# Comparison tables: BBOB 2010 noisy testbed in 2-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 [10, 6]. The experimental set-up is described in [9].

The performance measure provided in the following tables is the expected number of objective function evaluations to reach a given target function value (ERT, expected running time), divided by the respective value for the best algorithm. Consequently, the best (smallest) value is 1 and the value 1 appears in each column at least once. See [9] 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 $\mathrm{ERT}/\mathrm{ERT}_{\mathrm{best}}$ 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**

| $\Delta$ftarget | 1e+03 | 1e+02 | 1e+01 | 1e+00 | 1e-01 | 1e-02 | 1e-03 | 1e-04 | 1e-05 | 1e-07 | $\Delta$ftarget |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $\mathrm{ERT}_{\mathrm{best}}$/D | 0.50 | 0.50 | 2.1 | 5.6 | 10 | 13 | 14 | 16 | 17 | 18 | $\mathrm{ERT}_{\mathrm{best}}$/D |
| (1,2)-CMA-ES | **1** | **1** | **1.7** | **1.8** | **2.0** | **2.8** | 4.1 | 5.0 | 5.7 | 7.2 | (1,2)-CMA-ES [4, 2] |
| (1,2m)-CMA-ES | **1** | **1** | **1.6** | **1.7** | **2.3** | 3.2 | 4.2 | 4.6 | 6.1 | 7.6 | (1,2m)-CMA-ES [4] |
| (1,2ms)-CMA-ES | **1** | **1** | **1.0** | **1** | **2.1** | 3.0 | 3.6 | 4.2 | 5.2 | 6.8 | (1,2ms)-CMA-ES [4] |
| (1,2s)-CMA-ES | **1** | **1** | **2.0** | **2.3** | 3.1 | 3.6 | 6.8 | 7.2 | 8.3 | 9.4 | (1,2s)-CMA-ES [2] |
| (1,4)-CMA-ES | **1** | **1** | **2.2** | **1.8** | **2.4** | **3.0** | 3.5 | 4.1 | 4.6 | 5.6 | (1,4)-CMA-ES [5, 3] |
| (1,4m)-CMA-ES | **1** | **1** | **1.4** | **1.2** | **1.6** | **2.3** | 3.1 | 3.5 | 4.2 | 5.1 | (1,4m)-CMA-ES [5] |
| (1,4ms)-CMA-ES | **1** | **1** | **1.4** | **1.2** | **1.4** | **1.8** | **2.4** | **2.8** | **3.0** | **3.8** | (1,4ms)-CMA-ES [1, 5] |
| (1,4s)-CMA-ES | **1** | **1** | **2.0** | **1.8** | **1.6** | **2.3** | **2.8** | 3.4 | 3.5 | 4.5 | (1,4s)-CMA-ES [3] |
| avg NEWUOA | **1** | **1** | **1.4** | **1.2** | **1.0** | **1.0** | **1** | **1** | **1** | **1** | avg NEWUOA [15] |
| CMA-EGS (IPOP,r1) | 10 | 13 | 6.1 | 6.6 | 6.0 | 8.0 | 20 | 26 | 53 | 1541 | CMA-EGS (IPOP,r1) [7] |
| IPOP-aCMA-ES | **1** | **1** | **2.3** | **1.8** | **1.8** | 3.3 | 4.1 | 4.7 | 5.7 | 7.1 | IPOP-aCMA-ES [11] |
| IPOP-CMA-ES | **1** | **1** | **1.5** | **2.3** | **2.8** | 3.2 | 4.2 | 4.9 | 6.3 | 7.5 | IPOP-CMA-ES [14] |
| CMA+DE-MOS | **1** | **1** | **1.0** | **2.2** | 5.0 | 10 | 15 | 19 | 22 | 28 | CMA+DE-MOS [12] |
| NEWUOA | **1** | **1** | **1.1** | **1.3** | **1** | **1** | **1.2** | **1.2** | **1.2** | **1.2** | NEWUOA [15] |
| Basic RCGA | **1** | **1** | **1** | **2.3** | 16 | 27 | 33 | 46 | 64 | 118 | Basic RCGA [16] |
| SPSA | 24 | 41 | 75 | 113 | 135 | 391 | 381 | 365 | 365 | 395 | SPSA [8] |

Table 2: 02-D, running time excess $\mathrm{ERT}/\mathrm{ERT}_{\mathrm{best}}$ 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**

| $\Delta$ftarget | 1e+03 | 1e+02 | 1e+01 | 1e+00 | 1e-01 | 1e-02 | 1e-03 | 1e-04 | 1e-05 | 1e-07 | $\Delta$ftarget |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $\mathrm{ERT}_{\mathrm{best}}$/D | 0.50 | 0.50 | 1.8 | 7.4 | 14 | 25 | 35 | 41 | 42 | 44 | $\mathrm{ERT}_{\mathrm{best}}$/D |
| (1,2)-CMA-ES | **1** | **1** | **2.8** | **1.5** | **2.0** | **1.9** | **1.8** | **2.3** | **2.7** | 3.5 | (1,2)-CMA-ES [4, 2] |
| (1,2m)-CMA-ES | **1** | **1** | **1.7** | **1.3** | **1.2** | **1.6** | **1.8** | **1.9** | **2.2** | 3.1 | (1,2m)-CMA-ES [4] |
| (1,2ms)-CMA-ES | **1** | **1** | **1.6** | **1.0** | **1.6** | **1.7** | **1.7** | **1.9** | **2.3** | 3.1 | (1,2ms)-CMA-ES [4] |
| (1,2s)-CMA-ES | **1** | **1** | **1.6** | **1.3** | **1.6** | **1.7** | **2.0** | **2.1** | **2.8** | 4.3 | (1,2s)-CMA-ES [2] |
| (1,4)-CMA-ES | **1** | **1** | **2.0** | **1.3** | **1.5** | **1.4** | **1.4** | **1.5** | **1.6** | **2.3** | (1,4)-CMA-ES [5, 3] |
| (1,4m)-CMA-ES | **1** | **1** | **2.0** | **1.1** | **1.2** | **1.4** | **1.3** | **1.5** | **1.8** | **2.3** | (1,4m)-CMA-ES [5] |
| (1,4ms)-CMA-ES | **1** | **1** | **1.6** | **1.2** | **1** | **1** | **1** | **1.0** | **1.3** | **1.6** | (1,4ms)-CMA-ES [1, 5] |
| (1,4s)-CMA-ES | **1** | **1** | **1.7** | **1.1** | **1.2** | **1.0** | **1.1** | **1.1** | **1.3** | **1.8** | (1,4s)-CMA-ES [3] |
| avg NEWUOA | **1** | **1.2** | **2.0** | **1** | **1.0** | **1.5** | **1.1** | **1** | **1** | **1** | avg NEWUOA [15] |
| CMA-EGS (IPOP,r1) | 13 | 16 | 8.2 | 3.4 | 15 | 12 | 13 | 12 | 207 | 1347 | CMA-EGS (IPOP,r1) [7] |
| IPOP-aCMA-ES | **1** | **1** | **2.1** | **1.6** | **2.3** | **1.9** | **1.9** | **2.2** | **2.4** | 3.2 | IPOP-aCMA-ES [11] |
| IPOP-CMA-ES | **1** | **1** | **1.4** | **1.6** | **2.2** | **1.7** | **1.6** | **2.0** | **2.3** | **3.0** | IPOP-CMA-ES [14] |
| CMA+DE-MOS | **1** | **1** | **1.2** | **2.0** | 4.1 | 5.6 | 6.7 | 7.2 | 9.5 | 12 | CMA+DE-MOS [12] |
| NEWUOA | **1** | **1** | 3.6 | 5.2 | 3.6 | **2.3** | **1.8** | **1.6** | **1.5** | **1.5** | NEWUOA [15] |
| Basic RCGA | **1** | **1** | **1** | **1.6** | 9.2 | 15 | 15 | 20 | 30 | 51 | Basic RCGA [16] |
| SPSA | 9.1 | 16 | 14 | 113 | 103 | 85 | 69 | 238 | 256 | 1437 | SPSA [8] |

