | **2.1** | **2.3** | 6.6 | 10 | 16 | 19 | 22 | 30 | (1,4m)-CMA-ES [6] |
| (1,4ms)-CMA-ES | **1** | **1.1** | 3.3 | **2.4** | **4.8** | **8.5** | **11** | **14** | **17** | **24** | (1,4ms)-CMA-ES [1, 6] |
| (1,4s)-CMA-ES | **1** | **1** | 5.1 | 3.5 | 6.4 | **9.0** | 13 | 16 | **19** | **25** | (1,4s)-CMA-ES [4] |
| (1+1)-CMA-ES | **1** | **1** | **2.9** | 3.4 | 7.1 | 11 | 13 | 18 | 20 | 27 | (1+1)-CMA-ES [8] |
| (1+2ms)-CMA-ES | **1** | **1** | 3.0 | **2.4** | **6.0** | 9.3 | **13** | **16** | 20 | 25 | (1+2ms)-CMA-ES [2] |
| Artif Bee Colony | **1** | **1** | **2.3** | 7.4 | 22 | 38 | 60 | 82 | 105 | 151 | Artif Bee Colony [9] |
| avg NEWUOA | **1** | **1** | **1.9** | **1.1** | **1.1** | **0.97** | **0.97** | **0.97** | **0.97** | **0.97** | avg NEWUOA [24] |
| CMA-EGS (IPOP,r1) | **1** | 7.7 | 14 | 7.3 | 15 | 22 | 47 | 66 | 94 | 125 | CMA-EGS (IPOP,r1) [13] |
| Adap DE (F-AUC) | **1** | **1** | 3.6 | 6.1 | 19 | 29 | 39 | 58 | 69 | 101 | Adap DE (F-AUC) [11] |
| DE (Uniform) | **1** | **1** | **2.5** | 4.5 | 18 | 31 | 44 | 57 | 71 | 100 | DE (Uniform) [10] |
| IPOP-aCMA-ES | **1** | **1** | 3.6 | 3.3 | 8.3 | 11 | 17 | 22 | 26 | 36 | IPOP-aCMA-ES [17] |
| IPOP-CMA-ES | **1** | **1** | 5.1 | 4.5 | 10 | 15 | 19 | 23 | 27 | 36 | IPOP-CMA-ES [23] |
| CMA+DE-MOS | **1** | **1** | **2.3** | 3.6 | 22 | 44 | 74 | 92 | 122 | 171 | CMA+DE-MOS [19] |
| NBC-CMA | **1** | **1** | **2.5** | 4.1 | 29 | 53 | 69 | 85 | 94 | 116 | NBC-CMA [22] |
| POEMS | **1** | **1** | 172 | 84 | 116 | 324 | 694 | 986 | 1394 | 1965 | POEMS [18] |
| PM-AdapSS-DE | **1** | **1.1** | **2.3** | 3.3 | 16 | 25 | 38 | 55 | 67 | 91 | PM-AdapSS-DE [10, 11] |
| pPOEMS | **1** | **1** | 54 | 82 | 153 | 342 | 2401 | 4014 | 6242 | 12106 | pPOEMS [18, 21] |
| Basic RCGA | **1** | **1** | **2.2** | 9.2 | 46 | 77 | 188 | 346 | 466 | 734 | Basic RCGA [25] |
| SPSA | **1** | 27 | 42 | 20 | 26 | 28 | 33 | 38 | 46 | 61 | SPSA [14] |

Table 2: 02-D, running time excess ERT/ERT$_{\text{best 2009}}$ on $f_2$, in italics is given the median final function value and the median number of function evaluations to reach this value divided by dimension

**2 Ellipsoid separable**

| Δftarget | 1e+03 | 1e+02 | 1e+01 | 1e+00 | 1e-01 | 1e-02 | 1e-03 | 1e-04 | 1e-05 | 1e-07 | Δftarget |
|---|---|---|---|---|---|---|---|---|---|---|---|
| ERT$_{\text{best}}$/D | 4.9 | 6.2 | 8.2 | 9.5 | 12 | 13 | 13 | 14 | 14 | 14 | ERT$_{\text{best}}$/D |
| (1,2)-CMA-ES | 10 | 42 | 67 | 80 | 65 | 66 | 66 | 65 | 64 | 67 | (1,2)-CMA-ES [5, 3] |
| (1,2m)-CMA-ES | 15 | 30 | 85 | 99 | 85 | 86 | 86 | 83 | 82 | 85 | (1,2m)-CMA-ES [5] |
| (1,2ms)-CMA-ES | 4.8 | 26 | 55 | 70 | 61 | 62 | 63 | 61 | 61 | 63 | (1,2ms)-CMA-ES [5] |
| (1,2s)-CMA-ES | 4.9 | 46 | 201 | 214 | 168 | 166 | 166 | 160 | 157 | 156 | (1,2s)-CMA-ES [3] |
| (1,4)-CMA-ES | **3.0** | **4.8** | 17 | 26 | 24 | 26 | 27 | 26 | 27 | 28 | (1,4)-CMA-ES [6, 4] |
| (1,4m)-CMA-ES | 4.3 | 6.2 | 23 | 29 | 25 | 25 | 26 | 26 | 26 | 28 | (1,4m)-CMA-ES [6] |
| (1,4ms)-CMA-ES | **3.5** | 6.0 | 18 | 19 | 18 | 19 | 19 | 19 | 19 | 20 | (1,4ms)-CMA-ES [1, 6] |
| (1,4s)-CMA-ES | 3.6 | 9.3 | 19 | 26 | 22 | 23 | 23 | 23 | 23 | 24 | (1,4s)-CMA-ES [4] |
| (1+1)-CMA-ES | 4.2 | 8.1 | **11** | 16 | **14** | **15** | **15** | **15** | **16** | **17** | (1+1)-CMA-ES [8] |
| (1+2ms)-CMA-ES | 3.5 | **4.8** | **5.8** | **11** | **11** | **12** | **12** | **13** | **13** | **14** | (1+2ms)-CMA-ES [2] |
| Artif Bee Colony | 14 | 20 | 22 | 32 | 38 | 46 | 52 | 56 | 62 | 77 | Artif Bee Colony [9] |
| avg NEWUOA | **1.2** | **1.1** | **1.9** | **5.6** | **8.5** | **10** | **14** | 17 | 20 | 27 | avg NEWUOA [24] |
| CMA-EGS (IPOP,r1) | 11 | 269 | 1331 | 1953 | 4172 | 4065 | 3995 | 3783 | 3689 | 3624 | CMA-EGS (IPOP,r1) [13] |
| Adap DE (F-AUC) | 8.2 | 10 | 14 | 16 | 16 | 19 | 22 | 23 | 26 | 31 | Adap DE (F-AUC) [11] |
| DE (Uniform) | 8.0 | 10 | 12 | 16 | 16 | 19 | 22 | 23 | 27 | 32 | DE (Uniform) [10] |
| IPOP-aCMA-ES | 4.6 | 5.1 | 14 | 18 | 15 | 16 | 17 | **17** | **18** | **19** | IPOP-aCMA-ES [17] |
| IPOP-CMA-ES | 4.2 | 7.5 | 16 | 21 | 18 | 19 | 20 | 20 | 21 | 22 | IPOP-CMA-ES [23] |
| CMA+DE-MOS | 13 | 20 | 24 | 30 | 34 | 40 | 45 | 54 | 59 | 69 | CMA+DE-MOS [19] |
| NBC-CMA | 15 | 21 | 38 | 102 | 118 | 157 | 203 | 253 | 295 | 305 | NBC-CMA [22] |
| POEMS | 179 | 330 | 377 | 408 | 392 | 450 | 546 | 568 | 642 | 807 | POEMS [18] |
| PM-AdapSS-DE | 7.5 | 11 | 12 | **15** | 15 | 19 | 22 | 24 | 25 | 30 | PM-AdapSS-DE [10, 11] |
| pPOEMS | 156 | 708 | 1840 | 2152 | 2416 | 2672 | 3142 | 3515 | 4175 | 5218 | pPOEMS [18, 21] |
| Basic RCGA | 10 | 18 | 37 | 56 | 64 | 125 | 155 | 266 | 350 | 543 | Basic RCGA [25] |
| SPSA | 12 | 149 | 1599 | 8950 | 13921 | 17255 | *33e-2/1e5* | . | . | . | SPSA [14] |

Table 3: 02-D, running time excess ERT/ERT$_{\text{best 2009}}$ on $f_3$, in italics is given the median final function value and the median number of function evaluations to reach this value divided by dimension

**3 Rastrigin separable**

| Δftarget | 1e+03 | 1e+02 | 1e+01 | 1e+00 | 1e-01 | 1e-02 | 1e-03 | 1e-04 | 1e-05 | 1e-07 | Δftarget |
|---|---|---|---|---|---|---|---|---|---|---|---|
| ERT$_{\text{best}}$/D | 0.50 | 0.70 | 7.3 | 135 | 222 | 223 | 225 | 226 | 227 | 232 | ERT$_{\text{best}}$/D |
| (1,2)-CMA-ES | **1.1** | 3.2 | 14 | 15 | 47 | 47 | 47 | 47 | 47 | 46 | (1,2)-CMA-ES [5, 3] |
| (1,2m)-CMA-ES | **1** | **2.1** | **3.3** | 8.4 | 28 | 35 | 43 | 43 | 43 | 42 | (1,2m)-CMA-ES [5] |
| (1,2ms)-CMA-ES | **1.3** | 3.0 | **3.4** | 6.2 | 18 | 25 | 25 | 25 | 25 | 25 | (1,2ms)-CMA-ES [5] |
| (1,2s)-CMA-ES | **1** | 4.7 | 18 | 15 | 44 | 44 | 43 | 51 | 51 | 50 | (1,2s)-CMA-ES [3] |
| (1,4)-CMA-ES | **1.6** | **2.5** | 10 | 8.8 | 14 | 14 | 14 | 14 | 14 | 14 | (1,4)-CMA-ES [6, 4] |
| (1,4m)-CMA-ES | **1** | **1.1** | 3.5 | 3.8 | 5.4 | 6.1 | 6.1 | 6.1 | 6.2 | 6.2 | (1,4m)-CMA-ES [6] |
| (1,4ms)-CMA-ES | **1.3** | **2.0** | **2.1** | 3.0 | 8.5 | 11 | 11 | 11 | 11 | 11 | (1,4ms)-CMA-ES [1, 6] |
| (1,4s)-CMA-ES | **2.1** | 4.5 | 5.3 | 7.1 | 20 | 24 | 24 | 24 | 24 | 24 | (1,4s)-CMA-ES [4] |
| (1+1)-CMA-ES | **1** | **1.6** | 5.6 | 12 | 26 | 26 | 26 | 26 | 26 | 26 | (1+1)-CMA-ES [8] |
| (1+2ms)-CMA-ES | **1** | **1.5** | 9.2 | 6.6 | 8.6 | 8.6 | 8.6 | 8.6 | 8.6 | 8.5 | (1+2ms)-CMA-ES [2] |
| Artif Bee Colony | **1.1** | **1.7** | 5.6 | **1.7** | **1.6** | **2.4** | **2.9** | 3.5 | 4.1 | 5.0 | Artif Bee Colony [9] |
| avg NEWUOA | **1** | **2.7** | 5.1 | **1.6** | 3.2 | 3.2 | 3.2 | **3.2** | **3.2** | **3.1** | avg NEWUOA [24] |
| CMA-EGS (IPOP,r1) | 5.1 | 10 | 96 | 273 | 443 | 726 | 1244 | 2884 | 2875 | 2815 | CMA-EGS (IPOP,r1) [13] |
| Adap DE (F-AUC) | **1.3** | **1.6** | 5.3 | **2.0** | **1.6** | **2.0** | **2.4** | **2.6** | **2.8** | **3.1** | Adap DE (F-AUC) [11] |
| DE (Uniform) | **1.2** | **1.6** | 5.2 | **2.0** | **1.7** | **2.3** | **2.5** | **2.7** | **2.9** | **3.1** | DE (Uniform) [10] |
| IPOP-aCMA-ES | **1.1** | **2.5** | 4.2 | 3.5 | 7.1 | 7.4 | 7.6 | 7.7 | 7.8 | 8.0 | IPOP-aCMA-ES [17] |
| IPOP-CMA-ES | **1.2** | 4.2 | 4.2 | 3.3 | 7.7 | 8.0 | 8.7 | 8.9 | 9.0 | 9.1 | IPOP-CMA-ES [23] |
| CMA+DE-MOS | **1.1** | **2.2** | 6.7 | **2.4** | **2.2** | **2.9** | 3.4 | 3.8 | 4.3 | 5.1 | CMA+DE-MOS [19] |
| NBC-CMA | **1.3** | **1.7** | 6.3 | 4.9 | 6.5 | 9.4 | 10 | 10 | 10 | 10 | NBC-CMA [22] |
| POEMS | **1** | 220 | 42 | 10 | 12 | 18 | 23 | 29 | 32 | 41 | POEMS [18] |
| PM-AdapSS-DE | **1.3** | **1.6** | 5.0 | **1.8** | 34 | 34 | 34 | 34 | 34 | 34 | PM-AdapSS-DE [10, 11] |
| pPOEMS | **1** | **2.1** | 45 | 22 | 42 | 103 | 125 | 157 | 201 | 267 | pPOEMS [18, 21] |
| Basic RCGA | **1.1** | **1.6** | 5.9 | 18 | 18 | 38 | 67 | 79 | 81 | 83 | Basic RCGA [25] |
| SPSA | 22 | 10266 | 998 | 943 | 1281 | *14e-1/1e5* | . | . | . | . | SPSA [14] |

Table 4: 02-D, running time excess ERT/ERT$_{\text{best 2009}}$ on $f_4$, in italics is given the median final function value and the median number of function evaluations to reach this value divided by dimension