Table 3: 02-D, running time excess $\mathrm{ERT}/\mathrm{ERT}_{\mathrm{best}}$ 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**

| $\Delta$ftarget | 1e+03 | 1e+02 | 1e+01 | 1e+00 | 1e-01 | 1e-02 | 1e-03 | 1e-04 | 1e-05 | 1e-07 | $\Delta$ftarget |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $\mathrm{ERT}_{\mathrm{best}}$/D | 0.50 | 0.50 | 1.4 | 6.0 | 10 | 14 | 19 | 22 | 31 | 47 | $\mathrm{ERT}_{\mathrm{best}}$/D |
| (1,2)-CMA-ES | **1** | **1** | **2.2** | **2.2** | **2.5** | 3.1 | 3.3 | 3.9 | 3.5 | 3.3 | (1,2)-CMA-ES [4, 2] |
| (1,2m)-CMA-ES | **1** | **1** | **2.0** | **1.2** | **1.9** | **2.7** | 3.1 | 3.6 | 3.1 | 3.1 | (1,2m)-CMA-ES [4] |
| (1,2ms)-CMA-ES | **1** | **1** | **1.6** | **1.3** | **2.0** | **2.7** | **2.9** | 3.3 | **3.0** | **2.9** | (1,2ms)-CMA-ES [4] |
| (1,2s)-CMA-ES | **1** | **1** | **2.0** | **2.1** | 3.5 | 3.3 | 3.3 | 3.6 | 3.3 | 3.3 | (1,2s)-CMA-ES [2] |
| (1,4)-CMA-ES | **1** | **1** | **2.6** | **1.4** | **2.1** | **2.2** | **2.3** | **2.7** | **2.4** | **2.3** | (1,4)-CMA-ES [5, 3] |
| (1,4m)-CMA-ES | **1** | **1** | **1.8** | **1** | **1.7** | **2.1** | **2.2** | **2.6** | **2.2** | **2.1** | (1,4m)-CMA-ES [5] |
| (1,4ms)-CMA-ES | **1** | **1** | **1.5** | **1.1** | **1.3** | **1.6** | **1.7** | **1.9** | **1.7** | **1.6** | (1,4ms)-CMA-ES [1, 5] |
| (1,4s)-CMA-ES | **1** | **1** | **2.8** | **1.5** | **1.7** | **1.8** | **2.0** | **2.2** | **2.0** | **1.8** | (1,4s)-CMA-ES [3] |
| avg NEWUOA | **1** | **1** | **2.0** | **1.2** | **1.0** | **1** | **1** | **1** | **1.1** | **1** | avg NEWUOA [15] |
| CMA-EGS (IPOP,r1) | 12 | 19 | 12 | 4.5 | 5.6 | 6.5 | 8.5 | 17 | 13 | 27 | CMA-EGS (IPOP,r1) [7] |
| IPOP-aCMA-ES | **1** | **1** | **2.1** | **1.6** | **2.1** | **2.8** | **2.9** | 3.6 | 3.2 | 3.0 | IPOP-aCMA-ES [11] |
| IPOP-CMA-ES | **1** | **1** | **2.5** | **2.2** | **2.7** | **2.9** | 3.3 | 3.8 | 3.5 | 3.3 | IPOP-CMA-ES [14] |
| CMA+DE-MOS | **1** | **1** | **1.6** | **1.7** | 6.4 | 10 | 13 | 14 | 13 | 14 | CMA+DE-MOS [12] |
| NEWUOA | **1** | **1** | **2.1** | **1.0** | **1** | **1.0** | **1.0** | **1.1** | **1** | **1.1** | NEWUOA [15] |
| Basic RCGA | **1** | **1** | **1** | **2.5** | 10 | 17 | 27 | 38 | 42 | 62 | Basic RCGA [16] |
| SPSA | 22 | 38 | 237 | 128 | 124 | 126 | 361 | 918 | 1785 | 1794 | SPSA [8] |

Table 4: 02-D, running time excess $\mathrm{ERT}/\mathrm{ERT}_{\mathrm{best}}$ 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**