**4 Skew Rastrigin-Bueche separ**

| $\Delta$ftarget | 1e+03 | 1e+02 | 1e+01 | 1e+00 | 1e-01 | 1e-02 | 1e-03 | 1e-04 | 1e-05 | 1e-07 | $\Delta$ftarget |
|---|---|---|---|---|---|---|---|---|---|---|---|
| ERT$_{\text{best}}$/D | 0.50 | 0.50 | 11 | 172 | 230 | 248 | 261 | 270 | 272 | 283 | ERT$_{\text{best}}$/D |
| (1,2)-CMA-ES | **1** | 5.0 | 8.4 | 13 | 58 | 73 | 70 | 68 | 67 | 65 | (1,2)-CMA-ES [5, 3] |
| (1,2m)-CMA-ES | **1.1** | 3.1 | 7.9 | 10 | 26 | 30 | 29 | 28 | 28 | 27 | (1,2m)-CMA-ES [5] |
| (1,2ms)-CMA-ES | **1** | 3.2 | **2.2** | 13 | 48 | 46 | 43 | 42 | 42 | 40 | (1,2ms)-CMA-ES [5] |
| (1,2s)-CMA-ES | **1** | 8.9 | 6.9 | 30 | 72 | 68 | 65 | 63 | 63 | 61 | (1,2s)-CMA-ES [3] |
| (1,4)-CMA-ES | **1** | 3.0 | **1.3** | 7.9 | 27 | 25 | 24 | 23 | 23 | 22 | (1,4)-CMA-ES [6, 4] |
| (1,4m)-CMA-ES | **1** | **2.7** | **2.0** | 8.5 | 24 | 27 | 26 | 25 | 25 | 24 | (1,4m)-CMA-ES [6] |
| (1,4ms)-CMA-ES | **1** | 5.5 | 6.0 | 5.0 | 14 | 17 | 16 | 16 | 16 | 15 | (1,4ms)-CMA-ES [1, 6] |
| (1,4s)-CMA-ES | **1** | 3.3 | 3.4 | 3.9 | 18 | 17 | 16 | 16 | 16 | 15 | (1,4s)-CMA-ES [4] |
| (1+1)-CMA-ES | **1** | **2.0** | 3.6 | 13 | 48 | 44 | 42 | 41 | 41 | 39 | (1+1)-CMA-ES [8] |
| (1+2ms)-CMA-ES | **1** | **1.5** | **1.7** | 4.8 | **13** | **12** | **12** | **11** | **11** | **11** | (1+2ms)-CMA-ES [2] |
| Artif Bee Colony | **1.0** | **2.7** | 3.7 | **1.9** | **2.6** | **3.0** | **3.4** | **3.9** | **4.6** | **5.6** | Artif Bee Colony [9] |
| avg NEWUOA | **1** | 4.5 | 6.2 | 4.0 | 14 | 13 | 12 | 12 | 12 | 11 | avg NEWUOA [24] |
| CMA-EGS (IPOP,r1) | 11 | 23 | 19 | 178 | 1790 | 5680 | 5391 | 5242 | 5200 | 4998 | CMA-EGS (IPOP,r1) [13] |
| Adap DE (F-AUC) | **1** | **2.8** | 4.0 | **2.0** | 111 | 103 | 98 | 95 | 95 | 91 | Adap DE (F-AUC) [11] |
| DE (Uniform) | **1** | **2.5** | 4.5 | **1.9** | 111 | 104 | 142 | 137 | 136 | 131 | DE (Uniform) [10] |
| IPOP-aCMA-ES | **1** | 4.1 | 3.1 | 5.7 | 39 | 62 | 80 | 84 | 85 | 85 | IPOP-aCMA-ES [17] |
| IPOP-CMA-ES | **1.1** | 7.5 | 4.7 | 12 | 61 | 97 | 114 | 169 | 171 | 171 | IPOP-CMA-ES [23] |
| CMA+DE-MOS | **1.1** | 3.3 | 4.3 | 3.1 | **5.2** | **5.8** | **6.1** | **6.3** | **6.8** | **7.6** | CMA+DE-MOS [19] |
| NBC-CMA | **1** | **2.7** | 6.6 | 5.8 | 14 | 16 | 16 | 20 | 26 | 25 | NBC-CMA [22] |
| POEMS | **1** | 302 | 34 | 14 | 29 | 31 | 35 | 37 | 40 | 47 | POEMS [18] |
| PM-AdapSS-DE | **1** | 3.8 | 3.7 | 147 | 292 | 271 | 257 | 249 | 248 | 238 | PM-AdapSS-DE [10, 11] |
| pPOEMS | **1** | **2.6** | 34 | 31 | 45 | 103 | 131 | 150 | 180 | 216 | pPOEMS [18, 21] |
| Basic RCGA | **1.1** | 3.6 | 9.0 | 39 | 222 | 472 | 2793 | *36e-3/5e4* | . | . | Basic RCGA [25] |
| SPSA | 25 | 18094 | 4669 | 3783 | *47e-1/1e5* | . | . | . | . | . | SPSA [14] |

Table 5: 02-D, running time excess ERT/$\text{ERT}_{\text{best 2009}}$ on $f_5$, in italics is given the median final function value and the median number of function evaluations to reach this value divided by dimension

**5 Linear slope**

| Δftarget | 1e+03 | 1e+02 | 1e+01 | 1e+00 | 1e-01 | 1e-02 | 1e-03 | 1e-04 | 1e-05 | 1e-07 | Δftarget |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $\text{ERT}_{\text{best}}$/D | 0.50 | 0.50 | 1.8 | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 | $\text{ERT}_{\text{best}}$/D |
| (1,2)-CMA-ES | **1** | **1** | 5.0 | 8.3 | 9.0 | 9.0 | 9.0 | 9.0 | 9.0 | 9.0 | (1,2)-CMA-ES [5, 3] |
| (1,2m)-CMA-ES | **1** | **1** | **2.6** | 5.3 | 5.5 | 5.5 | 5.5 | 5.5 | 5.5 | 5.5 | (1,2m)-CMA-ES [5] |
| (1,2ms)-CMA-ES | **1** | **1** | **1.7** | **2.8** | **2.9** | **3.0** | **3.0** | **3.0** | **3.0** | **3.0** | (1,2ms)-CMA-ES [5] |
| (1,2s)-CMA-ES | **1** | **1** | **2.1** | 5.1 | 5.7 | 5.8 | 5.8 | 5.8 | 5.8 | 5.8 | (1,2s)-CMA-ES [3] |
| (1,4)-CMA-ES | **1** | **1** | **3.0** | 4.2 | 4.6 | 4.6 | 4.6 | 4.6 | 4.6 | 4.6 | (1,4)-CMA-ES [6, 4] |
| (1,4m)-CMA-ES | **1** | **1** | **2.5** | 4.6 | 4.8 | 4.8 | 4.8 | 4.8 | 4.8 | 4.8 | (1,4m)-CMA-ES [6] |
| (1,4ms)-CMA-ES | **1** | **1** | **2.1** | 3.2 | 3.6 | 3.6 | 3.6 | 3.6 | 3.6 | 3.6 | (1,4ms)-CMA-ES [1, 6] |
| (1,4s)-CMA-ES | **1** | **1** | **2.3** | 5.2 | 5.6 | 5.6 | 5.6 | 5.6 | 5.6 | 5.6 | (1,4s)-CMA-ES [4] |
| (1+1)-CMA-ES | **1** | **1** | **2.2** | 4.5 | 4.8 | 4.8 | 4.8 | 4.8 | 4.8 | 4.8 | (1+1)-CMA-ES [8] |
| (1+2ms)-CMA-ES | **1** | **1** | **1.8** | **2.9** | **3.2** | **3.2** | **3.2** | **3.2** | **3.2** | **3.2** | (1+2ms)-CMA-ES [2] |
| Artif Bee Colony | **1** | **1** | 4.6 | 19 | 25 | 26 | 26 | 26 | 26 | 26 | Artif Bee Colony [9] |
| avg NEWUOA | **1** | **1.2** | **1.1** | **1.5** | **1.6** | **1.6** | **1.6** | **1.6** | **1.6** | **1.6** | avg NEWUOA [24] |
| CMA-EGS (IPOP,r1) | **1** | **1.1** | 3.3 | 7.0 | 7.1 | 7.1 | 7.1 | 7.1 | 7.1 | 7.1 | CMA-EGS (IPOP,r1) [13] |
| Adap DE (F-AUC) | **1** | **1** | 3.3 | 9.0 | 10 | 10 | 10 | 10 | 10 | 10 | Adap DE (F-AUC) [11] |
| DE (Uniform) | **1** | **1.1** | 5.1 | 14 | 15 | 15 | 15 | 15 | 15 | 15 | DE (Uniform) [10] |
| IPOP-aCMA-ES | **1** | **1** | 3.2 | 5.7 | 6.1 | 6.1 | 6.1 | 6.1 | 6.1 | 6.1 | IPOP-aCMA-ES [17] |
| IPOP-CMA-ES | **1** | **1** | 3.0 | 7.0 | 8.0 | 8.0 | 8.0 | 8.0 | 8.0 | 8.0 | IPOP-CMA-ES [23] |
| CMA+DE-MOS | **1** | **1.2** | 5.9 | 19 | 23 | 24 | 24 | 24 | 24 | 24 | CMA+DE-MOS [19] |
| NBC-CMA | **1** | **1.1** | 4.3 | 61 | 72 | 75 | 75 | 75 | 75 | 75 | NBC-CMA [22] |
| POEMS | **1** | **1** | 127 | 141 | 157 | 167 | 172 | 173 | 173 | 173 | POEMS [18] |
| PM-AdapSS-DE | **1** | **1** | 7.0 | 9.2 | 11 | 11 | 11 | 11 | 11 | 11 | PM-AdapSS-DE [10, 11] |
| pPOEMS | **1** | **1** | 63 | 147 | 160 | 164 | 165 | 165 | 165 | 165 | pPOEMS [18, 21] |
| Basic RCGA | **1** | **1** | 5.7 | 606 | 1162 | 2198 | 3308 | 4594 | 5752 | 33282 | Basic RCGA [25] |
| SPSA | **1** | 6.9 | 18 | 37 | 40 | 40 | 40 | 40 | 40 | 40 | SPSA [14] |

Table 6: 02-D, running time excess ERT/ERT$_{\text{best 2009}}$ on $f_6$, in italics is given the median final function value and the median number of function evaluations to reach this value divided by dimension

**6 Attractive sector**

| Δftarget | 1e+03 | 1e+02 | 1e+01 | 1e+00 | 1e-01 | 1e-02 | 1e-03 | 1e-04 | 1e-05 | 1e-07 | Δftarget |
|---|---|---|---|---|---|---|---|---|---|---|---|
| ERT$_{\text{best}}$/D | 0.83 | 1.4 | 6.3 | 11 | 20 | 27 | 34 | 40 | 47 | 62 | ERT$_{\text{best}}$/D |
| (1,2)-CMA-ES | 3.4 | **2.4** | 4.4 | 4.7 | 3.9 | 5.1 | 6.5 | 6.6 | 6.8 | 6.5 | (1,2)-CMA-ES [5, 3] |
| (1,2m)-CMA-ES | **2.7** | **2.5** | **2.4** | 4.6 | 5.9 | 5.8 | 6.0 | 7.4 | 6.9 | 6.4 | (1,2m)-CMA-ES [5] |
| (1,2ms)-CMA-ES | 3.0 | 4.2 | 3.2 | 4.5 | 3.8 | 4.3 | 5.6 | 5.6 | 5.2 | 5.3 | (1,2ms)-CMA-ES [5] |
| (1,2s)-CMA-ES | 3.4 | **2.8** | 4.1 | 7.4 | 16 | 14 | 14 | 13 | 12 | 11 | (1,2s)-CMA-ES [3] |
| (1,4)-CMA-ES | 3.3 | **2.8** | **1.6** | **2.8** | **2.6** | **2.9** | 3.1 | 3.1 | 3.1 | 3.2 | (1,4)-CMA-ES [6, 4] |
| (1,4m)-CMA-ES | 3.5 | **2.3** | **1.4** | **2.2** | **2.7** | **3.0** | 3.0 | 3.0 | **3.0** | 3.0 | (1,4m)-CMA-ES [6] |
| (1,4ms)-CMA-ES | **1.8** | **1.5** | **1.7** | **2.7** | **2.5** | **2.4** | **2.5** | **2.4** | **2.4** | **2.3** | (1,4ms)-CMA-ES [1, 6] |
| (1,4s)-CMA-ES | 6.1 | 4.4 | **2.0** | **2.6** | **2.7** | **2.6** | **2.7** | **2.8** | **2.7** | **2.6** | (1,4s)-CMA-ES [4] |
| (1+1)-CMA-ES | 3.9 | **2.7** | **2.1** | **2.5** | **2.2** | **2.3** | **2.2** | **2.2** | **2.1** | **2.1** | (1+1)-CMA-ES [8] |
| (1+2ms)-CMA-ES | **2.1** | **1.6** | **1.1** | **1.9** | **1.8** | **2.0** | **1.9** | **2.0** | **2.0** | **2.0** | (1+2ms)-CMA-ES [2] |
| Artif Bee Colony | 5.4 | 3.9 | **2.8** | 9.5 | 20 | 51 | 149 | 571 | 874 | 1167 | Artif Bee Colony [9] |
| avg NEWUOA | **1.4** | **2.1** | 3.1 | 4.7 | 3.9 | 4.4 | 4.4 | 4.5 | 4.7 | 4.6 | avg NEWUOA [24] |
| CMA-EGS (IPOP,r1) | 13 | 132 | 72 | 909 | 1848 | 1428 | 1564 | 1318 | 1120 | 1129 | CMA-EGS (IPOP,r1) [13] |
| Adap DE (F-AUC) | **2.8** | **1.9** | **2.9** | 5.9 | 6.3 | 7.3 | 7.8 | 8.5 | 8.6 | 8.9 | Adap DE (F-AUC) [11] |
| DE (Uniform) | **2.8** | **3.0** | **2.9** | 7.8 | 7.8 | 8.5 | 9.1 | 9.2 | 9.4 | 10 | DE (Uniform) [10] |
| IPOP-aCMA-ES | 4.2 | **3.0** | **2.1** | 3.2 | 3.2 | 3.5 | 4.0 | 4.0 | 4.0 | 3.8 | IPOP-aCMA-ES [17] |
| IPOP-CMA-ES | 4.6 | 3.5 | **2.3** | 5.0 | 4.2 | 4.7 | 4.5 | 4.6 | 4.4 | 4.5 | IPOP-CMA-ES [23] |
| CMA+DE-MOS | 3.2 | **2.3** | **2.4** | 12 | 13 | 16 | 16 | 18 | 17 | 18 | CMA+DE-MOS [19] |
| NBC-CMA | 3.1 | **2.6** | **3.0** | 8.4 | 33 | 28 | 24 | 22 | 20 | 17 | NBC-CMA [22] |
| POEMS | 204 | 157 | 61 | 92 | 99 | 112 | 121 | 138 | 136 | 147 | POEMS [18] |
| PM-AdapSS-DE | **2.9** | **2.3** | **1.9** | 4.0 | 6.1 | 8.2 | 8.8 | 9.0 | 8.8 | 8.9 | PM-AdapSS-DE [10, 11] |
| pPOEMS | 68 | 62 | 54 | 116 | 362 | 602 | 806 | 846 | 915 | 976 | pPOEMS [18, 21] |
| Basic RCGA | 4.3 | 16 | 6.0 | 121 | 375 | 596 | 1340 | 1819 | 3139 | 5724 | Basic RCGA [25] |
| SPSA | 75 | 4649 | 10152 | 8487 | 7901 | 8286 | 19888 | *27e-2/1e5* | . | . | SPSA [14] |

Table 7: 02-D, running time excess ERT/ERT$_{\text{best 2009}}$ on $f_7$, in italics is given the median final function value and the median number of function evaluations to reach this value divided by dimension

### 7 Step-ellipsoid

| Δftarget | 1e+03 | 1e+02 | 1e+01 | 1e+00 | 1e-01 | 1e-02 | 1e-03 | 1e-04 | 1e-05 | 1e-07 | Δftarget |
|---|---|---|---|---|---|---|---|---|---|---|---|
| ERT$_{\text{best}}$/D | 0.50 | 1 | 1.6 | 11 | 30 | 97 | 108 | 108 | 108 | 121 | ERT$_{\text{best}}$/D |
| (1,2)-CMA-ES | **1.5** | 3.5 | 6.2 | 6.5 | 24 | 13 | 37 | 37 | 37 | 259 | (1,2)-CMA-ES [5, 3] |
| (1,2m)-CMA-ES | **1.9** | **2.0** | 5.5 | 9.2 | 10 | 17 | 23 | 23 | 23 | 54 | (1,2m)-CMA-ES [5] |
| (1,2ms)-CMA-ES | **1.5** | **1.9** | 4.3 | 4.5 | 13 | 24 | 32 | 32 | 32 | 69 | (1,2ms)-CMA-ES [5] |
| (1,2s)-CMA-ES | **2.5** | 3.5 | 21 | 21 | 15 | 27 | 35 | 35 | 35 | 89 | (1,2s)-CMA-ES [3] |
| (1,4)-CMA-ES | **2.4** | **2.5** | 5.1 | 3.6 | 4.1 | **2.8** | **3.0** | **3.0** | **3.0** | 4.3 | (1,4)-CMA-ES [6, 4] |
| (1,4m)-CMA-ES | **1.1** | **1.8** | 4.9 | 5.7 | 4.8 | 4.9 | 5.3 | 5.3 | 5.3 | 5.6 | (1,4m)-CMA-ES [6] |
| (1,4ms)-CMA-ES | **1.3** | **1.5** | 16 | 6.3 | 4.4 | **2.3** | **2.7** | **2.7** | **2.7** | 6.4 | (1,4ms)-CMA-ES [1, 6] |
| (1,4s)-CMA-ES | **1.7** | **2.1** | **3.5** | 5.0 | 3.8 | 3.6 | 5.6 | 5.6 | 5.6 | 7.7 | (1,4s)-CMA-ES [4] |
| (1+1)-CMA-ES | **1.1** | **1.2** | **3.7** | **2.7** | **2.0** | **0.72** | **0.70** | **0.70** | **0.70** | **0.72** | (1+1)-CMA-ES [8] |
| (1+2ms)-CMA-ES | **1.3** | **1.6** | 4.7 | 4.3 | **2.6** | **1.1** | **1.0** | **1.0** | **1.0** | **0.99** | (1+2ms)-CMA-ES [2] |
| Artif Bee Colony | **1.5** | **1.8** | 6.4 | 4.2 | 9.5 | 17 | 60 | 60 | 60 | 123 | Artif Bee Colony [9] |
| avg NEWUOA | **1.7** | **2.7** | 4.0 | 3.7 | 6.8 | 5.0 | 10 | 10 | 10 | 9.0 | avg NEWUOA [24] |
| CMA-EGS (IPOP,r1) | 268 | 296 | 861 | 719 | 589 | 936 | 1093 | 1093 | 1093 | 1610 | CMA-EGS (IPOP,r1) [13] |
| Adap DE (F-AUC) | **1.3** | **1.7** | **3.9** | **2.9** | **2.3** | **1.3** | **1.4** | **1.4** | **1.4** | **1.6** | Adap DE (F-AUC) [11] |
| DE (Uniform) | **1.8** | **2.5** | 6.5 | 3.9 | **2.8** | **1.3** | **1.3** | **1.3** | **1.3** | **1.4** | DE (Uniform) [10] |
| IPOP-aCMA-ES | **2.4** | **2.7** | 6.2 | 3.8 | **2.6** | **1.0** | **1.1** | **1.1** | **1.1** | **1.4** | IPOP-aCMA-ES [17] |
| IPOP-CMA-ES | **1.3** | **2.9** | 7.4 | 4.0 | 3.7 | **1.9** | **1.7** | **1.7** | **1.7** | **1.9** | IPOP-CMA-ES [23] |
| CMA+DE-MOS | **1.4** | **2.4** | 4.3 | 3.9 | 5.2 | 3.0 | 3.4 | 3.4 | 3.4 | 3.5 | CMA+DE-MOS [19] |
| NBC-CMA | **1.9** | **2.1** | 4.0 | 3.9 | 4.5 | **2.5** | **2.7** | **2.7** | **2.7** | 4.5 | NBC-CMA [22] |
| POEMS | 182 | 189 | 166 | 39 | 41 | 19 | 22 | 22 | 22 | 24 | POEMS [18] |
| PM-AdapSS-DE | **1.5** | **2.2** | 4.3 | **3.2** | **2.6** | **1.4** | **1.4** | **1.4** | **1.4** | **1.6** | PM-AdapSS-DE [10, 11] |
| pPOEMS | **1.7** | 33 | 109 | 41 | 45 | 69 | 96 | 96 | 96 | 125 | pPOEMS [18, 21] |
| Basic RCGA | **1.2** | **1.5** | 4.1 | 7.0 | 81 | 127 | 240 | 240 | 240 | 302 | Basic RCGA [25] |
| SPSA | 354 | 7871 | 17652 | 39270 | *34e-1/1e5* | . | . | . | . | . | SPSA [14] |

Table 8: 02-D, running time excess ERT/ERT$_{\text{best 2009}}$ on $f_8$, in italics is given the median final function value and the median number of function evaluations to reach this value divided by dimension

**8 Rosenbrock original**

| Δftarget | 1e+03 | 1e+02 | 1e+01 | 1e+00 | 1e-01 | 1e-02 | 1e-03 | 1e-04 | 1e-05 | 1e-07 | Δftarget |
|---|---|---|---|---|---|---|---|---|---|---|---|
| ERT$_{\text{best}}$/D | 0.60 | 1.6 | 2.7 | 6.0 | 18 | 23 | 43 | 46 | 47 | 56 | ERT$_{\text{best}}$/D |
| (1,2)-CMA-ES | 6.5 | 6.0 | 26 | 65 | 36 | 35 | 22 | 22 | 23 | 20 | (1,2)-CMA-ES [5, 3] |
| (1,2m)-CMA-ES | 5.2 | 4.1 | 24 | 47 | 27 | 30 | 18 | 18 | 18 | 16 | (1,2m)-CMA-ES [5] |
| (1,2ms)-CMA-ES | 5.3 | 5.4 | 5.7 | 19 | 15 | 21 | 12 | 12 | 12 | 11 | (1,2ms)-CMA-ES [5] |
| (1,2s)-CMA-ES | 6.1 | 4.5 | 53 | 236 | 123 | 117 | 87 | 90 | 96 | 82 | (1,2s)-CMA-ES [3] |
| (1,4)-CMA-ES | 4.8 | 3.1 | 5.3 | 22 | 14 | 13 | 8.0 | 8.2 | 8.4 | 7.7 | (1,4)-CMA-ES [6, 4] |
| (1,4m)-CMA-ES | 3.4 | 3.8 | 5.5 | 8.0 | 6.8 | 7.9 | 5.4 | 5.7 | 6.1 | 5.6 | (1,4m)-CMA-ES [6] |
| (1,4ms)-CMA-ES | 3.3 | **2.7** | **2.9** | 10 | 7.0 | 8.7 | 5.1 | 5.0 | 5.2 | 4.7 | (1,4ms)-CMA-ES [1, 6] |
| (1,4s)-CMA-ES | 3.1 | **2.6** | 5.6 | 18 | 11 | 11 | 7.0 | 7.2 | 7.2 | 6.5 | (1,4s)-CMA-ES [4] |
| (1+1)-CMA-ES | 4.1 | 3.1 | 5.2 | 12 | 6.5 | **6.8** | **4.0** | **4.2** | **4.3** | **4.0** | (1+1)-CMA-ES [8] |
| (1+2ms)-CMA-ES | **2.5** | **1.9** | **3.6** | **6.6** | **5.0** | **5.3** | **3.2** | **3.2** | **3.4** | **3.2** | (1+2ms)-CMA-ES [2] |
| Artif Bee Colony | 3.7 | **2.6** | 5.7 | 10 | 18 | 188 | 822 | 4247 | 18261 | *92e-6/1e5* | Artif Bee Colony [9] |
| avg NEWUOA | 3.9 | **2.5** | **2.6** | **4.6** | **2.4** | **2.4** | **1.4** | **1.4** | **1.4** | **1.3** | avg NEWUOA [24] |
| CMA-EGS (IPOP,r1) | 36 | 16 | 20 | 42 | 34 | 43 | 24 | 26 | 26 | 25 | CMA-EGS (IPOP,r1) [13] |
| Adap DE (F-AUC) | 4.6 | 3.9 | 7.3 | 11 | **6.3** | 10 | 6.7 | 7.7 | 8.2 | 8.5 | Adap DE (F-AUC) [11] |
| DE (Uniform) | **2.9** | **2.9** | 6.6 | 10 | 399 | 320 | 173 | 163 | 161 | 136 | DE (Uniform) [10] |
| IPOP-aCMA-ES | 5.2 | 4.5 | 6.6 | **7.9** | 7.6 | 8.6 | 5.2 | 5.2 | 5.6 | 5.2 | IPOP-aCMA-ES [17] |
| IPOP-CMA-ES | 9.2 | 5.2 | 5.5 | 14 | 10 | 11 | 6.3 | 6.4 | 6.7 | 6.1 | IPOP-CMA-ES [23] |
| CMA+DE-MOS | **2.6** | **2.9** | 6.2 | 16 | 15 | 22 | 14 | 15 | 17 | 17 | CMA+DE-MOS [19] |
| NBC-CMA | **2.9** | 3.5 | 6.0 | 10 | 13 | 20 | 13 | 14 | 17 | 17 | NBC-CMA [22] |
| POEMS | 238 | 111 | 207 | 379 | 173 | 185 | 119 | 138 | 177 | 193 | POEMS [18] |
| PM-AdapSS-DE | 3.4 | 3.3 | 6.9 | 8.0 | 7.5 | 8.5 | 6.0 | 6.9 | 7.5 | 7.9 | PM-AdapSS-DE [10, 11] |
| pPOEMS | 40 | 85 | 111 | 109 | 128 | 486 | 463 | 546 | 796 | 1002 | pPOEMS [18, 21] |
| Basic RCGA | **2.6** | 3.1 | 10 | 16 | 144 | 478 | 781 | 1572 | 7166 | 12810 | Basic RCGA [25] |
| SPSA | 931 | 548 | 3157 | 7112 | 22724 | 61485 | 33559 | *85e-2/1e5* | . | . | SPSA [14] |

Table 9: 02-D, running time excess ERT/ERT$_{\text{best 2009}}$ on $f_9$, in italics is given the median final function value and the median number of function evaluations to reach this value divided by dimension

**9 Rosenbrock rotated**

| Δftarget | 1e+03 | 1e+02 | 1e+01 | 1e+00 | 1e-01 | 1e-02 | 1e-03 | 1e-04 | 1e-05 | 1e-07 | Δftarget |
|---|---|---|---|---|---|---|---|---|---|---|---|
| ERT$_{\text{best}}$/D | 0.50 | 0.50 | 0.50 | 8.9 | 15 | 22 | 34 | 38 | 41 | 46 | ERT$_{\text{best}}$/D |
| (1,2)-CMA-ES | **2.9** | 8.1 | 69 | 38 | 55 | 51 | 36 | 33 | 32 | 29 | (1,2)-CMA-ES [5, 3] |
| (1,2m)-CMA-ES | **2.7** | 10 | 24 | 19 | 26 | 28 | 21 | 19 | 19 | 18 | (1,2m)-CMA-ES [5] |
| (1,2ms)-CMA-ES | 3.2 | **6.1** | 22 | 15 | 22 | 22 | 17 | 16 | 16 | 15 | (1,2ms)-CMA-ES [5] |
| (1,2s)-CMA-ES | 3.3 | **6.4** | 21 | 43 | 108 | 87 | 65 | 60 | 59 | 55 | (1,2s)-CMA-ES [3] |
| (1,4)-CMA-ES | 6.0 | 10 | **21** | 8.0 | 11 | 11 | 8.1 | 7.5 | 7.7 | 7.4 | (1,4)-CMA-ES [6, 4] |
| (1,4m)-CMA-ES | **2.7** | 6.9 | 22 | **3.2** | 11 | 9.5 | 7.5 | 7.1 | 7.1 | 7.2 | (1,4m)-CMA-ES [6] |
| (1,4ms)-CMA-ES | **2.9** | 8.3 | 29 | **4.0** | **6.1** | 6.2 | 4.7 | 4.5 | 4.5 | 4.6 | (1,4ms)-CMA-ES [1, 6] |
| (1,4s)-CMA-ES | 3.5 | 9.1 | **15** | 8.3 | 10 | 10 | 8.0 | 7.5 | 7.6 | 7.2 | (1,4s)-CMA-ES [4] |
| (1+1)-CMA-ES | 5.3 | 10 | 21 | 5.5 | 6.4 | **5.7** | **4.2** | **4.1** | **4.2** | **4.1** | (1+1)-CMA-ES [8] |
| (1+2ms)-CMA-ES | 3.5 | 6.9 | 26 | 5.0 | **5.3** | **5.1** | **3.7** | **3.6** | **3.6** | **3.7** | (1+2ms)-CMA-ES [2] |
| Artif Bee Colony | 3.9 | 10 | 29 | 6.8 | 14 | 42 | 242 | 1552 | 5121 | 9398 | Artif Bee Colony [9] |
| avg NEWUOA | 7.7 | 10 | 22 | **4.7** | **4.0** | **3.2** | **2.3** | **2.1** | **2.0** | **1.9** | avg NEWUOA [24] |
| CMA-EGS (IPOP,r1) | 16 | 39 | 693 | 65 | 58 | 49 | 34 | 31 | 31 | 29 | CMA-EGS (IPOP,r1) [13] |
| Adap DE (F-AUC) | 5.0 | 14 | 44 | 7.9 | 489 | 342 | 224 | 200 | 388 | 344 | Adap DE (F-AUC) [11] |
| DE (Uniform) | 3.1 | 8.9 | 28 | 7.3 | 10 | 12 | 10 | 10 | 10 | 11 | DE (Uniform) [10] |
| IPOP-aCMA-ES | **2.0** | **4.8** | 22 | 6.8 | 8.8 | 8.0 | 6.3 | 5.8 | 6.0 | 5.9 | IPOP-aCMA-ES [17] |
| IPOP-CMA-ES | 3.7 | 11 | 39 | 10 | 12 | 11 | 7.8 | 7.4 | 7.3 | 7.2 | IPOP-CMA-ES [23] |
| CMA+DE-MOS | **1.9** | 11 | **20** | 6.2 | 8.4 | 11 | 11 | 11 | 13 | 14 | CMA+DE-MOS [19] |
| NBC-CMA | 3.3 | 7.3 | 32 | 8.1 | 18 | 17 | 13 | 14 | 16 | 17 | NBC-CMA [22] |
| POEMS | 337 | 444 | 558 | 58 | 75 | 104 | 106 | 106 | 127 | 156 | POEMS [18] |
| PM-AdapSS-DE | 7.1 | 19 | 33 | 11 | 497 | 716 | 467 | 412 | 390 | 346 | PM-AdapSS-DE [10, 11] |
| pPOEMS | 159 | 319 | 558 | 51 | 173 | 500 | 609 | 674 | 894 | 1105 | pPOEMS [18, 21] |
| Basic RCGA | 3.3 | 10 | 49 | 8.0 | 29 | 206 | 994 | 1278 | 2857 | 15260 | Basic RCGA [25] |
| SPSA | 469 | 1759 | 55199 | 8901 | *96e-2/1e5* | . | . | . | . | . | SPSA [14] |

Table 10: 02-D, running time excess ERT/$\mathrm{ERT}_{\mathrm{best\ 2009}}$ on $f_{10}$, in italics is given the median final function value and the median number of function evaluations to reach this value divided by dimension