| Δftarget | 1e+03 | 1e+02 | 1e+01 | 1e+00 | 1e-01 | 1e-02 | 1e-03 | 1e-04 | 1e-05 | 1e-07 | Δftarget |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $\mathrm{ERT}_{\mathrm{best}}$/D | 1.5 | 2.5 | 7.9 | 42 | 113 | 212 | 242 | 260 | 271 | 297 | $\mathrm{ERT}_{\mathrm{best}}$/D |
| (1,2)-CMA-ES | **1.7** | 3.3 | **2.6** | 4.9 | 7.9 | 8.9 | 10 | 9.5 | 9.5 | 13 | (1,2)-CMA-ES [4, 2] |
| (1,2m)-CMA-ES | **1** | 3.2 | **2.0** | 3.7 | 4.2 | 4.9 | 5.1 | 5.0 | 4.9 | 4.7 | (1,2m)-CMA-ES [4] |
| (1,2ms)-CMA-ES | **1.3** | **1.5** | **1.7** | **2.4** | 3.8 | 4.8 | 5.6 | 5.7 | 5.9 | 5.8 | (1,2ms)-CMA-ES [4] |
| (1,2s)-CMA-ES | 4.4 | 3.8 | 3.1 | 6.4 | 10 | 13 | 15 | 28 | 28 | 33 | (1,2s)-CMA-ES [2] |
| (1,4)-CMA-ES | **1.7** | **2.8** | **2.3** | **2.2** | **2.4** | **1.6** | **1.6** | **1.6** | **1.6** | **1.5** | (1,4)-CMA-ES [5, 3] |
| (1,4m)-CMA-ES | **1.8** | **2.5** | **1.9** | 3.1 | **2.0** | **1.4** | **1.3** | **1.3** | **1.3** | **1.3** | (1,4m)-CMA-ES [5] |
| (1,4ms)-CMA-ES | **1.0** | **1** | **1** | **1.3** | **1.5** | **1** | **1** | **1** | **1** | **1** | (1,4ms)-CMA-ES [1, 5] |
| (1,4s)-CMA-ES | **1.1** | **1.3** | **1.2** | **2.0** | **2.5** | **2.1** | **2.0** | **1.9** | **1.9** | **1.8** | (1,4s)-CMA-ES [3] |
| avg NEWUOA | **2.1** | **2.2** | **1.5** | **1.3** | **1.1** | **2.0** | **2.7** | 3.1 | 3.2 | 3.8 | avg NEWUOA [15] |
| CMA-EGS (IPOP,r1) | 18 | 14 | 6.9 | 3.3 | 22 | 41 | 102 | 95 | 144 | 174 | CMA-EGS (IPOP,r1) [7] |
| IPOP-aCMA-ES | **1.1** | **1.7** | **1.2** | **1** | **1** | **1.0** | **1.1** | **1.1** | **1.1** | **1.2** | IPOP-aCMA-ES [11] |
| IPOP-CMA-ES | **2.1** | **2.6** | **1.7** | **2.5** | **2.3** | **1.8** | **2.0** | **2.0** | **2.1** | **2.0** | IPOP-CMA-ES [14] |
| CMA+DE-MOS | **1.1** | **1.8** | **2.2** | **1.9** | **2.6** | **2.4** | **2.6** | **2.8** | 3.1 | 3.3 | CMA+DE-MOS [12] |
| NEWUOA | **2.9** | **2.3** | **2.2** | **2.3** | **2.9** | 3.7 | 5.2 | 6.1 | 5.9 | 5.6 | NEWUOA [15] |
| Basic RCGA | **1.3** | **1.6** | **2.6** | 3.2 | 29 | 50 | 125 | 249 | 806 | *10e-5/5e4* | Basic RCGA [16] |
| SPSA | 244 | 232 | 287 | 294 | 3694 | *39e-2/1e5* | . | . | . | . | SPSA [8] |

Table 5: 02-D, running time excess $\mathrm{ERT}/\mathrm{ERT}_{\mathrm{best}}$ 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**

| Δftarget | 1e+03 | 1e+02 | 1e+01 | 1e+00 | 1e-01 | 1e-02 | 1e-03 | 1e-04 | 1e-05 | 1e-07 | Δftarget |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $\mathrm{ERT}_{\mathrm{best}}/D$ | 1.4 | 3.6 | 11 | 55 | 186 | 278 | 354 | 383 | 402 | 449 | $\mathrm{ERT}_{\mathrm{best}}/D$ |
| (1,2)-CMA-ES | **2.4** | **2.6** | **1.8** | 4.8 | 8.8 | 12 | 17 | 28 | 33 | 30 | (1,2)-CMA-ES [4, 2] |
| (1,2m)-CMA-ES | **2.0** | **1.9** | **2.9** | **2.3** | **2.2** | 5.6 | 9.3 | 18 | 18 | 17 | (1,2m)-CMA-ES [4] |
| (1,2ms)-CMA-ES | **1** | **1** | **1.1** | **1.1** | 3.2 | 8.7 | 12 | 16 | 20 | 18 | (1,2ms)-CMA-ES [4] |
| (1,2s)-CMA-ES | **2.0** | **1.8** | **2.9** | 4.8 | 4.2 | 11 | 23 | 60 | 60 | 71 | (1,2s)-CMA-ES [2] |
| (1,4)-CMA-ES | **1.8** | **2.2** | **1.4** | 4.7 | **2.8** | 3.2 | 3.4 | 3.2 | 3.1 | **2.9** | (1,4)-CMA-ES [5, 3] |
| (1,4m)-CMA-ES | **1.1** | **1.3** | **1** | 3.0 | **1.8** | **2.4** | **2.1** | **2.2** | **2.1** | **2.0** | (1,4m)-CMA-ES [5] |
| (1,4ms)-CMA-ES | **2.3** | **1.5** | **1.4** | **2.3** | **2.5** | **3.0** | **2.9** | **3.0** | 3.3 | 3.0 | (1,4ms)-CMA-ES [1, 5] |
| (1,4s)-CMA-ES | **1.4** | 3.3 | **1.3** | 3.3 | **3.0** | 4.1 | 3.9 | 3.9 | 3.8 | 3.5 | (1,4s)-CMA-ES [3] |
| avg NEWUOA | **2.7** | **2.1** | **1.7** | **1.8** | **2.2** | 5.8 | 16 | 28 | 96 | 177 | avg NEWUOA [15] |
| CMA-EGS (IPOP,r1) | 21 | 12 | 4.5 | **2.3** | 39 | 159 | 515 | 1122 | 1659 | 3153 | CMA-EGS (IPOP,r1) [7] |
| IPOP-aCMA-ES | 3.5 | **1.8** | **1.6** | **1.1** | **1** | **1** | **1** | **1** | **1** | **1** | IPOP-aCMA-ES [11] |
| IPOP-CMA-ES | **2.7** | **2.1** | **1.4** | **2.2** | **2.2** | 3.6 | 3.1 | **2.9** | **2.9** | **2.8** | IPOP-CMA-ES [14] |
| CMA+DE-MOS | **1.1** | **1.3** | **1.5** | **1** | **1.6** | **1.9** | **1.8** | **1.9** | **2.0** | **2.2** | CMA+DE-MOS [12] |
| NEWUOA | **2.6** | **1.5** | **1.9** | **2.2** | 3.0 | 4.2 | 12 | 21 | 20 | 52 | NEWUOA [15] |
| Basic RCGA | **1.4** | **2.2** | **2.0** | **1.5** | 13 | 33 | 89 | 236 | 569 | *18e-5/5e4* | Basic RCGA [16] |
| SPSA | 217 | 170 | 78 | 204 | 1418 | 5355 | *34e-2/1e5* | . | . | . | SPSA [8] |

Table 6: 02-D, running time excess $\mathrm{ERT}/\mathrm{ERT}_{\mathrm{best}}$ on $f_{106}$, in italics is given the median final function value and the median number of function evaluations to reach this value divided by dimension