**10 Ellipsoid**

| ∆ftarget | 1e+03 | 1e+02 | 1e+01 | 1e+00 | 1e-01 | 1e-02 | 1e-03 | 1e-04 | 1e-05 | 1e-07 | ∆ftarget |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $\mathrm{ERT}_{\mathrm{best}}$/D | 2.9 | 5.7 | 15 | 23 | 27 | 30 | 34 | 38 | 41 | 49 | $\mathrm{ERT}_{\mathrm{best}}$/D |
| (1,2)-CMA-ES | 13 | 56 | 39 | 39 | 36 | 34 | 30 | 28 | 27 | 23 | (1,2)-CMA-ES [5, 3] |
| (1,2m)-CMA-ES | 8.9 | 25 | 49 | 36 | 33 | 30 | 27 | 26 | 25 | 22 | (1,2m)-CMA-ES [5] |
| (1,2ms)-CMA-ES | 6.4 | 14 | 29 | 23 | 22 | 23 | 21 | 20 | 19 | 17 | (1,2ms)-CMA-ES [5] |
| (1,2s)-CMA-ES | 6.7 | 109 | 120 | 115 | 106 | 95 | 92 | 85 | 80 | 68 | (1,2s)-CMA-ES [3] |
| (1,4)-CMA-ES | 6.4 | 6.0 | 8.9 | 11 | 11 | 11 | 10 | 9.2 | 8.8 | 8.0 | (1,4)-CMA-ES [6, 4] |
| (1,4m)-CMA-ES | 7.9 | 10 | 12 | 13 | 12 | 11 | 10 | 10 | 9.4 | 8.5 | (1,4m)-CMA-ES [6] |
| (1,4ms)-CMA-ES | 6.1 | **5.9** | 7.9 | 7.5 | 8.1 | 7.6 | 7.1 | 6.8 | 6.6 | 5.9 | (1,4ms)-CMA-ES [1, 6] |
| (1,4s)-CMA-ES | **5.8** | 8.7 | 8.8 | 8.3 | 8.7 | 8.4 | 8.4 | 7.9 | 7.5 | 6.7 | (1,4s)-CMA-ES [4] |
| (1+1)-CMA-ES | 9.3 | 7.0 | 6.4 | **5.5** | **5.6** | **5.6** | **5.2** | **5.0** | **5.0** | **4.6** | (1+1)-CMA-ES [8] |
| (1+2ms)-CMA-ES | **5.9** | **4.6** | **5.7** | 5.6 | **5.4** | **5.0** | **4.8** | **4.6** | **4.5** | **4.2** | (1+2ms)-CMA-ES [2] |
| Artif Bee Colony | 12 | 13 | 20 | 97 | 771 | 6940 | *11e-3/1e5* | . | . | . | Artif Bee Colony [9] |
| avg NEWUOA | **2.6** | **3.6** | **3.8** | **4.8** | 6.9 | 7.6 | 8.8 | 9.5 | 10 | 11 | avg NEWUOA [24] |
| CMA-EGS (IPOP,r1) | 13 | 62 | 144 | 364 | 642 | 865 | 772 | 697 | 647 | 545 | CMA-EGS (IPOP,r1) [13] |
| Adap DE (F-AUC) | 12 | 10 | 6.8 | 6.9 | 7.2 | 7.8 | 8.2 | 8.4 | 8.5 | 8.6 | Adap DE (F-AUC) [11] |
| DE (Uniform) | 9.1 | 10 | 7.2 | 7.0 | 7.5 | 8.1 | 8.4 | 8.6 | 9.1 | 9.3 | DE (Uniform) [10] |
| IPOP-aCMA-ES | 8.8 | 8.8 | **5.3** | **5.4** | **5.8** | **6.1** | **5.9** | **5.6** | **5.4** | **5.3** | IPOP-aCMA-ES [17] |
| IPOP-CMA-ES | 9.4 | 9.1 | 10 | 8.7 | 8.4 | 7.8 | 7.5 | 7.1 | 6.9 | 6.4 | IPOP-CMA-ES [23] |
| CMA+DE-MOS | 13 | 14 | 13 | 19 | 20 | 20 | 20 | 20 | 20 | 20 | CMA+DE-MOS [19] |
| NBC-CMA | 16 | 24 | 25 | 51 | 64 | 77 | 81 | 90 | 96 | 87 | NBC-CMA [22] |
| POEMS | 103 | 87 | 302 | 742 | 1322 | 1758 | 1884 | 2353 | 2694 | 2655 | POEMS [18] |
| PM-AdapSS-DE | 8.8 | 10 | 7.4 | 6.5 | 7.3 | 7.4 | 7.8 | 8.2 | 8.5 | 8.9 | PM-AdapSS-DE [10, 11] |
| pPOEMS | 90 | 117 | 155 | 463 | 837 | 1017 | 1256 | 1447 | 1579 | 1747 | pPOEMS [18, 21] |
| Basic RCGA | 25 | 27 | 115 | 1504 | 1874 | 3104 | 6551 | 19727 | *17e-3/5e4* | . | Basic RCGA [25] |
| SPSA | 29 | 229 | 874 | 1873 | 16681 | 24345 | *27e-2/1e5* | . | . | . | SPSA [14] |

Table 11: 02-D, running time excess ERT/ERT$_{\text{best 2009}}$ on $f_{11}$, in italics is given the median final function value and the median number of function evaluations to reach this value divided by dimension

**11 Discus**

| Δftarget | 1e+03 | 1e+02 | 1e+01 | 1e+00 | 1e-01 | 1e-02 | 1e-03 | 1e-04 | 1e-05 | 1e-07 | Δftarget |
|---|---|---|---|---|---|---|---|---|---|---|---|
| ERT$_{\text{best}}$/D | 4.7 | 5.7 | 18 | 22 | 25 | 31 | 34 | 38 | 41 | 49 | ERT$_{\text{best}}$/D |
| (1,2)-CMA-ES | 5.1 | 22 | 26 | 35 | 35 | 31 | 28 | 26 | 25 | 22 | (1,2)-CMA-ES [5, 3] |
| (1,2m)-CMA-ES | 12 | 44 | 33 | 36 | 34 | 30 | 28 | 26 | 25 | 22 | (1,2m)-CMA-ES [5] |
| (1,2ms)-CMA-ES | 4.6 | 21 | 24 | 26 | 27 | 26 | 25 | 23 | 22 | 19 | (1,2ms)-CMA-ES [5] |
| (1,2s)-CMA-ES | 5.3 | 35 | 53 | 75 | 105 | 87 | 85 | 77 | 72 | 61 | (1,2s)-CMA-ES [3] |
| (1,4)-CMA-ES | 3.9 | 11 | 12 | 12 | 11 | 10 | 10 | 9.1 | 8.8 | 7.9 | (1,4)-CMA-ES [6, 4] |
| (1,4m)-CMA-ES | 4.9 | 6.6 | 12 | 13 | 12 | 11 | 10 | 10 | 9.3 | 8.3 | (1,4m)-CMA-ES [6] |
| (1,4ms)-CMA-ES | **3.2** | **6.1** | 6.9 | 8.5 | 9.2 | 8.4 | 8.0 | 7.4 | 7.1 | 6.4 | (1,4ms)-CMA-ES [1, 6] |
| (1,4s)-CMA-ES | 10 | 18 | 11 | 10 | 10 | 8.6 | 8.3 | 7.9 | 7.6 | 6.7 | (1,4s)-CMA-ES [4] |
| (1+1)-CMA-ES | 4.5 | 6.9 | **4.2** | **6.5** | **6.7** | **5.8** | **5.5** | **5.3** | **5.1** | **4.8** | (1+1)-CMA-ES [8] |
| (1+2ms)-CMA-ES | **3.9** | **5.6** | **3.3** | **5.5** | **5.6** | **5.0** | **4.9** | **4.6** | **4.6** | **4.2** | (1+2ms)-CMA-ES [2] |
| Artif Bee Colony | 7.3 | 13 | 11 | 103 | 813 | 7859 | 40809 | *11e-3/1e5* | . | . | Artif Bee Colony [9] |
| avg NEWUOA | **1.3** | **1.5** | **1.5** | **3.3** | **5.1** | **5.4** | 6.8 | 7.3 | 8.0 | 8.8 | avg NEWUOA [24] |
| CMA-EGS (IPOP,r1) | 8.1 | 128 | 517 | 994 | 1265 | 1264 | 1159 | 1041 | 962 | 812 | CMA-EGS (IPOP,r1) [13] |
| Adap DE (F-AUC) | 7.6 | 13 | 6.3 | 7.0 | 8.0 | 7.9 | 8.2 | 8.7 | 8.8 | 9.0 | Adap DE (F-AUC) [11] |
| DE (Uniform) | 9.0 | 12 | 6.0 | 6.9 | 7.8 | 8.3 | 8.5 | 8.9 | 9.0 | 9.4 | DE (Uniform) [10] |
| IPOP-aCMA-ES | 4.2 | 6.7 | 5.1 | 6.7 | 6.9 | 6.2 | **6.0** | **5.9** | **5.8** | **5.5** | IPOP-aCMA-ES [17] |
| IPOP-CMA-ES | 5.1 | 12 | 7.5 | 8.3 | 8.7 | 7.6 | 7.4 | 7.1 | 6.8 | 6.4 | IPOP-CMA-ES [23] |
| CMA+DE-MOS | 11 | 23 | 13 | 19 | 23 | 21 | 21 | 21 | 21 | 20 | CMA+DE-MOS [19] |
| NBC-CMA | 13 | 22 | 24 | 41 | 58 | 66 | 87 | 97 | 101 | 88 | NBC-CMA [22] |
| POEMS | 68 | 69 | 533 | 811 | 1297 | 1891 | 2292 | 2546 | 2824 | 3255 | POEMS [18] |
| PM-AdapSS-DE | 7.9 | 12 | 6.2 | 7.3 | 8.2 | 8.3 | 8.8 | 9.1 | 9.1 | 9.4 | PM-AdapSS-DE [10, 11] |
| pPOEMS | 76 | 124 | 113 | 477 | 866 | 1087 | 1260 | 1491 | 1643 | 1787 | pPOEMS [18, 21] |
| Basic RCGA | 10 | 23 | 75 | 958 | 2135 | 6917 | *44e-3/5e4* | . | . | . | Basic RCGA [25] |
| SPSA | 15 | 483 | 1404 | 4983 | 17942 | 46844 | 42861 | 38450 | *50e-2/1e5* | . | SPSA [14] |

Table 12: 02-D, running time excess ERT/ERT$_{\text{best 2009}}$ on $f_{12}$, in italics is given the median final function value and the median number of function evaluations to reach this value divided by dimension

**12 Bent cigar**

| Δftarget | 1e+03 | 1e+02 | 1e+01 | 1e+00 | 1e-01 | 1e-02 | 1e-03 | 1e-04 | 1e-05 | 1e-07 | Δftarget |
|---|---|---|---|---|---|---|---|---|---|---|---|
| ERT$_{\text{best}}$/D | 5.0 | 9.2 | 18 | 23 | 38 | 47 | 52 | 63 | 76 | 97 | ERT$_{\text{best}}$/D |
| (1,2)-CMA-ES | 5.9 | 12 | 12 | 24 | 27 | 31 | 33 | 31 | 35 | 30 | (1,2)-CMA-ES [5, 3] |
| (1,2m)-CMA-ES | 5.4 | 30 | 32 | 28 | 26 | 26 | 24 | 22 | 20 | 21 | (1,2m)-CMA-ES [5] |
| (1,2ms)-CMA-ES | 21 | 38 | 42 | 52 | 43 | 37 | 34 | 29 | 25 | 21 | (1,2ms)-CMA-ES [5] |
| (1,2s)-CMA-ES | 5.9 | 37 | 95 | 170 | 142 | 116 | 105 | 88 | 73 | 57 | (1,2s)-CMA-ES [3] |
| (1,4)-CMA-ES | 9.3 | 12 | 16 | 21 | 18 | 16 | 16 | 14 | 13 | 11 | (1,4)-CMA-ES [6, 4] |
| (1,4m)-CMA-ES | 8.6 | 11 | 16 | 21 | 19 | 18 | 17 | 16 | 15 | 13 | (1,4m)-CMA-ES [6] |
| (1,4ms)-CMA-ES | 4.5 | 8.0 | 16 | 22 | 18 | 16 | 15 | 14 | 12 | 10 | (1,4ms)-CMA-ES [1, 6] |
| (1,4s)-CMA-ES | **2.9** | 6.8 | 14 | 20 | 16 | 15 | 14 | 13 | 11 | 10 | (1,4s)-CMA-ES [4] |
| (1+1)-CMA-ES | 4.6 | 7.0 | 8.8 | 10 | 7.7 | **7.0** | **6.7** | **6.1** | **5.6** | **5.2** | (1+1)-CMA-ES [8] |
| (1+2ms)-CMA-ES | 4.6 | **3.2** | **4.2** | **7.6** | **6.9** | **6.5** | **6.5** | **6.4** | **5.9** | **5.6** | (1+2ms)-CMA-ES [2] |
| Artif Bee Colony | 8.9 | 7.7 | 13 | 175 | 568 | 1467 | 2630 | 3353 | 2793 | 2258 | Artif Bee Colony [9] |
| avg NEWUOA | **1.7** | **1.1** | **0.96** | **1.6** | **1.5** | **1.5** | **1.5** | **1.5** | **1.4** | **1.4** | avg NEWUOA [24] |
| CMA-EGS (IPOP,r1) | 10 | 438 | 1070 | 8143 | 10929 | 8731 | 12445 | 22378 | 18388 | *15e-1/1e5* | CMA-EGS (IPOP,r1) [13] |
| Adap DE (F-AUC) | 11 | 7.9 | 8.1 | 8.2 | **7.5** | 7.1 | 7.6 | 7.9 | 7.6 | 7.2 | Adap DE (F-AUC) [11] |
| DE (Uniform) | 10 | 7.7 | 8.1 | 320 | 417 | 334 | 302 | 253 | 209 | 165 | DE (Uniform) [10] |
| IPOP-aCMA-ES | **4.4** | **3.8** | **5.0** | **7.8** | 8.3 | 8.2 | 8.5 | 8.1 | 13 | 11 | IPOP-aCMA-ES [17] |
| IPOP-CMA-ES | 4.6 | 7.0 | 10 | 12 | 9.3 | 9.0 | 8.6 | 7.8 | 7.3 | 6.5 | IPOP-CMA-ES [23] |
| CMA+DE-MOS | 13 | 12 | 16 | 22 | 18 | 18 | 19 | 19 | 18 | 17 | CMA+DE-MOS [19] |
| NBC-CMA | 14 | 13 | 20 | 66 | 73 | 69 | 76 | 80 | 69 | 57 | NBC-CMA [22] |
| POEMS | 91 | 79 | 332 | 726 | 1039 | 1490 | 2235 | 2363 | 2530 | 2595 | POEMS [18] |
| PM-AdapSS-DE | 9.5 | 9.0 | 8.3 | 8.6 | 197 | 334 | 301 | 405 | 334 | 263 | PM-AdapSS-DE [10, 11] |
| pPOEMS | 76 | 78 | 282 | 408 | 622 | 667 | 730 | 788 | 801 | 843 | pPOEMS [18, 21] |
| Basic RCGA | 13 | 23 | 118 | 730 | 852 | 804 | 1022 | 912 | 1577 | 1575 | Basic RCGA [25] |
| SPSA | 3230 | 4072 | 15645 | 60799 | 37286 | 29781 | *30e+0/1e5* | . | . | . | SPSA [14] |

Table 13: 02-D, running time excess ERT/ERT$_{\text{best 2009}}$ on $f_{13}$, in italics is given the median final function value and the median number of function evaluations to reach this value divided by dimension

**13 Sharp ridge**

| Δftarget | 1e+03 | 1e+02 | 1e+01 | 1e+00 | 1e-01 | 1e-02 | 1e-03 | 1e-04 | 1e-05 | 1e-07 | Δftarget |
|---|---|---|---|---|---|---|---|---|---|---|---|
| ERT$_{\text{best}}$/D | 0.50 | 2.3 | 11 | 18 | 23 | 30 | 35 | 42 | 47 | 61 | ERT$_{\text{best}}$/D |
| (1,2)-CMA-ES | **2.2** | 3.4 | 17 | 30 | 31 | 29 | 29 | 28 | 28 | 37 | (1,2)-CMA-ES [5, 3] |
| (1,2m)-CMA-ES | **1.1** | 3.5 | 13 | 32 | 41 | 39 | 40 | 50 | 67 | 68 | (1,2m)-CMA-ES [5] |
| (1,2ms)-CMA-ES | **2.1** | 13 | 11 | 26 | 30 | 31 | 37 | 43 | 51 | 51 | (1,2ms)-CMA-ES [5] |
| (1,2s)-CMA-ES | **1.1** | 19 | 69 | 57 | 99 | 97 | 94 | 115 | 102 | 152 | (1,2s)-CMA-ES [3] |
| (1,4)-CMA-ES | **1.3** | 3.9 | 7.1 | 10 | 10 | 8.5 | 10 | 10 | 10 | 10 | (1,4)-CMA-ES [6, 4] |
| (1,4m)-CMA-ES | **1.7** | 3.5 | 6.3 | 7.7 | 7.7 | 11 | 11 | 11 | 11 | 11 | (1,4m)-CMA-ES [6] |
| (1,4ms)-CMA-ES | **1.5** | **2.4** | **2.9** | 6.5 | 8.2 | 7.2 | 7.4 | 7.4 | 7.3 | 8.0 | (1,4ms)-CMA-ES [1, 6] |
| (1,4s)-CMA-ES | **1.3** | 6.3 | 9.2 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | (1,4s)-CMA-ES [4] |
| (1+1)-CMA-ES | **1.4** | **2.3** | **4.1** | **5.6** | **6.8** | **6.6** | **6.1** | **6.0** | **7.1** | **8.0** | (1+1)-CMA-ES [8] |
| (1+2ms)-CMA-ES | **1.1** | **1.8** | **3.7** | **5.6** | 9.1 | 8.2 | 8.1 | 7.5 | 8.1 | 8.9 | (1+2ms)-CMA-ES [2] |
| Artif Bee Colony | **1.4** | 3.6 | 5.6 | 61 | 2262 | 18469 | *23e-3/1e5* | . | . | . | Artif Bee Colony [9] |
| avg NEWUOA | **1.8** | 6.7 | 6.7 | 17 | 38 | 54 | 73 | 131 | 140 | 771 | avg NEWUOA [24] |
| CMA-EGS (IPOP,r1) | 17 | 95 | 386 | 2717 | 4951 | 9966 | *48e-3/1e5* | . | . | . | CMA-EGS (IPOP,r1) [13] |
| Adap DE (F-AUC) | **1.5** | 4.1 | 4.5 | 6.9 | 8.2 | 8.5 | 9.3 | 9.4 | 9.3 | 9.5 | Adap DE (F-AUC) [11] |
| DE (Uniform) | **1.5** | **2.8** | 4.5 | 7.1 | 8.5 | 8.2 | 8.8 | 9.5 | 10 | 10 | DE (Uniform) [10] |
| IPOP-aCMA-ES | **1.7** | 4.2 | 4.3 | **6.1** | **6.2** | **5.9** | **6.1** | **5.9** | **5.9** | **5.8** | IPOP-aCMA-ES [17] |
| IPOP-CMA-ES | **1.4** | **2.1** | 5.0 | 6.3 | **6.7** | **6.3** | **6.6** | **6.9** | **6.8** | **7.1** | IPOP-CMA-ES [23] |
| CMA+DE-MOS | **1.3** | **2.7** | 7.7 | 17 | 19 | 19 | 20 | 20 | 19 | 19 | CMA+DE-MOS [19] |
| NBC-CMA | **1.5** | 3.0 | 7.9 | 14 | 17 | 25 | 44 | 52 | 48 | 40 | NBC-CMA [22] |
| POEMS | 125 | 104 | 54 | 103 | 146 | 491 | 1449 | 4402 | 15360 | 69407 | POEMS [18] |
| PM-AdapSS-DE | **1.7** | 3.3 | 5.2 | 6.4 | 7.8 | 8.1 | 8.7 | 9.1 | 9.2 | 9.1 | PM-AdapSS-DE [10, 11] |
| pPOEMS | **1.4** | 51 | 48 | 233 | 856 | 1073 | 1441 | 1587 | 1967 | 2202 | pPOEMS [18, 21] |
| Basic RCGA | **1.4** | 3.6 | 85 | 1010 | 2805 | 7126 | 20886 | *19e-2/5e4* | . | . | Basic RCGA [25] |
| SPSA | 23 | 27 | 47 | 332 | 2459 | 15906 | 20509 | 17764 | 31370 | *21e-3/1e5* | SPSA [14] |

Table 14: 02-D, running time excess ERT/ERT$_{\text{best 2009}}$ on $f_{14}$, in italics is given the median final function value and the median number of function evaluations to reach this value divided by dimension

**14 Sum of different powers**

| Δftarget | 1e+03 | 1e+02 | 1e+01 | 1e+00 | 1e-01 | 1e-02 | 1e-03 | 1e-04 | 1e-05 | 1e-07 | Δftarget |
|---|---|---|---|---|---|---|---|---|---|---|---|
| ERT$_{\text{best}}$/D | 0.50 | 0.50 | 0.70 | 3.7 | 8.1 | 12 | 19 | 28 | 34 | 45 | ERT$_{\text{best}}$/D |
| (1,2)-CMA-ES | **1** | **1.7** | 9.2 | 10 | 7.4 | 11 | 18 | 20 | 22 | 29 | (1,2)-CMA-ES [5, 3] |
| (1,2m)-CMA-ES | **1** | **1.1** | **2.1** | **2.3** | 4.5 | 5.5 | 11 | 14 | 22 | 30 | (1,2m)-CMA-ES [5] |
| (1,2ms)-CMA-ES | **1** | **1** | **1.7** | **2.6** | 3.9 | 4.7 | 10 | 13 | 19 | 24 | (1,2ms)-CMA-ES [5] |
| (1,2s)-CMA-ES | **1** | **1.9** | **1.9** | 3.9 | 8.3 | 13 | 29 | 56 | 64 | 86 | (1,2s)-CMA-ES [3] |
| (1,4)-CMA-ES | **1** | **2.0** | **2.6** | **2.8** | **2.8** | 4.3 | 4.8 | 5.8 | 7.3 | 8.7 | (1,4)-CMA-ES [6, 4] |
| (1,4m)-CMA-ES | **1** | **1.4** | **1.9** | **1.3** | **3.0** | 3.8 | 6.1 | 6.3 | 7.9 | 10 | (1,4m)-CMA-ES [6] |
| (1,4ms)-CMA-ES | **1** | **1.2** | **1.9** | **2.3** | **2.5** | **3.1** | 4.1 | 4.4 | 5.3 | 7.0 | (1,4ms)-CMA-ES [1, 6] |
| (1,4s)-CMA-ES | **1** | **1.3** | **2.3** | **2.3** | **2.3** | 3.3 | 5.1 | 5.6 | 7.2 | 8.2 | (1,4s)-CMA-ES [4] |
| (1+1)-CMA-ES | **1** | **1** | **1.8** | **2.1** | **2.7** | **3.2** | **3.1** | **4.0** | **4.5** | **5.0** | (1+1)-CMA-ES [8] |
| (1+2ms)-CMA-ES | **1** | **1.2** | **1.5** | **1.8** | 3.1 | 3.5 | **3.5** | **3.9** | **3.9** | **4.0** | (1+2ms)-CMA-ES [2] |
| Artif Bee Colony | **1** | **1.3** | **1.6** | 4.7 | 10 | 18 | 27 | 607 | 11891 | *22e-6/1e5* | Artif Bee Colony [9] |
| avg NEWUOA | **1** | **1.4** | 3.4 | **2.2** | **1.4** | **1.3** | **1.6** | **1.8** | **2.2** | 6.8 | avg NEWUOA [24] |
| CMA-EGS (IPOP,r1) | 4.3 | 7.9 | 19 | 17 | 10 | 15 | 21 | 25 | 37 | 581 | CMA-EGS (IPOP,r1) [13] |
| Adap DE (F-AUC) | **1** | **1.1** | **1.1** | 3.6 | 5.6 | 10 | 10 | 8.4 | 8.7 | 9.0 | Adap DE (F-AUC) [11] |
| DE (Uniform) | **1** | **1.5** | **1.7** | 3.6 | 7.8 | 9.5 | 8.5 | 8.1 | 8.9 | 9.3 | DE (Uniform) [10] |
| IPOP-aCMA-ES | **1** | **1.1** | **2.3** | **2.7** | 3.3 | 4.9 | 4.9 | 4.9 | 4.8 | **5.9** | IPOP-aCMA-ES [17] |
| IPOP-CMA-ES | **1** | **1.3** | **2.2** | **2.9** | 4.6 | 5.1 | 4.7 | 5.2 | 6.0 | 7.2 | IPOP-CMA-ES [23] |
| CMA+DE-MOS | **1** | **1.2** | **1.8** | 4.3 | 13 | 17 | 18 | 18 | 19 | 20 | CMA+DE-MOS [19] |
| NBC-CMA | **1** | **1.3** | **2.0** | **2.9** | 11 | 17 | 14 | 13 | 16 | 22 | NBC-CMA [22] |
| POEMS | **1** | 185 | 213 | 74 | 67 | 141 | 165 | 177 | 246 | 2034 | POEMS [18] |
| PM-AdapSS-DE | **1** | **1.5** | **1.7** | **2.7** | 7.6 | 10 | 9.3 | 8.9 | 8.6 | 9.0 | PM-AdapSS-DE [10, 11] |
| pPOEMS | **1** | **1.7** | **2.2** | 57 | 66 | 391 | 760 | 984 | 1037 | 1666 | pPOEMS [18, 21] |
| Basic RCGA | **1** | **1.2** | **1.5** | 3.6 | 28 | 33 | 71 | 284 | 456 | 1630 | Basic RCGA [25] |
| SPSA | 22 | 57 | 242 | 984 | 530 | 452 | 850 | 5362 | 41592 | 31154 | SPSA [14] |

Table 15: 02-D, running time excess ERT/ERT$_{\text{best 2009}}$ on $f_{15}$, in italics is given the median final function value and the median number of function evaluations to reach this value divided by dimension

**15 Rastrigin**

| $\Delta$ftarget | 1e+03 | 1e+02 | 1e+01 | 1e+00 | 1e-01 | 1e-02 | 1e-03 | 1e-04 | 1e-05 | 1e-07 | $\Delta$ftarget |
|---|---|---|---|---|---|---|---|---|---|---|---|
| ERT$_{\text{best}}$/D | 0.50 | 0.60 | 19 | 146 | 517 | 533 | 556 | 582 | 616 | 706 | ERT$_{\text{best}}$/D |
| (1,2)-CMA-ES | **1.1** | 4.2 | **2.9** | 14 | 17 | 17 | 16 | 15 | 15 | 13 | (1,2)-CMA-ES [5, 3] |
| (1,2m)-CMA-ES | **1.3** | **2.9** | **0.83** | 7.8 | 10 | 13 | 13 | 13 | 12 | 11 | (1,2m)-CMA-ES [5] |
| (1,2ms)-CMA-ES | **1** | 4.2 | **2.4** | 6.8 | 9.5 | 9.2 | 8.9 | 8.5 | 8.1 | 7.1 | (1,2ms)-CMA-ES [5] |
| (1,2s)-CMA-ES | **1** | 5.6 | 9.5 | 15 | 20 | 24 | 23 | 22 | 21 | 18 | (1,2s)-CMA-ES [3] |
| (1,4)-CMA-ES | **1.3** | 5.4 | **2.1** | 3.6 | **2.7** | **2.7** | **2.6** | **2.5** | **2.4** | **2.1** | (1,4)-CMA-ES [6, 4] |
| (1,4m)-CMA-ES | **1.1** | 4.4 | **1.1** | **2.8** | 4.7 | 4.9 | 4.7 | 4.5 | 4.3 | 3.8 | (1,4m)-CMA-ES [6] |
| (1,4ms)-CMA-ES | **1.5** | 3.4 | **2.2** | 3.6 | 5.0 | 4.9 | 4.7 | 4.5 | 4.2 | 3.7 | (1,4ms)-CMA-ES [1, 6] |
| (1,4s)-CMA-ES | **1.1** | 4.7 | **2.4** | 5.8 | 9.4 | 9.1 | 8.8 | 8.4 | 7.9 | 7.0 | (1,4s)-CMA-ES [4] |
| (1+1)-CMA-ES | **1** | **2.8** | 3.1 | 4.0 | 6.5 | 6.3 | 6.1 | 5.8 | 5.5 | 4.9 | (1+1)-CMA-ES [8] |
| (1+2ms)-CMA-ES | **1.1** | **2.8** | **1.6** | 3.4 | 6.0 | 5.8 | 5.6 | 5.4 | 5.1 | 4.5 | (1+2ms)-CMA-ES [2] |
| Artif Bee Colony | **1.1** | **2.3** | **1.9** | 8.8 | 17 | 75 | 164 | 309 | 495 | 672 | Artif Bee Colony [9] |
| avg NEWUOA | **1** | **2.6** | **2.5** | **2.5** | 3.3 | 3.2 | 3.1 | **2.9** | **2.8** | **2.4** | avg NEWUOA [24] |
| CMA-EGS (IPOP,r1) | 4.9 | 189 | 108 | 64 | 158 | 331 | 418 | 1128 | 1067 | 933 | CMA-EGS (IPOP,r1) [13] |
| Adap DE (F-AUC) | **1.2** | **2.4** | **1.8** | **1.7** | **0.77** | **0.95** | **0.98** | **1.0** | **1.0** | **1.0** | Adap DE (F-AUC) [11] |
| DE (Uniform) | **1.2** | **2.1** | **1.8** | **1.5** | **0.67** | **0.88** | **0.95** | **0.97** | **1.0** | **1.0** | DE (Uniform) [10] |
| IPOP-aCMA-ES | **1.1** | 3.9 | **1.3** | **2.6** | **2.5** | **2.9** | **2.8** | **2.8** | **2.7** | **2.4** | IPOP-aCMA-ES [17] |
| IPOP-CMA-ES | **1** | **2.5** | **0.98** | **2.8** | **2.5** | **2.5** | **2.4** | **2.4** | **2.3** | **2.1** | IPOP-CMA-ES [23] |
| CMA+DE-MOS | **1** | **2.4** | **1.6** | 4.0 | **2.7** | 3.3 | 3.4 | 3.4 | 3.3 | 3.1 | CMA+DE-MOS [19] |
| NBC-CMA | **1.1** | **2.8** | **2.2** | **2.7** | 3.2 | 4.2 | 4.2 | 4.2 | 4.0 | 3.6 | NBC-CMA [22] |
| POEMS | **1** | 143 | 17 | 20 | 76 | 76 | 75 | 74 | 71 | 65 | POEMS [18] |
| PM-AdapSS-DE | **1.1** | **2.3** | **2.1** | **1.7** | 15 | 14 | 14 | 13 | 13 | 11 | PM-AdapSS-DE [10, 11] |
| pPOEMS | **1** | 7.1 | 19 | 46 | 25 | 50 | 63 | 72 | 82 | 92 | pPOEMS [18, 21] |
| Basic RCGA | **1** | **1.6** | 3.1 | 32 | 32 | 40 | 51 | 62 | 79 | 114 | Basic RCGA [25] |
| SPSA | 28 | 962 | 39 | 1133 | 1352 | *11e-1/1e5* | . | . | . | . | SPSA [14] |

Table 16: 02-D, running time excess ERT/ERT$_{\text{best 2009}}$ on $f_{16}$, in italics is given the median final function value and the median number of function evaluations to reach this value divided by dimension