**106 Rosenbrock moderate Cauchy**

| Δftarget | 1e+03 | 1e+02 | 1e+01 | 1e+00 | 1e-01 | 1e-02 | 1e-03 | 1e-04 | 1e-05 | 1e-07 | Δftarget |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $\mathrm{ERT}_{\mathrm{best}}$/D | 1.4 | 3.4 | 7.0 | 22 | 93 | 155 | 184 | 208 | 222 | 246 | $\mathrm{ERT}_{\mathrm{best}}$/D |
| (1,2)-CMA-ES | 3.3 | 4.3 | 11 | 19 | 10 | 8.5 | 8.0 | 7.5 | 7.2 | 6.7 | (1,2)-CMA-ES [4, 2] |
| (1,2m)-CMA-ES | **2.1** | **2.8** | **2.6** | 4.4 | 3.6 | 3.5 | 3.7 | 3.5 | 3.6 | 3.5 | (1,2m)-CMA-ES [4] |
| (1,2ms)-CMA-ES | **1.6** | **1.9** | **2.1** | **1.4** | 3.6 | **2.8** | 3.0 | **3.0** | **2.9** | **2.8** | (1,2ms)-CMA-ES [4] |
| (1,2s)-CMA-ES | **2.0** | **2.0** | **1.5** | 30 | 23 | 19 | 18 | 20 | 19 | 21 | (1,2s)-CMA-ES [2] |
| (1,4)-CMA-ES | **2.3** | **1.9** | **2.4** | 3.9 | **2.0** | **1.5** | **1.5** | **1.4** | **1.4** | **1.5** | (1,4)-CMA-ES [5, 3] |
| (1,4m)-CMA-ES | **1.2** | **1** | **1.6** | **2.2** | **1.5** | **1.2** | **1.3** | **1.2** | **1.3** | **1.3** | (1,4m)-CMA-ES [5] |
| (1,4ms)-CMA-ES | **2.0** | **1.8** | **1.2** | **1** | **1** | **1** | **1** | **1** | **1** | **1** | (1,4ms)-CMA-ES [1, 5] |
| (1,4s)-CMA-ES | **1.2** | **1.0** | **1** | 3.4 | **2.2** | **1.7** | **1.6** | **1.5** | **1.5** | **1.4** | (1,4s)-CMA-ES [3] |
| avg NEWUOA | **1.9** | **1.3** | **1.4** | **1.6** | **1.6** | **1.9** | 3.1 | 3.3 | 4.7 | 7.8 | avg NEWUOA [15] |
| CMA-EGS (IPOP,r1) | 23 | 21 | 37 | 32 | 11 | 8.8 | 8.3 | 7.6 | 39 | 39 | CMA-EGS (IPOP,r1) [7] |
| IPOP-aCMA-ES | **1.4** | **2.1** | 3.2 | **2.7** | **1.6** | **1.6** | **1.5** | **1.5** | **1.5** | **1.6** | IPOP-aCMA-ES [11] |
| IPOP-CMA-ES | **1.3** | **1.3** | **1.5** | 3.2 | **2.5** | **2.4** | **2.5** | **2.5** | **2.5** | **2.6** | IPOP-CMA-ES [14] |
| CMA+DE-MOS | **1.1** | **1.3** | **2.4** | 4.4 | **2.9** | 3.2 | 3.6 | 3.5 | 3.9 | 4.4 | CMA+DE-MOS [12] |
| NEWUOA | **1.3** | **1.2** | **1.0** | **2.2** | **1.5** | **2.1** | 3.1 | 3.2 | 5.3 | 7.6 | NEWUOA [15] |
| Basic RCGA | **1** | **1.9** | **2.6** | 4.2 | 14 | 94 | 295 | 381 | 726 | 2913 | Basic RCGA [16] |
| SPSA | 426 | 532 | 1013 | 2191 | 2546 | 9115 | *40e-2/1e5* | . | . | . | SPSA [8] |

Table 7: 02-D, running time excess $\mathrm{ERT}/\mathrm{ERT}_{\mathrm{best}}$ on $f_{107}$, in italics is given the median final function value and the median number of function evaluations to reach this value divided by dimension

**107 Sphere Gauss**

| $\Delta$ftarget | 1e+03 | 1e+02 | 1e+01 | 1e+00 | 1e-01 | 1e-02 | 1e-03 | 1e-04 | 1e-05 | 1e-07 | $\Delta$ftarget |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $\mathrm{ERT}_{\mathrm{best}}$/D | 0.50 | 0.50 | 1.6 | 12 | 22 | 37 | 59 | 75 | 141 | 206 | $\mathrm{ERT}_{\mathrm{best}}$/D |
| (1,2)-CMA-ES | **1** | **1** | 17 | 8.1 | 6.3 | 6.0 | 6.8 | 10 | 10 | 13 | (1,2)-CMA-ES [4, 2] |
| (1,2m)-CMA-ES | **1** | **1** | **2.5** | **2.9** | **2.6** | **2.8** | **2.2** | **2.1** | **1.3** | **1.6** | (1,2m)-CMA-ES [4] |
| (1,2ms)-CMA-ES | **1** | **1** | **1.3** | **1.2** | **1.2** | **2.2** | **2.1** | **2.5** | **1.5** | **2.0** | (1,2ms)-CMA-ES [4] |
| (1,2s)-CMA-ES | **1** | **1** | 3.1 | **1.4** | 3.3 | 9.2 | 10 | 12 | 6.9 | 9.3 | (1,2s)-CMA-ES [2] |
| (1,4)-CMA-ES | **1** | **1** | 5.9 | **2.0** | 4.9 | 3.9 | **2.9** | **2.8** | **1.9** | **1.9** | (1,4)-CMA-ES [5, 3] |
| (1,4m)-CMA-ES | **1** | **1** | 4.1 | **1.2** | **2.8** | **2.3** | **1.8** | **1.7** | **1.5** | **1.4** | (1,4m)-CMA-ES [5] |
| (1,4ms)-CMA-ES | **1** | **1** | **1.2** | **1** | **1** | **1** | **1** | **1** | **1.3** | **1.2** | (1,4ms)-CMA-ES [1, 5] |
| (1,4s)-CMA-ES | **1** | **1** | 3.4 | 6.3 | 5.0 | 3.6 | 3.3 | **2.8** | **1.8** | **2.0** | (1,4s)-CMA-ES [3] |
| avg NEWUOA | **1** | **1** | 7.7 | 18 | 15 | 20 | 21 | 41 | 40 | 82 | avg NEWUOA [15] |
| CMA-EGS (IPOP,r1) | 9.2 | 14 | 11 | 3.9 | 7.1 | 5.5 | 34 | 112 | 138 | 311 | CMA-EGS (IPOP,r1) [7] |
| IPOP-aCMA-ES | **1** | **1** | **2.9** | **1.5** | **1.7** | **2.0** | **1.5** | **1.6** | **1** | **1** | IPOP-aCMA-ES [11] |
| IPOP-CMA-ES | **1** | **1** | 3.1 | **1.1** | **1.7** | **1.9** | **1.5** | **1.6** | **1.0** | **1.0** | IPOP-CMA-ES [14] |
| CMA+DE-MOS | **1** | **1** | **1.4** | **1.1** | 3.9 | 6.9 | 8.0 | 7.8 | 5.1 | 4.6 | CMA+DE-MOS [12] |
| NEWUOA | **1** | **1** | 15 | 12 | 20 | 27 | 27 | 50 | 74 | 85 | NEWUOA [15] |
| Basic RCGA | **1** | **1** | **1** | **1.1** | 5.8 | 13 | 13 | 12 | 12 | 20 | Basic RCGA [16] |
| SPSA | 16 | 21 | 272 | 814 | 2429 | 6194 | 5209 | 18783 | *27e-3/1e5* | . | SPSA [8] |