**16 Weierstrass**

| Δftarget | 1e+03 | 1e+02 | 1e+01 | 1e+00 | 1e-01 | 1e-02 | 1e-03 | 1e-04 | 1e-05 | 1e-07 | Δftarget |
|---|---|---|---|---|---|---|---|---|---|---|---|
| ERT$_{\text{best}}$/D | 0.50 | 0.57 | 4.6 | 25 | 87 | 163 | 179 | 195 | 205 | 269 | ERT$_{\text{best}}$/D |
| (1,2)-CMA-ES | **1** | **1.6** | 3.0 | 14 | 19 | 44 | 74 | 120 | 115 | 125 | (1,2)-CMA-ES [5, 3] |
| (1,2m)-CMA-ES | **1** | **1.1** | 23 | 14 | 32 | 21 | 20 | 21 | 21 | 19 | (1,2m)-CMA-ES [5] |
| (1,2ms)-CMA-ES | **1** | **1.2** | 12 | 20 | 27 | 21 | 29 | 34 | 48 | 41 | (1,2ms)-CMA-ES [5] |
| (1,2s)-CMA-ES | **1** | **1.5** | 23 | 39 | 41 | 74 | 107 | 725 | 696 | 530 | (1,2s)-CMA-ES [3] |
| (1,4)-CMA-ES | **1** | **1.9** | 10 | 13 | 7.1 | 4.2 | **4.4** | 4.9 | 4.8 | 4.0 | (1,4)-CMA-ES [6, 4] |
| (1,4m)-CMA-ES | **1** | **1.4** | 4.0 | 9.1 | 5.4 | 4.3 | 4.4 | **4.2** | 7.6 | 5.8 | (1,4m)-CMA-ES [6] |
| (1,4ms)-CMA-ES | **1** | **1.6** | **2.6** | 5.9 | **3.6** | 5.3 | 4.9 | 4.6 | 5.3 | 4.2 | (1,4ms)-CMA-ES [1, 6] |
| (1,4s)-CMA-ES | **1** | **1.5** | 7.6 | 10 | 10 | 6.2 | 12 | 12 | 11 | 21 | (1,4s)-CMA-ES [4] |
| (1+1)-CMA-ES | **1** | **1.5** | 5.6 | 6.8 | 5.6 | 5.6 | 7.4 | 10 | 12 | 10 | (1+1)-CMA-ES [8] |
| (1+2ms)-CMA-ES | **1** | **1.5** | 3.6 | 7.6 | 5.4 | 7.6 | 7.7 | 11 | 11 | 10 | (1+2ms)-CMA-ES [2] |
| Artif Bee Colony | **1** | **1.5** | **2.2** | **3.4** | 8.7 | 38 | 202 | 1036 | 4754 | 3686 | Artif Bee Colony [9] |
| avg NEWUOA | **1** | 12 | 15 | 9.1 | 5.5 | 6.8 | 13 | 21 | 37 | 73 | avg NEWUOA [24] |
| CMA-EGS (IPOP,r1) | **1.7** | 8.5 | 166 | 134 | 236 | 489 | 2332 | *53e-4/1e5* | . | . | CMA-EGS (IPOP,r1) [13] |
| Adap DE (F-AUC) | **1** | **1.6** | **1.5** | **4.9** | **3.5** | **3.6** | **4.0** | **4.1** | **4.1** | **3.5** | Adap DE (F-AUC) [11] |
| DE (Uniform) | **1** | **1.2** | **2.8** | 6.8 | 4.0 | 3.8 | 4.6 | 4.6 | 4.7 | 4.0 | DE (Uniform) [10] |
| IPOP-aCMA-ES | **1** | **1.1** | 3.8 | 8.3 | 6.1 | **3.7** | **3.6** | **3.4** | **3.3** | **2.7** | IPOP-aCMA-ES [17] |
| IPOP-CMA-ES | **1** | **1.4** | **2.5** | 11 | 5.0 | **3.5** | 4.6 | 4.3 | **4.2** | **3.4** | IPOP-CMA-ES [23] |
| CMA+DE-MOS | **1** | **1.6** | 5.3 | 6.0 | **3.8** | 5.0 | 5.8 | 5.7 | 6.5 | 6.5 | CMA+DE-MOS [19] |
| NBC-CMA | **1** | **1.5** | **2.4** | 5.3 | 12 | 17 | 22 | 21 | 23 | 19 | NBC-CMA [22] |
| POEMS | **1** | 100 | 67 | 152 | 81 | 137 | 132 | 126 | 125 | 103 | POEMS [18] |
| PM-AdapSS-DE | **1** | **1.2** | 3.1 | **4.2** | 4.6 | 47 | 44 | 41 | 39 | 30 | PM-AdapSS-DE [10, 11] |
| pPOEMS | **1** | **1.6** | 39 | 22 | 58 | 106 | 162 | 229 | 264 | 283 | pPOEMS [18, 21] |
| Basic RCGA | **1** | **1.5** | **1.8** | 5.2 | 68 | 73 | 87 | 160 | 219 | 290 | Basic RCGA [25] |
| SPSA | 13 | 71 | 71 | 137 | 298 | 424 | 822 | 2207 | 7266 | *30e-4/1e5* | SPSA [14] |

Table 17: 02-D, running time excess ERT/ERT$_{\text{best 2009}}$ on $f_{17}$, in italics is given the median final function value and the median number of function evaluations to reach this value divided by dimension

**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$_{\text{best}}$/D | 0.50 | 0.50 | 1.3 | 30 | 66 | 138 | 198 | 372 | 543 | 828 | ERT$_{\text{best}}$/D |
| (1,2)-CMA-ES | **1** | **1.3** | 38 | 9.1 | 18 | 17 | 59 | 393 | *99e-5/1e4* | . | (1,2)-CMA-ES [5, 3] |
| (1,2m)-CMA-ES | **1** | **1.3** | 3.7 | **1.6** | 4.6 | 5.2 | 7.4 | 11 | 60 | 84 | (1,2m)-CMA-ES [5] |
| (1,2ms)-CMA-ES | **1** | **1.1** | **1.8** | **2.5** | **2.9** | 4.2 | 14 | 27 | 62 | 180 | (1,2ms)-CMA-ES [5] |
| (1,2s)-CMA-ES | **1** | **2.9** | 7.4 | 4.5 | 17 | 48 | 332 | *33e-4/1e4* | . | . | (1,2s)-CMA-ES [3] |
| (1,4)-CMA-ES | **1** | **1.3** | 3.8 | **2.0** | 3.6 | 3.1 | 5.0 | 5.7 | 13 | 39 | (1,4)-CMA-ES [6, 4] |
| (1,4m)-CMA-ES | **1** | **1.3** | 3.2 | **1.8** | **2.6** | **2.6** | **2.9** | 3.7 | 12 | 18 | (1,4m)-CMA-ES [6] |
| (1,4ms)-CMA-ES | **1.1** | **1.4** | **2.4** | 5.2 | 3.3 | **2.5** | 3.7 | 11 | 36 | 32 | (1,4ms)-CMA-ES [1, 6] |
| (1,4s)-CMA-ES | **1** | **1.3** | 6.2 | **1.8** | 3.7 | 5.3 | 10 | 27 | *30e-6/1e4* | . | (1,4s)-CMA-ES [4] |
| (1+1)-CMA-ES | **1** | **2.5** | 4.0 | 3.3 | 4.5 | 12 | 19 | 19 | 33 | 22 | (1+1)-CMA-ES [8] |
| (1+2ms)-CMA-ES | **1** | **1.9** | 3.1 | **1.7** | **2.2** | 4.0 | 3.0 | 4.3 | 5.6 | 3.7 | (1+2ms)-CMA-ES [2] |
| Artif Bee Colony | **1.0** | **1.3** | **2.2** | **2.5** | 6.7 | 10 | 94 | 231 | 436 | *29e-6/1e5* | Artif Bee Colony [9] |
| avg NEWUOA | **1.1** | **1.3** | 12 | 4.6 | 13 | 33 | 117 | *75e-4/5e3* | . | . | avg NEWUOA [24] |
| CMA-EGS (IPOP,r1) | 5.3 | 17 | 14 | 6.5 | 61 | 310 | 811 | 3768 | *14e-4/1e5* | . | CMA-EGS (IPOP,r1) [13] |
| Adap DE (F-AUC) | **1** | **1.1** | **2.9** | **1.9** | **2.5** | **2.0** | **2.1** | **1.5** | **1.3** | **1.2** | Adap DE (F-AUC) [11] |
| DE (Uniform) | **1** | **1.1** | **2.5** | **1.8** | **2.5** | **2.1** | **2.1** | **1.5** | **1.3** | **1.2** | DE (Uniform) [10] |
| IPOP-aCMA-ES | **1** | **1.3** | 5.4 | **2.6** | **2.2** | **1.8** | **1.5** | **1.2** | **1.3** | **1.1** | IPOP-aCMA-ES [17] |
| IPOP-CMA-ES | **1** | **1** | 19 | **2.4** | **2.0** | **1.6** | **1.7** | **1.4** | **1.5** | **1.1** | IPOP-CMA-ES [23] |
| CMA+DE-MOS | **1** | **1.5** | **2.2** | 4.9 | 6.6 | 5.0 | 5.0 | 3.3 | 3.1 | **2.6** | CMA+DE-MOS [19] |
| NBC-CMA | **1** | **1** | **1.9** | **2.8** | 4.6 | **3.0** | **2.5** | **1.7** | **1.5** | **2.1** | NBC-CMA [22] |
| POEMS | **1** | 66 | 130 | 18 | 33 | 28 | 32 | 24 | 21 | 19 | POEMS [18] |
| PM-AdapSS-DE | **1.1** | **1.2** | **2.5** | **1.6** | **2.2** | **2.0** | **2.1** | **1.5** | **1.4** | **1.2** | PM-AdapSS-DE [10, 11] |
| pPOEMS | **1** | **1.3** | 51 | 23 | 116 | 179 | 220 | 157 | 142 | 133 | pPOEMS [18, 21] |
| Basic RCGA | **1** | **1.2** | **2.9** | 5.0 | 47 | 61 | 103 | 77 | 124 | *23e-7/5e4* | Basic RCGA [25] |
| SPSA | 1935 | 16834 | 27903 | 1683 | 771 | 1105 | *17e-3/1e5* | . | . | . | SPSA [14] |

Table 18: 02-D, running time excess ERT/ERT$_{\text{best 2009}}$ on $f_{18}$, in italics is given the median final function value and the median number of function evaluations to reach this value divided by dimension

**18 Schaffer F7, condition 1000**

| Δftarget | 1e+03 | 1e+02 | 1e+01 | 1e+00 | 1e-01 | 1e-02 | 1e-03 | 1e-04 | 1e-05 | 1e-07 | Δftarget |
|---|---|---|---|---|---|---|---|---|---|---|---|
| ERT$_{\text{best}}$/D | 0.50 | 1.6 | 10 | 67 | 333 | 625 | 854 | 1036 | 1219 | 1429 | ERT$_{\text{best}}$/D |
| (1,2)-CMA-ES | **1.1** | 17 | 8.4 | 7.7 | 16 | 72 | 82 | 144 | *28e-3/1e4* | . | (1,2)-CMA-ES [5, 3] |
| (1,2m)-CMA-ES | **1.1** | 25 | 6.5 | 17 | 17 | 53 | 168 | 138 | *20e-3/1e4* | . | (1,2m)-CMA-ES [5] |
| (1,2ms)-CMA-ES | **1.5** | 4.3 | **1.7** | 8.2 | 7.8 | 23 | *13e-3/1e4* | . | . | . | (1,2ms)-CMA-ES [5] |
| (1,2s)-CMA-ES | **1.3** | 3.1 | 74 | 41 | 39 | *98e-3/1e4* | . | . | . | . | (1,2s)-CMA-ES [3] |
| (1,4)-CMA-ES | **1.1** | **2.4** | 3.5 | 10 | 8.1 | 10 | 11 | 22 | 119 | 102 | (1,4)-CMA-ES [6, 4] |
| (1,4m)-CMA-ES | **1.1** | 16 | 3.5 | 5.7 | 3.7 | 4.2 | 6.9 | 15 | 37 | 31 | (1,4m)-CMA-ES [6] |
| (1,4ms)-CMA-ES | **1.1** | **1.4** | **0.70** | 4.1 | **2.6** | 8.0 | 20 | 144 | *14e-4/1e4* | . | (1,4ms)-CMA-ES [1, 6] |
| (1,4s)-CMA-ES | **1.6** | **1.3** | **0.93** | 6.7 | 6.3 | 12 | 15 | 144 | *10e-4/1e4* | . | (1,4s)-CMA-ES [4] |
| (1+1)-CMA-ES | **1.7** | 8.1 | **2.4** | 10 | 17 | 33 | 172 | *16e-3/1e4* | . | . | (1+1)-CMA-ES [8] |
| (1+2ms)-CMA-ES | **1** | **1.3** | **1.3** | 7.6 | 12 | 39 | 173 | 143 | *16e-3/1e4* | . | (1+2ms)-CMA-ES [2] |
| Artif Bee Colony | **1.2** | **1.1** | **2.4** | 8.2 | 20 | 596 | 2565 | *20e-3/1e5* | . | . | Artif Bee Colony [9] |
| avg NEWUOA | **1.7** | 7.9 | 5.4 | 9.0 | 6.1 | 62 | *58e-3/6e3* | . | . | . | avg NEWUOA [24] |
| CMA-EGS (IPOP,r1) | 8.2 | 8.1 | 12 | 463 | 541 | *27e-2/1e5* | . | . | . | . | CMA-EGS (IPOP,r1) [13] |
| Adap DE (F-AUC) | **1.1** | **1.3** | **2.6** | **1.4** | **0.73** | **0.62** | **0.66** | **0.68** | **0.74** | **0.81** | Adap DE (F-AUC) [11] |
| DE (Uniform) | **1.1** | **0.98** | **2.9** | **1.8** | **0.77** | **0.63** | **0.63** | **0.65** | **0.71** | **0.80** | DE (Uniform) [10] |
| IPOP-aCMA-ES | **2.1** | **2.1** | **1.4** | 3.9 | **1.2** | **0.78** | **0.71** | **0.71** | **0.85** | **0.92** | IPOP-aCMA-ES [17] |
| IPOP-CMA-ES | **1** | **2.9** | 4.9 | 3.7 | **1.5** | **1.1** | **1.1** | **1.1** | **1.0** | **1.1** | IPOP-CMA-ES [23] |
| CMA+DE-MOS | **1.5** | **1.3** | **2.5** | 3.8 | **2.6** | **1.9** | **2.1** | **1.9** | **2.6** | **2.5** | CMA+DE-MOS [19] |
| NBC-CMA | **1.1** | **1.1** | **2.4** | 8.6 | **2.9** | **2.3** | **2.3** | **2.1** | **2.0** | **2.2** | NBC-CMA [22] |
| POEMS | 36 | 84 | 31 | 17 | 10 | 8.9 | 8.9 | 33 | 32 | 30 | POEMS [18] |
| PM-AdapSS-DE | **1.1** | **0.90** | **2.6** | **1.5** | **0.71** | **0.65** | **0.63** | **0.65** | **0.70** | **0.77** | PM-AdapSS-DE [10, 11] |
| pPOEMS | **1.1** | 11 | 29 | 37 | 56 | 57 | 63 | 70 | 77 | 94 | pPOEMS [18, 21] |
| Basic RCGA | **1.1** | **1.4** | **2.1** | 114 | 137 | 352 | 836 | *71e-3/5e4* | . | . | Basic RCGA [25] |
| SPSA | 24 | 6520 | 3903 | 2418 | 1211 | 2253 | *10e-1/1e5* | . | . | . | SPSA [14] |

Table 19: 02-D, running time excess ERT/ERT$_{\text{best 2009}}$ on $f_{19}$, in italics is given the median final function value and the median number of function evaluations to reach this value divided by dimension

**19 Griewank-Rosenbrock F8F2**

| Δftarget | 1e+03 | 1e+02 | 1e+01 | 1e+00 | 1e-01 | 1e-02 | 1e-03 | 1e-04 | 1e-05 | 1e-07 | Δftarget |
|---|---|---|---|---|---|---|---|---|---|---|---|
| ERT$_{\text{best}}$/D | 0.50 | 0.50 | 0.50 | 0.50 | 13 | 108 | 114 | 120 | 126 | 138 | ERT$_{\text{best}}$/D |
| (1,2)-CMA-ES | **1** | **1** | 3.9 | 128 | 18 | 21 | 31 | 44 | 52 | 49 | (1,2)-CMA-ES [5, 3] |
| (1,2m)-CMA-ES | **1** | **1.1** | **2.7** | **30** | 21 | 19 | 39 | 43 | 58 | 54 | (1,2m)-CMA-ES [5] |
| (1,2ms)-CMA-ES | **1** | **1.2** | 3.7 | 56 | 17 | 13 | 23 | 30 | 37 | 40 | (1,2ms)-CMA-ES [5] |
| (1,2s)-CMA-ES | **1** | **1** | **3.1** | 68 | 12 | 32 | 41 | 50 | 56 | 53 | (1,2s)-CMA-ES [3] |
| (1,4)-CMA-ES | **1** | **1.1** | 4.3 | **28** | 14 | 15 | 28 | 36 | 39 | 36 | (1,4)-CMA-ES [6, 4] |
| (1,4m)-CMA-ES | **1** | **1** | 4.8 | 35 | 11 | 9.1 | **10** | 17 | 16 | **15** | (1,4m)-CMA-ES [6] |
| (1,4ms)-CMA-ES | **1** | **1.2** | 6.3 | 42 | 12 | 17 | 25 | 28 | 27 | 29 | (1,4ms)-CMA-ES [1, 6] |
| (1,4s)-CMA-ES | **1** | **1** | 9.4 | 57 | 25 | 14 | 22 | 22 | 24 | 22 | (1,4s)-CMA-ES [4] |
| (1+1)-CMA-ES | **1** | **1** | **3.1** | 52 | 76 | 24 | 23 | 22 | 21 | 20 | (1+1)-CMA-ES [8] |
| (1+2ms)-CMA-ES | **1** | **1** | 4.7 | 50 | 16 | 13 | **12** | **12** | **11** | **10** | (1+2ms)-CMA-ES [2] |
| Artif Bee Colony | **1** | **1.1** | 6.1 | 56 | 11 | **7.7** | 16 | 37 | 73 | 882 | Artif Bee Colony [9] |
| avg NEWUOA | **1** | **1.3** | 8.0 | 106 | 13 | 22 | 21 | 20 | 19 | 18 | avg NEWUOA [24] |
| CMA-EGS (IPOP,r1) | 4.9 | 8.7 | 87 | 144 | 24 | 118 | 281 | 493 | 1300 | 2054 | CMA-EGS (IPOP,r1) [13] |
| Adap DE (F-AUC) | **1** | **1.3** | 6.5 | 63 | **8.3** | 147 | 143 | 138 | 132 | 122 | Adap DE (F-AUC) [11] |
| DE (Uniform) | **1** | **1.3** | 3.9 | 36 | 8.8 | 72 | 70 | 67 | 67 | 62 | DE (Uniform) [10] |
| IPOP-aCMA-ES | **1** | **1.4** | 5.1 | 32 | 9.2 | **8.7** | 14 | 19 | 19 | 18 | IPOP-aCMA-ES [17] |
| IPOP-CMA-ES | **1** | **1.1** | 6.3 | **22** | 9.0 | 17 | 17 | 18 | 18 | 17 | IPOP-CMA-ES [23] |
| CMA+DE-MOS | **1** | **1.1** | 3.8 | **30** | **6.7** | **1.9** | **3.1** | **4.0** | **5.0** | **5.4** | CMA+DE-MOS [19] |
| NBC-CMA | **1** | **1.3** | 5.4 | 36 | **7.9** | 11 | 13 | **16** | **16** | 18 | NBC-CMA [22] |
| POEMS | **1** | 102 | 310 | 549 | 46 | 464 | 451 | 432 | 415 | 389 | POEMS [18] |
| PM-AdapSS-DE | **1** | **2.1** | 5.5 | 43 | 10 | 341 | 327 | 312 | 299 | 276 | PM-AdapSS-DE [10, 11] |
| pPOEMS | **1** | **1.3** | 68 | 539 | 49 | 38 | 81 | 122 | 185 | 258 | pPOEMS [18, 21] |
| Basic RCGA | **1** | **1.1** | 5.7 | 47 | 8.9 | 18 | 22 | 71 | 107 | 453 | Basic RCGA [25] |
| SPSA | 20 | 67 | 573 | 982 | 202 | 889 | 1595 | 2506 | 11291 | *48e-4/1e5* | SPSA [14] |

Table 20: 02-D, running time excess ERT/ERT$_{\text{best 2009}}$ on $f_{20}$, in italics is given the median final function value and the median number of function evaluations to reach this value divided by dimension

**20 Schwefel x*sin(x)**

| Δftarget | 1e+03 | 1e+02 | 1e+01 | 1e+00 | 1e-01 | 1e-02 | 1e-03 | 1e-04 | 1e-05 | 1e-07 | Δftarget |
|---|---|---|---|---|---|---|---|---|---|---|---|
| ERT$_{\text{best}}$/D | 1.1 | 1.6 | 1.9 | 30 | 182 | 183 | 183 | 184 | 185 | 188 | ERT$_{\text{best}}$/D |
| (1,2)-CMA-ES | 6.4 | 4.8 | 6.0 | 15 | 24 | 37 | 37 | 37 | 37 | 37 | (1,2)-CMA-ES [5, 3] |
| (1,2m)-CMA-ES | **2.3** | **3.0** | 3.2 | 13 | 24 | 34 | 34 | 34 | 34 | 33 | (1,2m)-CMA-ES [5] |
| (1,2ms)-CMA-ES | **2.2** | **2.2** | **2.1** | 17 | 31 | 54 | 54 | 54 | 54 | 53 | (1,2ms)-CMA-ES [5] |
| (1,2s)-CMA-ES | 5.7 | 45 | 98 | 20 | 38 | 51 | 52 | 57 | 57 | 56 | (1,2s)-CMA-ES [3] |
| (1,4)-CMA-ES | 3.2 | 3.4 | 3.1 | 9.3 | 6.9 | 7.8 | 7.8 | 7.9 | 7.9 | 7.9 | (1,4)-CMA-ES [6, 4] |
| (1,4m)-CMA-ES | **1.8** | **2.3** | **2.4** | 10 | 12 | 13 | 13 | 13 | 13 | 13 | (1,4m)-CMA-ES [6] |
| (1,4ms)-CMA-ES | 3.2 | 3.6 | 3.7 | 11 | 14 | 15 | 17 | 17 | 17 | 17 | (1,4ms)-CMA-ES [1, 6] |
| (1,4s)-CMA-ES | **2.1** | **1.7** | **1.6** | 8.4 | 10 | 11 | 12 | 12 | 12 | 12 | (1,4s)-CMA-ES [4] |
| (1+1)-CMA-ES | **3.0** | 3.1 | 3.6 | 16 | 4.9 | 4.9 | **5.0** | **5.0** | **5.1** | **5.1** | (1+1)-CMA-ES [8] |
| (1+2ms)-CMA-ES | **1.6** | **1.7** | **1.7** | 11 | 4.8 | **4.9** | **4.9** | **5.0** | **5.0** | **5.0** | (1+2ms)-CMA-ES [2] |
| Artif Bee Colony | **2.1** | **2.6** | **2.6** | 4.6 | **2.2** | **4.1** | 6.0 | 7.8 | 10 | 16 | Artif Bee Colony [9] |
| avg NEWUOA | **3.0** | **2.2** | **2.1** | 10 | **4.0** | **4.0** | **4.0** | **4.0** | **4.0** | **3.9** | avg NEWUOA [24] |
| CMA-EGS (IPOP,r1) | 22 | 17 | 15 | 60 | 336 | 1100 | 3695 | *49e-3/1e5* | . | . | CMA-EGS (IPOP,r1) [13] |
| Adap DE (F-AUC) | **2.0** | **2.9** | **2.9** | **4.6** | 482 | 481 | 481 | 480 | 476 | 470 | Adap DE (F-AUC) [11] |
| DE (Uniform) | **1.8** | **2.9** | **2.9** | **4.2** | 276 | 276 | 276 | 276 | 274 | 270 | DE (Uniform) [10] |
| IPOP-aCMA-ES | **1.8** | **1.4** | **1.8** | 12 | 10 | 11 | 12 | 12 | 12 | 12 | IPOP-aCMA-ES [17] |
| IPOP-CMA-ES | 4.5 | 5.7 | 5.6 | 12 | 11 | 12 | 12 | 13 | 13 | 13 | IPOP-CMA-ES [23] |
| CMA+DE-MOS | **2.0** | **2.6** | 3.2 | 10 | **4.8** | 6.7 | 7.8 | 8.4 | 9.0 | 12 | CMA+DE-MOS [19] |
| NBC-CMA | **2.2** | 3.6 | 3.6 | 11 | 6.7 | 7.6 | 8.1 | 8.4 | 8.5 | 8.7 | NBC-CMA [22] |
| POEMS | 190 | 135 | 121 | 28 | 40 | 45 | 49 | 55 | 61 | 68 | POEMS [18] |
| PM-AdapSS-DE | 3.3 | **2.5** | **2.2** | **4.0** | 628 | 627 | 627 | 626 | 620 | 612 | PM-AdapSS-DE [10, 11] |
| pPOEMS | 75 | 101 | 92 | 45 | 43 | 83 | 132 | 185 | 228 | 301 | pPOEMS [18, 21] |
| Basic RCGA | **2.1** | 3.7 | 3.6 | 33 | 38 | 143 | 335 | 641 | 849 | 1182 | Basic RCGA [25] |
| SPSA | 65 | 78 | 101 | 9123 | 7680 | 7652 | 7654 | 7639 | *11e-1/1e5* | . | SPSA [14] |

Table 21: 02-D, running time excess ERT/ERT$_{\text{best 2009}}$ on $f_{21}$, in italics is given the median final function value and the median number of function evaluations to reach this value divided by dimension

**21 Gallagher 101 peaks**

| $\Delta$ftarget | 1e+03 | 1e+02 | 1e+01 | 1e+00 | 1e-01 | 1e-02 | 1e-03 | 1e-04 | 1e-05 | 1e-07 | $\Delta$ftarget |
|---|---|---|---|---|---|---|---|---|---|---|---|
| ERT$_{\text{best}}$/D | 0.50 | 0.50 | 0.83 | 25 | 87 | 138 | 145 | 153 | 162 | 165 | ERT$_{\text{best}}$/D |
| (1,2)-CMA-ES | **1** | **1** | **1.3** | 15 | 14 | 16 | 16 | 17 | 17 | 17 | (1,2)-CMA-ES [5, 3] |
| (1,2m)-CMA-ES | **1** | **1** | **1.6** | 7.6 | 8.8 | 8.7 | 13 | 17 | 17 | 16 | (1,2m)-CMA-ES [5] |
| (1,2ms)-CMA-ES | **1** | **1** | **1.8** | 5.5 | 13 | 13 | 16 | 16 | 15 | 15 | (1,2ms)-CMA-ES [5] |
| (1,2s)-CMA-ES | **1** | **1** | **1.5** | 20 | 14 | 13 | 20 | 21 | 20 | 20 | (1,2s)-CMA-ES [3] |
| (1,4)-CMA-ES | **1** | **1** | **1.4** | 8.9 | 5.8 | 4.4 | 4.4 | 4.2 | 4.1 | 4.1 | (1,4)-CMA-ES [6, 4] |
| (1,4m)-CMA-ES | **1** | **1** | **1.6** | 5.6 | 4.9 | 4.2 | 6.7 | 6.6 | 6.3 | 6.3 | (1,4m)-CMA-ES [6] |
| (1,4ms)-CMA-ES | **1** | **1** | **1.4** | 6.6 | 4.7 | 3.7 | **3.6** | **3.4** | **3.3** | **3.5** | (1,4ms)-CMA-ES [1, 6] |
| (1,4s)-CMA-ES | **1** | **1** | **1.4** | 9.3 | 7.6 | 6.0 | 5.7 | 5.5 | 5.2 | 5.2 | (1,4s)-CMA-ES [4] |
| (1+1)-CMA-ES | **1** | **1** | **1.6** | 12 | 11 | 7.2 | 6.9 | 6.5 | 6.2 | 6.2 | (1+1)-CMA-ES [8] |
| (1+2ms)-CMA-ES | **1** | **1** | **1.3** | 12 | 7.9 | 5.1 | 4.9 | 4.6 | 4.4 | 4.4 | (1+2ms)-CMA-ES [2] |
| Artif Bee Colony | **1** | **1** | **1.2** | **2.0** | **1.8** | **2.6** | 5.5 | 10 | 26 | 59 | Artif Bee Colony [9] |
| avg NEWUOA | **1** | **1** | 6.1 | 6.5 | 4.6 | **2.9** | **2.8** | **2.7** | **2.6** | **2.7** | avg NEWUOA [24] |
| CMA-EGS (IPOP,r1) | **1** | 7.5 | 12 | 23 | 34 | 75 | 96 | 201 | 234 | 500 | CMA-EGS (IPOP,r1) [13] |
| Adap DE (F-AUC) | **1** | **1** | **1.3** | 284 | 83 | 53 | 51 | 48 | 46 | 45 | Adap DE (F-AUC) [11] |
| DE (Uniform) | **1** | **1** | **1.5** | **2.1** | **1.0** | **1.1** | **1.5** | **1.6** | **1.6** | **2.0** | DE (Uniform) [10] |
| IPOP-aCMA-ES | **1** | **1** | **1.5** | 6.2 | 7.0 | 4.9 | 5.3 | 5.4 | 5.2 | 25 | IPOP-aCMA-ES [17] |
| IPOP-CMA-ES | **1** | **1** | **1.3** | 13 | 7.7 | 5.4 | 13 | 13 | 13 | 14 | IPOP-CMA-ES [23] |
| CMA+DE-MOS | **1** | **1** | **1.5** | **1.8** | **4.3** | 4.9 | 5.3 | 6.5 | 10 | 12 | CMA+DE-MOS [19] |
| NBC-CMA | **1** | **1** | **0.96** | **2.3** | 7.1 | 25 | 30 | 36 | 35 | 35 | NBC-CMA [22] |
| POEMS | **1** | **1** | 111 | 143 | 309 | 198 | 191 | 182 | 178 | 178 | POEMS [18] |
| PM-AdapSS-DE | **1** | **1** | **1.7** | **1.7** | 83 | 53 | 51 | 48 | 46 | 45 | PM-AdapSS-DE [10, 11] |
| pPOEMS | **1** | **1** | **1.8** | 17 | 8.0 | 14 | 25 | 44 | 60 | 105 | pPOEMS [18, 21] |
| Basic RCGA | **1** | **1** | **1.4** | 14 | 13 | 34 | 71 | 96 | 197 | 285 | Basic RCGA [25] |
| SPSA | **1** | 21 | 47 | 94 | 266 | 218 | 223 | 297 | 320 | 753 | SPSA [14] |

Table 22: 02-D, running time excess ERT/ERT$_{\text{best 2009}}$ on $f_{22}$, in italics is given the median final function value and the median number of function evaluations to reach this value divided by dimension