Table 8: 02-D, running time excess $\mathrm{ERT}/\mathrm{ERT}_{\mathrm{best}}$ 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**

| $\Delta$ftarget | 1e+03 | 1e+02 | 1e+01 | 1e+00 | 1e-01 | 1e-02 | 1e-03 | 1e-04 | 1e-05 | 1e-07 | $\Delta$ftarget |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $\mathrm{ERT}_{\mathrm{best}}$/D | 0.50 | 0.50 | 2.1 | 15 | 164 | 586 | 1170 | 2574 | 3799 | 6046 | $\mathrm{ERT}_{\mathrm{best}}$/D |
| (1,2)-CMA-ES | **1** | **1.2** | 7.4 | 13 | 3.4 | 4.5 | 21 | *26e-4/1e4* | . | . | (1,2)-CMA-ES [4, 2] |
| (1,2m)-CMA-ES | **1** | **1** | 13 | 17 | 5.5 | 7.9 | 60 | *29e-4/1e4* | . | . | (1,2m)-CMA-ES [4] |
| (1,2ms)-CMA-ES | **1** | **1** | 13 | 7.8 | 3.4 | 13 | 56 | *60e-4/1e4* | . | . | (1,2ms)-CMA-ES [4] |
| (1,2s)-CMA-ES | **1** | **1** | 7.3 | 12 | 6.1 | 11 | *56e-4/1e4* | . | . | . | (1,2s)-CMA-ES [2] |
| (1,4)-CMA-ES | **1** | **1** | 21 | 12 | **2.5** | **2.6** | 11 | 55 | 37 | *61e-5/1e4* | (1,4)-CMA-ES [5, 3] |
| (1,4m)-CMA-ES | **1** | **1** | 37 | 13 | 3.6 | **2.9** | 6.9 | 18 | *50e-5/1e4* | . | (1,4m)-CMA-ES [5] |
| (1,4ms)-CMA-ES | **1** | **1** | 5.9 | 14 | 3.7 | 7.0 | 8.3 | 17 | *48e-5/1e4* | . | (1,4ms)-CMA-ES [1, 5] |
| (1,4s)-CMA-ES | **1** | **1** | 62 | 26 | 5.4 | 4.6 | 7.0 | 18 | 39 | *51e-5/1e4* | (1,4s)-CMA-ES [3] |
| avg NEWUOA | **1** | **1** | 37 | 42 | 13 | 22 | 24 | *14e-3/6e3* | . | . | avg NEWUOA [15] |
| CMA-EGS (IPOP,r1) | 1612 | 6028 | 1734 | 309 | 88 | 82 | 78 | 61 | 183 | 243 | CMA-EGS (IPOP,r1) [7] |
| IPOP-aCMA-ES | **1** | **1.2** | **2.4** | 5.9 | **2.2** | **1** | **1** | **1** | **1** | **1.0** | IPOP-aCMA-ES [11] |
| IPOP-CMA-ES | **1** | **1** | **1.6** | **3.8** | **1** | **1.2** | **1.4** | **1.0** | **1.1** | **1** | IPOP-CMA-ES [14] |
| CMA+DE-MOS | **1** | **1** | **1.0** | **1** | **1.4** | **2.1** | **2.4** | **4.2** | **4.3** | **4.9** | CMA+DE-MOS [12] |
| NEWUOA | **1** | **1** | 52 | 56 | 15 | 27 | 36 | *13e-3/6e3* | . | . | NEWUOA [15] |
| Basic RCGA | **1** | **1** | **1** | **1.3** | 7.2 | 24 | 31 | 28 | 45 | *21e-5/5e4* | Basic RCGA [16] |
| SPSA | 27 | 126 | 88 | 100 | 62 | 107 | *28e-4/1e5* | . | . | . | SPSA [8] |

Table 9: 02-D, running time excess $\mathrm{ERT}/\mathrm{ERT}_{\mathrm{best}}$ 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**