**22 Gallagher 21 peaks**

| Δftarget | 1e+03 | 1e+02 | 1e+01 | 1e+00 | 1e-01 | 1e-02 | 1e-03 | 1e-04 | 1e-05 | 1e-07 | Δftarget |
|---|---|---|---|---|---|---|---|---|---|---|---|
| ERT$_{\text{best}}$/D | 0.50 | 0.50 | 2.5 | 13 | 84 | 109 | 125 | 142 | 144 | 153 | ERT$_{\text{best}}$/D |
| (1,2)-CMA-ES | **1** | **1** | **2.1** | 17 | 6.1 | 9.1 | 8.6 | 8.3 | 12 | 12 | (1,2)-CMA-ES [5, 3] |
| (1,2m)-CMA-ES | **1** | **1** | **1.4** | 34 | 19 | 24 | 25 | 22 | 23 | 22 | (1,2m)-CMA-ES [5] |
| (1,2ms)-CMA-ES | **1** | **1** | **1.3** | 15 | 10 | 11 | 14 | 20 | 23 | 22 | (1,2ms)-CMA-ES [5] |
| (1,2s)-CMA-ES | **1** | **1** | **1.6** | 31 | 18 | 18 | 23 | 28 | 31 | 30 | (1,2s)-CMA-ES [3] |
| (1,4)-CMA-ES | **1** | **1** | **2.2** | 10 | 8.3 | 7.0 | 6.5 | 5.9 | 6.6 | 6.3 | (1,4)-CMA-ES [6, 4] |
| (1,4m)-CMA-ES | **1** | **1** | **1.6** | 14 | 11 | 11 | 11 | 10 | 9.5 | 9.1 | (1,4m)-CMA-ES [6] |
| (1,4ms)-CMA-ES | **1** | **1** | 3.2 | 19 | 6.5 | 5.7 | 5.3 | 4.7 | 4.6 | 4.4 | (1,4ms)-CMA-ES [1, 6] |
| (1,4s)-CMA-ES | **1** | **1** | **1.5** | 16 | 5.1 | 6.0 | 5.5 | 4.9 | 5.3 | 5.1 | (1,4s)-CMA-ES [4] |
| (1+1)-CMA-ES | **1** | **1** | 6.6 | 19 | 4.4 | 3.6 | 3.3 | **3.0** | **3.0** | **2.9** | (1+1)-CMA-ES [8] |
| (1+2ms)-CMA-ES | **1** | **1** | **1** | 8.5 | 4.4 | **3.5** | **3.2** | **2.8** | **2.8** | **2.7** | (1+2ms)-CMA-ES [2] |
| Artif Bee Colony | **1** | **1** | **1.4** | **2.7** | **2.8** | 4.2 | 8.9 | 21 | 47 | 373 | Artif Bee Colony [9] |
| avg NEWUOA | **1** | **1** | **3.0** | 3.8 | **1.3** | **1.1** | **1.1** | **1.1** | **1.1** | **1.3** | avg NEWUOA [24] |
| CMA-EGS (IPOP,r1) | **1** | 8.5 | 4.8 | 12 | 34 | 50 | 119 | 184 | 274 | 760 | CMA-EGS (IPOP,r1) [13] |
| Adap DE (F-AUC) | **1** | **1** | **1.9** | **2.2** | 184 | 143 | 125 | 110 | 108 | 103 | Adap DE (F-AUC) [11] |
| DE (Uniform) | **1** | **1** | **1.3** | **2.2** | **1.0** | **1.3** | **1.5** | **1.7** | **1.8** | **2.2** | DE (Uniform) [10] |
| IPOP-aCMA-ES | **1** | **1** | **1.2** | 4.7 | 5.5 | 4.7 | 7.7 | 7.2 | 7.2 | 15 | IPOP-aCMA-ES [17] |
| IPOP-CMA-ES | **1** | **1** | **1.6** | 5.9 | 5.0 | 5.0 | 4.8 | 5.3 | 23 | 72 | IPOP-CMA-ES [23] |
| CMA+DE-MOS | **1** | **1** | **1.2** | 3.7 | **2.9** | 3.8 | 4.7 | 5.2 | 6.2 | 8.4 | CMA+DE-MOS [19] |
| NBC-CMA | **1** | **1** | **1.3** | **2.2** | 8.4 | 21 | 31 | 28 | 28 | 28 | NBC-CMA [22] |
| POEMS | **1** | **1** | 66 | 31 | 604 | 467 | 412 | 365 | 364 | 350 | POEMS [18] |
| PM-AdapSS-DE | **1** | **1** | **1.5** | **2.4** | 86 | 67 | 59 | 52 | 51 | 49 | PM-AdapSS-DE [10, 11] |
| pPOEMS | **1** | **1** | 39 | 26 | 17 | 32 | 44 | 58 | 70 | 129 | pPOEMS [18, 21] |
| Basic RCGA | **1** | **1** | **1.4** | **2.1** | 11 | 25 | 69 | 119 | 232 | 604 | Basic RCGA [25] |
| SPSA | **1** | 22 | 107 | 284 | 373 | 750 | 1930 | 9991 | 9800 | *38e-4/1e5* | SPSA [14] |

Table 23: 02-D, running time excess $\mathrm{ERT}/\mathrm{ERT}_{\mathrm{best\ 2009}}$ on $f_{23}$, in italics is given the median final function value and the median number of function evaluations to reach this value divided by dimension

**23 Katsuuras**

| Δftarget | 1e+03 | 1e+02 | 1e+01 | 1e+00 | 1e-01 | 1e-02 | 1e-03 | 1e-04 | 1e-05 | 1e-07 | Δftarget |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $\mathrm{ERT}_{\mathrm{best}}/\mathrm{D}$ | 0.50 | 0.50 | 3.9 | 96 | 117 | 131 | 150 | 157 | 174 | 190 | $\mathrm{ERT}_{\mathrm{best}}/\mathrm{D}$ |
| (1,2)-CMA-ES | **1** | **1** | **1.5** | 22 | 214 | 253 | 222 | 213 | 192 | 243 | (1,2)-CMA-ES [5, 3] |
| (1,2m)-CMA-ES | **1** | **1** | 4.2 | 10 | 76 | 81 | 71 | 68 | 62 | 57 | (1,2m)-CMA-ES [5] |
| (1,2ms)-CMA-ES | **1** | **1** | **2.2** | 18 | 90 | 99 | 90 | 86 | 78 | 72 | (1,2ms)-CMA-ES [5] |
| (1,2s)-CMA-ES | **1** | **1** | **1.6** | 14 | 103 | 225 | 288 | 276 | 249 | 770 | (1,2s)-CMA-ES [3] |
| (1,4)-CMA-ES | **1** | **1** | **2.1** | 11 | 23 | 23 | 27 | 26 | 24 | 22 | (1,4)-CMA-ES [6, 4] |
| (1,4m)-CMA-ES | **1** | **1** | 3.8 | 13 | 19 | 17 | 15 | 15 | 13 | 13 | (1,4m)-CMA-ES [6] |
| (1,4ms)-CMA-ES | **1** | **1** | 4.5 | 8.5 | 13 | 13 | 12 | **12** | **11** | **10** | (1,4ms)-CMA-ES [1, 6] |
| (1,4s)-CMA-ES | **1** | **1** | **2.2** | 14 | 29 | 29 | 26 | 25 | 22 | 21 | (1,4s)-CMA-ES [4] |
| (1+1)-CMA-ES | **1** | **1** | 8.2 | 3.1 | **4.5** | **4.5** | **4.5** | **6.1** | **5.6** | **5.4** | (1+1)-CMA-ES [8] |
| (1+2ms)-CMA-ES | **1** | **1** | **2.0** | **2.2** | 6.7 | 14 | 14 | 13 | **12** | **11** | (1+2ms)-CMA-ES [2] |
| Artif Bee Colony | **1** | **1** | **2.1** | 15 | 1791 | *13e-2/1e5* | . | . | . | . | Artif Bee Colony [9] |
| avg NEWUOA | **1** | **1** | 4.2 | 6.7 | 25 | 103 | 262 | *49e-3/6e3* | . | . | avg NEWUOA [24] |
| CMA-EGS (IPOP,r1) | **1** | **2.5** | 4.0 | 12 | 2604 | *17e-2/1e5* | . | . | . | . | CMA-EGS (IPOP,r1) [13] |
| Adap DE (F-AUC) | **1** | **1** | **1.8** | **2.4** | **5.4** | **7.6** | **9.3** | **11** | 13 | 15 | Adap DE (F-AUC) [11] |
| DE (Uniform) | **1** | **1** | **2.5** | **2.3** | 6.0 | **8.2** | 10 | 12 | 13 | 16 | DE (Uniform) [10] |
| IPOP-aCMA-ES | **1** | **1** | **2.8** | 6.6 | 16 | 19 | 17 | 16 | 15 | 14 | IPOP-aCMA-ES [17] |
| IPOP-CMA-ES | **1** | **1** | **1.9** | 7.8 | 162 | 233 | 204 | 196 | 177 | 162 | IPOP-CMA-ES [23] |
| CMA+DE-MOS | **1** | **1** | **2.0** | 5.5 | 24 | 40 | 44 | 46 | 43 | 42 | CMA+DE-MOS [19] |
| NBC-CMA | **1** | **1** | **1.8** | 10 | 737 | 761 | 668 | 639 | 576 | 529 | NBC-CMA [22] |
| POEMS | **1** | **1** | 13 | 41 | 253 | 245 | 233 | 234 | 225 | 230 | POEMS [18] |
| PM-AdapSS-DE | **1** | **1** | **2.0** | **1.9** | **5.8** | 8.5 | **10** | 12 | 13 | 16 | PM-AdapSS-DE [10, 11] |
| pPOEMS | **1** | **1** | 11 | 61 | 659 | 866 | 996 | 1160 | 1199 | 1404 | pPOEMS [18, 21] |
| Basic RCGA | **1** | **1** | **1.9** | 5.2 | 256 | 889 | 4692 | 4487 | *29e-3/5e4* | . | Basic RCGA [25] |
| SPSA | **1** | 13 | 18 | 264 | *49e-2/1e5* | . | . | . | . | . | SPSA [14] |

Table 24: 02-D, running time excess ERT/$\text{ERT}_{\text{best 2009}}$ on $f_{24}$, in italics is given the median final function value and the median number of function evaluations to reach this value divided by dimension

**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 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $\text{ERT}_{\text{best}}$/D | 0.50 | 0.50 | 9.1 | 429 | 4257 | 11700 | 12056 | 12360 | 12360 | 12360 | $\text{ERT}_{\text{best}}$/D |
| (1,2)-CMA-ES | **1** | **1** | 6.6 | 12 | *40e-2/1e4* | . | . | . | . | . | (1,2)-CMA-ES [5, 3] |
| (1,2m)-CMA-ES | **1** | **1** | **1.5** | 5.7 | 35 | *43e-2/1e4* | . | . | . | . | (1,2m)-CMA-ES [5] |
| (1,2ms)-CMA-ES | **1** | **1** | **1.3** | 7.8 | 33 | *46e-2/1e4* | . | . | . | . | (1,2ms)-CMA-ES [5] |
| (1,2s)-CMA-ES | **1** | **1** | **2.3** | 19 | 35 | 13 | 12 | 12 | 12 | 12 | (1,2s)-CMA-ES [3] |
| (1,4)-CMA-ES | **1** | **1** | **1.2** | 8.6 | 17 | *22e-2/1e4* | . | . | . | . | (1,4)-CMA-ES [6, 4] |
| (1,4m)-CMA-ES | **1** | **1** | **2.4** | 4.6 | **3.3** | 5.8 | 5.7 | 5.5 | 5.5 | 5.5 | (1,4m)-CMA-ES [6] |
| (1,4ms)-CMA-ES | **1** | **1** | **2.8** | 5.9 | 5.7 | **3.9** | **3.8** | **3.7** | **3.7** | **3.7** | (1,4ms)-CMA-ES [1, 6] |
| (1,4s)-CMA-ES | **1** | **1** | **1.6** | 4.9 | 7.8 | 12 | 12 | 12 | 12 | 12 | (1,4s)-CMA-ES [4] |
| (1+1)-CMA-ES | **1** | **1** | 36 | 6.0 | 7.5 | **2.7** | **2.6** | **2.6** | **2.6** | **2.6** | (1+1)-CMA-ES [8] |
| (1+2ms)-CMA-ES | **1** | **1** | 4.2 | **4.0** | **5.3** | 12 | 12 | 12 | 12 | 12 | (1+2ms)-CMA-ES [2] |
| Artif Bee Colony | **1** | **1** | **2.1** | 4.2 | 16 | 122 | *62e-3/1e5* | . | . | . | Artif Bee Colony [9] |
| avg NEWUOA | **1** | **1** | 3.3 | **1.9** | **1.4** | 6.2 | 6.0 | 5.9 | 5.9 | 5.9 | avg NEWUOA [24] |
| CMA-EGS (IPOP,r1) | 19 | 19 | 3.9 | 48 | 60 | *16e-2/1e5* | . | . | . | . | CMA-EGS (IPOP,r1) [13] |
| Adap DE (F-AUC) | **1** | **1** | **1.5** | 934 | 94 | 34 | 33 | 32 | 32 | 32 | Adap DE (F-AUC) [11] |
| DE (Uniform) | **1** | **1** | **2.2** | 351 | 35 | 17 | 17 | 16 | 16 | 16 | DE (Uniform) [10] |
| IPOP-aCMA-ES | **1** | **1** | **1.6** | 80 | 374 | 477 | 463 | 452 | 452 | 452 | IPOP-aCMA-ES [17] |
| IPOP-CMA-ES | **1** | **1** | **1.2** | 27 | 375 | *31e-2/4e5* | . | . | . | . | IPOP-CMA-ES [23] |
| CMA+DE-MOS | **1** | **1** | **1.7** | **3.7** | 6.5 | **3.1** | **3.9** | **4.1** | **4.2** | **5.0** | CMA+DE-MOS [19] |
| NBC-CMA | **1** | **1** | **1.9** | 48 | 32 | 24 | 28 | 37 | 37 | 37 | NBC-CMA [22] |
| POEMS | **1** | **1** | 28 | 4554 | 481 | 176 | 171 | 167 | 167 | 167 | POEMS [18] |
| PM-AdapSS-DE | **1** | **1** | **1.8** | 351 | 35 | 13 | 13 | 12 | 12 | 12 | PM-AdapSS-DE [10, 11] |
| pPOEMS | **1** | **1.1** | 23 | 507 | 56 | 27 | 27 | 27 | 28 | 29 | pPOEMS [18, 21] |
| Basic RCGA | **1** | **1** | **2.4** | 73 | 78 | 61 | 59 | 58 | 58 | 58 | Basic RCGA [25] |
| SPSA | 41 | 51 | 1717 | *31e-1/1e5* | . | . | . | . | . | . | SPSA [14] |

# 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 [20], 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 [20], 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 [20], 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 [20], 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 [20], 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 [20], pages 1559–1566.

[7] Anne Auger, Steffen Finck, Nikolaus Hansen, and Raymond Ros. BBOB 2009: Comparison tables of all algorithms on all noiseless functions. Technical Report RT-0383, INRIA, April 2010.

[8] 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.

[9] Mohammed El-Abd. Black-box optimization benchmarking for noiseless function testbed using artificial bee colony algorithm. In Pelikan and Branke [20], pages 1719–1724.

[10] 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 [20], pages 1527–1534.

[11] 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 [20], pages 1535–1542.

[12] 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.

[13] Steffen Finck and Hans-Georg Beyer. Benchmarking CMA-EGS on the BBOB 2010 noiseless function testbed. In Pelikan and Branke [20], pages 1633–1640.

[14] Steffen Finck and Hans-Georg Beyer. Benchmarking SPSA on BBOB-2010 noiseless function testbed. In Pelikan and Branke [20], pages 1657–1664.

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

[16] 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.

[17] Nikolaus Hansen and Raymond Ros. Benchmarking a weighted negative covariance matrix update on the BBOB-2010 noiseless testbed. In Pelikan and Branke [20], pages 1673–1680.

[18] Jirí Kubalík. Black-box optimization benchmarking of two variants of the POEMS algorithm on the noiseless testbed. In Pelikan and Branke [20], pages 1567–1574.

[19] Antonio LaTorre, Santiago Muelas, and José María Peña. Benchmarking a MOS-based algorithm on the BBOB-2010 noiseless function testbed. In Pelikan and Branke [20], pages 1649–1656.

[20] 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.

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

[22] Mike Preuss. Niching the CMA-ES via nearest-better clustering. In Pelikan and Branke [20], pages 1711–1718.

[23] Raymond Ros. Black-box optimization benchmarking the IPOP-CMA-ES on the noiseless testbed: comparison to the BIPOP-CMA-ES. In Pelikan and Branke [20], pages 1503–1510.

[24] Raymond Ros. Comparison of NEWUOA with different numbers of interpolation points on the BBOB noiseless testbed. In Pelikan and Branke [20], pages 1487–1494.

[25] Thanh-Do Tran and Gang-Gyoo Jin. Real-coded genetic algorithm benchmarked on noiseless black-box optimization testbed. In Pelikan and Branke [20], pages 1731–1738.