| Δftarget | 1e+03 | 1e+02 | 1e+01 | 1e+00 | 1e-01 | 1e-02 | 1e-03 | 1e-04 | 1e-05 | 1e-07 | Δftarget |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $\mathrm{ERT}_{\mathrm{best}}$/D | 0.50 | 0.50 | 1.5 | 6.5 | 18 | 32 | 46 | 65 | 85 | 114 | $\mathrm{ERT}_{\mathrm{best}}$/D |
| (1,2)-CMA-ES | **1** | **1.5** | **1.5** | **2.5** | **1.6** | **1.6** | 3.1 | **2.8** | **2.9** | 3.9 | (1,2)-CMA-ES [4, 2] |
| (1,2m)-CMA-ES | **1** | **1** | **1.6** | **1.4** | **1.0** | **1.5** | **1.7** | **1.7** | **1.8** | **2.3** | (1,2m)-CMA-ES [4] |
| (1,2ms)-CMA-ES | **1** | **1** | **1** | **1.0** | **1** | **1.2** | **1.4** | **1.3** | **1.3** | **1.6** | (1,2ms)-CMA-ES [4] |
| (1,2s)-CMA-ES | **1** | **1** | 3.9 | **2.7** | **1.8** | 6.7 | 6.9 | 5.5 | 4.6 | 6.5 | (1,2s)-CMA-ES [2] |
| (1,4)-CMA-ES | **1** | **1** | **2.6** | **1.6** | **1.1** | **1.0** | **1.3** | **1.3** | **1.4** | **1.6** | (1,4)-CMA-ES [5, 3] |
| (1,4m)-CMA-ES | **1** | **1** | 3.1 | **1.9** | **1.4** | **1.1** | **1.4** | **1.4** | **1.3** | **1.5** | (1,4m)-CMA-ES [5] |
| (1,4ms)-CMA-ES | **1** | **1** | **1.5** | **1.4** | **1.1** | **1.0** | **1** | **1** | **1** | **1** | (1,4ms)-CMA-ES [1, 5] |
| (1,4s)-CMA-ES | **1** | **1** | **1.3** | **1** | **1.0** | **1** | **1.2** | **1.1** | **1.1** | **1.1** | (1,4s)-CMA-ES [3] |
| avg NEWUOA | **1** | **1** | **2.0** | **1.9** | 5.5 | 7.3 | 6.6 | 8.3 | 8.3 | 13 | avg NEWUOA [15] |
| CMA-EGS (IPOP,r1) | 14 | 21 | 13 | 5.1 | 3.9 | 7.4 | 85 | 71 | 503 | 12353 | CMA-EGS (IPOP,r1) [7] |
| IPOP-aCMA-ES | **1** | **1** | **1.9** | **1.5** | **1.2** | **1.2** | **1.5** | **1.8** | **1.7** | **2.0** | IPOP-aCMA-ES [11] |
| IPOP-CMA-ES | **1** | **1** | **1.2** | **1.1** | **1.4** | **1.2** | **1.5** | **1.6** | **1.9** | **2.3** | IPOP-CMA-ES [14] |
| CMA+DE-MOS | **1** | **1** | **1.4** | **1.7** | 3.1 | 6.2 | 6.5 | 8.0 | 8.1 | 10 | CMA+DE-MOS [12] |
| NEWUOA | **1** | **1** | **2.0** | **2.7** | 4.3 | 5.9 | 7.6 | 10 | 12 | 15 | NEWUOA [15] |
| Basic RCGA | **1** | **1** | **1.1** | **1.9** | 5.4 | 10 | 14 | 18 | 20 | 28 | Basic RCGA [16] |
| SPSA | 19 | 32 | 169 | 97 | 98 | 365 | 1216 | 1808 | 5210 | *72e-6/1e5* | SPSA [8] |

Table 10: 02-D, running time excess ERT/$\mathrm{ERT}_{\mathrm{best}}$ on $f_{110}$, in italics is given the median final function value and the median number of function evaluations to reach this value divided by dimension

**110 Rosenbrock Gauss**

| Δftarget | 1e+03 | 1e+02 | 1e+01 | 1e+00 | 1e-01 | 1e-02 | 1e-03 | 1e-04 | 1e-05 | 1e-07 | Δftarget |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $\mathrm{ERT}_{\mathrm{best}}$/D | 1.4 | 3.7 | 11 | 31 | 474 | 1082 | 2208 | 3495 | 3971 | 4118 | $\mathrm{ERT}_{\mathrm{best}}$/D |
| (1,2)-CMA-ES | **1.4** | **1** | 7.5 | 5.9 | **2.3** | 3.7 | 3.6 | 9.2 | 36 | *22e-5/1e4* | (1,2)-CMA-ES [4, 2] |
| (1,2m)-CMA-ES | 6.2 | 4.3 | **2.5** | 3.2 | **1.4** | **2.0** | **2.3** | 3.4 | 4.9 | 17 | (1,2m)-CMA-ES [4] |
| (1,2ms)-CMA-ES | **1.3** | **2.0** | **1.7** | 3.1 | **1** | **1.9** | 4.3 | 5.0 | 18 | 36 | (1,2ms)-CMA-ES [4] |
| (1,2s)-CMA-ES | **2.2** | 9.2 | 5.3 | 10 | **2.8** | **2.9** | 3.3 | 5.5 | 8.0 | 34 | (1,2s)-CMA-ES [2] |
| (1,4)-CMA-ES | **1.3** | **1.3** | **1.2** | 3.4 | **2.7** | 3.6 | **2.9** | **2.9** | 3.7 | 5.5 | (1,4)-CMA-ES [5, 3] |
| (1,4m)-CMA-ES | **2.0** | **1.8** | **1.0** | **1** | **1.1** | **1** | **1** | **1** | **1.2** | **1.5** | (1,4m)-CMA-ES [5] |
| (1,4ms)-CMA-ES | **2.1** | **1.4** | **2.3** | **2.9** | **1.4** | **2.6** | **2.1** | **2.5** | **2.8** | 3.7 | (1,4ms)-CMA-ES [1, 5] |
| (1,4s)-CMA-ES | **1.7** | **1.6** | **1.2** | 4.5 | **1.9** | **2.0** | **1.5** | **1.7** | **3.0** | 3.0 | (1,4s)-CMA-ES [3] |
| avg NEWUOA | **1.6** | 6.1 | 3.4 | **2.8** | **1.6** | **1.8** | 3.6 | 7.1 | 6.2 | *12e-4/5e3* | avg NEWUOA [15] |
| CMA-EGS (IPOP,r1) | 88 | 71 | 29 | 13 | 8.6 | 121 | 650 | *99e-4/1e5* | . | . | CMA-EGS (IPOP,r1) [7] |
| IPOP-aCMA-ES | **1.4** | **1.4** | **1.2** | **2.0** | 4.0 | 3.2 | **1.7** | **1.1** | **1** | **1** | IPOP-aCMA-ES [11] |
| IPOP-CMA-ES | 3.1 | **2.1** | **1.5** | 4.5 | **2.7** | 3.1 | **1.7** | **1.2** | **1.1** | **1.1** | IPOP-CMA-ES [14] |
| CMA+DE-MOS | **1.1** | **1.3** | **2.1** | 159 | 11 | 9.0 | 4.8 | 3.2 | **2.8** | **2.9** | CMA+DE-MOS [12] |
| NEWUOA | 9.4 | 8.7 | 5.3 | 8.1 | **1.9** | **2.7** | 4.8 | 22 | *19e-4/5e3* | . | NEWUOA [15] |
| Basic RCGA | **1** | **1.2** | **1** | **2.3** | 3.4 | 13 | 17 | 24 | 58 | 174 | Basic RCGA [16] |
| SPSA | 222 | 118 | 109 | 464 | 908 | *38e-2/1e5* | . | . | . | . | SPSA [8] |

Table 11: 02-D, running time excess $\mathrm{ERT}/\mathrm{ERT}_{\mathrm{best}}$ on $f_{111}$, in italics is given the median final function value and the median number of function evaluations to reach this value divided by dimension

**111 Rosenbrock unif**

| Δftarget | 1e+03 | 1e+02 | 1e+01 | 1e+00 | 1e-01 | 1e-02 | 1e-03 | 1e-04 | 1e-05 | 1e-07 | Δftarget |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $\mathrm{ERT}_{\mathrm{best}}$/D | 1.5 | 4.2 | 13 | 91 | 1411 | 5390 | 24725 | 35229 | 39383 | 42765 | $\mathrm{ERT}_{\mathrm{best}}$/D |
| (1,2)-CMA-ES | 7.1 | 6.4 | 5.5 | 5.5 | 3.1 | 3.1 | *21e-3/1e4* | . | . | . | (1,2)-CMA-ES [4, 2] |
| (1,2m)-CMA-ES | **1.4** | 7.3 | 8.3 | **2.3** | **2.9** | 13 | *30e-3/1e4* | . | . | . | (1,2m)-CMA-ES [4] |
| (1,2ms)-CMA-ES | 7.9 | 15 | 10 | 5.8 | **1.9** | 5.9 | *17e-3/1e4* | . | . | . | (1,2ms)-CMA-ES [4] |
| (1,2s)-CMA-ES | 14 | 6.9 | 8.2 | 6.8 | **1.7** | 5.9 | *15e-3/1e4* | . | . | . | (1,2s)-CMA-ES [2] |
| (1,4)-CMA-ES | 25 | 19 | 11 | 3.1 | **1.4** | **1.8** | **1.3** | **2.0** | 3.8 | *61e-4/1e4* | (1,4)-CMA-ES [5, 3] |
| (1,4m)-CMA-ES | 23 | 13 | 10 | 4.3 | **1.5** | **1.4** | **2.8** | *47e-4/1e4* | . | . | (1,4m)-CMA-ES [5] |
| (1,4ms)-CMA-ES | 7.9 | 4.8 | **3.4** | **2.9** | **1.6** | 3.5 | **2.8** | *12e-3/1e4* | . | . | (1,4ms)-CMA-ES [1, 5] |
| (1,4s)-CMA-ES | 3.5 | 14 | 10 | 5.0 | **2.3** | **1.7** | **1.9** | *17e-4/1e4* | . | . | (1,4s)-CMA-ES [3] |
| avg NEWUOA | 29 | 43 | 42 | 19 | 13 | 17 | *26e-2/6e3* | . | . | . | avg NEWUOA [15] |
| CMA-EGS (IPOP,r1) | 228 | 538 | 181 | 42 | 5.6 | 7.3 | 8.5 | 42 | 37 | *22e-4/1e5* | CMA-EGS (IPOP,r1) [7] |
| IPOP-aCMA-ES | **1.8** | **2.4** | 6.9 | **2.2** | **1** | **1.6** | **1** | **1** | **1** | **1** | IPOP-aCMA-ES [11] |
| IPOP-CMA-ES | **1.3** | 3.8 | 4.6 | **2.2** | **1.2** | **1** | **1.1** | **1.1** | **1.1** | **1.1** | IPOP-CMA-ES [14] |
| CMA+DE-MOS | **1.1** | **1.2** | **1.9** | **1.4** | 11 | 12 | 3.2 | **2.5** | **2.6** | **2.6** | CMA+DE-MOS [12] |
| NEWUOA | 55 | 29 | 19 | 16 | 4.8 | 5.3 | *68e-3/6e3* | . | . | . | NEWUOA [15] |
| Basic RCGA | **1** | **1** | **1** | **1** | **2.3** | **2.0** | **1.5** | 6.6 | 19 | *32e-5/5e4* | Basic RCGA [16] |
| SPSA | 29 | 20 | 48 | 99 | 44 | 273 | *51e-3/1e5* | . | . | . | SPSA [8] |

Table 12: 02-D, running time excess ERT/$\mathrm{ERT}_{\mathrm{best}}$ on $f_{112}$, in italics is given the median final function value and the median number of function evaluations to reach this value divided by dimension

**112 Rosenbrock Cauchy**

| Δftarget | 1e+03 | 1e+02 | 1e+01 | 1e+00 | 1e-01 | 1e-02 | 1e-03 | 1e-04 | 1e-05 | 1e-07 | Δftarget |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $\mathrm{ERT}_{\mathrm{best}}$/D | 1.5 | 3.5 | 11 | 32 | 195 | 366 | 416 | 445 | 474 | 530 | $\mathrm{ERT}_{\mathrm{best}}$/D |
| (1,2)-CMA-ES | **2.4** | **2.4** | **2.3** | 5.8 | 10 | 6.8 | 7.2 | 7.9 | 10 | 8.9 | (1,2)-CMA-ES [4, 2] |
| (1,2m)-CMA-ES | **1.2** | **1.4** | 8.4 | 19 | 6.2 | 4.8 | 5.9 | 5.8 | 5.6 | 5.2 | (1,2m)-CMA-ES [4] |
| (1,2ms)-CMA-ES | **1.8** | **2.1** | **1.9** | 10 | 3.3 | **2.9** | 3.1 | 3.1 | 3.0 | **2.9** | (1,2ms)-CMA-ES [4] |
| (1,2s)-CMA-ES | 4.7 | 3.9 | **2.0** | 24 | 14 | 21 | 34 | 50 | 47 | 80 | (1,2s)-CMA-ES [2] |
| (1,4)-CMA-ES | **2.5** | **2.2** | **1.2** | **2.5** | **1.3** | **1.3** | **1.4** | **1.5** | **1.5** | **1.5** | (1,4)-CMA-ES [5, 3] |
| (1,4m)-CMA-ES | **2.8** | **2.2** | **1.1** | **1** | **1** | **1.0** | **1.1** | **1.2** | **1.2** | **1.2** | (1,4m)-CMA-ES [5] |
| (1,4ms)-CMA-ES | **1.6** | **1.4** | **1.6** | 3.4 | **1.4** | **1** | **1** | **1** | **1** | **1** | (1,4ms)-CMA-ES [1, 5] |
| (1,4s)-CMA-ES | **1.2** | **1.3** | **1.1** | **2.9** | **1.8** | **1.3** | **1.4** | **1.4** | **1.4** | **1.3** | (1,4s)-CMA-ES [3] |
| avg NEWUOA | **1.8** | **1.5** | **1.3** | **2.5** | **1.8** | 6.5 | 30 | 164 | *19e-4/5e3* | . | avg NEWUOA [15] |
| CMA-EGS (IPOP,r1) | 14 | 16 | 6.8 | 10 | 8.0 | 113 | 428 | *12e-4/1e5* | . | . | CMA-EGS (IPOP,r1) [7] |
| IPOP-aCMA-ES | **1.2** | **1** | **1.2** | 3.7 | **1.6** | **1.3** | **1.3** | **1.3** | **1.3** | **1.3** | IPOP-aCMA-ES [11] |
| IPOP-CMA-ES | **1.0** | **1.3** | **1** | **1.2** | **1.0** | **1.3** | **1.6** | **1.6** | **1.6** | **1.8** | IPOP-CMA-ES [14] |
| CMA+DE-MOS | **1** | **1.3** | **1.7** | **2.6** | **1.7** | **2.5** | **2.9** | 3.1 | 3.4 | 3.8 | CMA+DE-MOS [12] |
| NEWUOA | **2.0** | **1.5** | **1.2** | **3.0** | **1.9** | **2.5** | 14 | 156 | 146 | *70e-5/5e3* | NEWUOA [15] |
| Basic RCGA | **1.8** | **1.7** | **2.2** | **2.1** | 6.7 | 61 | 118 | 158 | 348 | 645 | Basic RCGA [16] |
| SPSA | 4746 | 2169 | 744 | 766 | 1076 | 3836 | 3379 | *21e-2/1e5* | . | . | SPSA [8] |

Table 13: 02-D, running time excess ERT/$\mathrm{ERT}_{\mathrm{best}}$ on $f_{113}$, in italics is given the median final function value and the median number of function evaluations to reach this value divided by dimension

**113 Step-ellipsoid Gauss**

| $\Delta$ftarget | 1e+03 | 1e+02 | 1e+01 | 1e+00 | 1e-01 | 1e-02 | 1e-03 | 1e-04 | 1e-05 | 1e-07 | $\Delta$ftarget |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $\mathrm{ERT}_{\mathrm{best}}$/D | 0.63 | 1.7 | 5.3 | 59 | 277 | 482 | 643 | 643 | 643 | 841 | $\mathrm{ERT}_{\mathrm{best}}$/D |
| (1,2)-CMA-ES | **1.5** | 5.3 | 3.6 | **2.0** | **2.0** | 3.3 | 4.7 | 4.7 | 4.7 | 6.2 | (1,2)-CMA-ES [4, 2] |
| (1,2m)-CMA-ES | **1.8** | **2.9** | **2.0** | **1.1** | **1.2** | **1.1** | **1.4** | **1.4** | **1.4** | **2.1** | (1,2m)-CMA-ES [4] |
| (1,2ms)-CMA-ES | **2.2** | 3.1 | **2.0** | **1.8** | **1.8** | **2.7** | 3.0 | 3.0 | 3.0 | **2.6** | (1,2ms)-CMA-ES [4] |
| (1,2s)-CMA-ES | 11 | 5.3 | 4.4 | **2.5** | **2.1** | **2.6** | 5.3 | 5.3 | 5.3 | 5.8 | (1,2s)-CMA-ES [2] |
| (1,4)-CMA-ES | **1.6** | **1.2** | **1.3** | 3.9 | **2.1** | **1.9** | **2.2** | **2.2** | **2.2** | **2.2** | (1,4)-CMA-ES [5, 3] |
| (1,4m)-CMA-ES | **1.4** | 10 | 3.9 | **1.7** | **1.9** | **1.7** | **2.2** | **2.2** | **2.2** | **1.8** | (1,4m)-CMA-ES [5] |
| (1,4ms)-CMA-ES | **2.7** | **2.4** | **1.6** | **1.9** | **2.4** | **1.7** | **1.4** | **1.4** | **1.4** | **1.1** | (1,4ms)-CMA-ES [1, 5] |
| (1,4s)-CMA-ES | **2.3** | 3.5 | 5.7 | **2.2** | **2.6** | **2.5** | **1.9** | **1.9** | **1.9** | **2.1** | (1,4s)-CMA-ES [3] |
| avg NEWUOA | **1.6** | 7.9 | 4.3 | **1.6** | **1.5** | **2.7** | 4.5 | 4.5 | 4.5 | 6.9 | avg NEWUOA [15] |
| CMA-EGS (IPOP,r1) | 28 | 18 | 7.6 | 11 | 55 | 142 | 160 | 160 | 160 | 289 | CMA-EGS (IPOP,r1) [7] |
| IPOP-aCMA-ES | **1.9** | **1.9** | **1** | **2.7** | **2.7** | **1.7** | **1.9** | **1.9** | **1.9** | **1.5** | IPOP-aCMA-ES [11] |
| IPOP-CMA-ES | **1** | **1.6** | **1.7** | 5.0 | **2.3** | **1.5** | **1.3** | **1.3** | **1.3** | **1.2** | IPOP-CMA-ES [14] |
| CMA+DE-MOS | **1.1** | **1.3** | **1.4** | **1.0** | **1** | **1** | **1** | **1** | **1** | **1** | CMA+DE-MOS [12] |
| NEWUOA | **1.9** | 5.4 | 5.4 | **1.5** | **2.6** | 4.2 | 5.7 | 5.7 | 5.7 | 7.2 | NEWUOA [15] |
| Basic RCGA | **1.2** | **1** | **2.1** | **1** | 13 | 26 | 29 | 29 | 29 | 27 | Basic RCGA [16] |
| SPSA | 14 | 12 | 8.3 | 278 | 142 | 512 | 393 | 393 | 393 | 396 | SPSA [8] |

Table 14: 02-D, running time excess ERT/$\mathrm{ERT}_{\mathrm{best}}$ 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**

| Δftarget | 1e+03 | 1e+02 | 1e+01 | 1e+00 | 1e-01 | 1e-02 | 1e-03 | 1e-04 | 1e-05 | 1e-07 | Δftarget |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $\mathrm{ERT}_{\mathrm{best}}$/D | 0.70 | 1.5 | 5.0 | 81 | 572 | 904 | 2236 | 2236 | 2236 | 3587 | $\mathrm{ERT}_{\mathrm{best}}$/D |
| (1,2)-CMA-ES | **1.1** | 15 | 6.2 | 4.1 | 3.9 | 13 | 30 | 30 | 30 | 40 | (1,2)-CMA-ES [4, 2] |
| (1,2m)-CMA-ES | 12 | 23 | 13 | 3.2 | **2.8** | 8.5 | 8.3 | 8.3 | 8.3 | *32e-4/1e4* | (1,2m)-CMA-ES [4] |
| (1,2ms)-CMA-ES | 6.3 | 22 | 23 | 5.0 | 3.5 | 9.0 | 20 | 20 | 20 | *63e-4/1e4* | (1,2ms)-CMA-ES [4] |
| (1,2s)-CMA-ES | 12 | 18 | 11 | 3.4 | 5.1 | 10 | 9.3 | 9.3 | 9.3 | 19 | (1,2s)-CMA-ES [2] |
| (1,4)-CMA-ES | **1.4** | 24 | 15 | 3.1 | **2.3** | 5.6 | 5.7 | 5.7 | 5.7 | 20 | (1,4)-CMA-ES [5, 3] |
| (1,4m)-CMA-ES | **1.1** | 10 | 6.8 | 4.0 | 3.5 | 8.7 | 6.1 | 6.1 | 6.1 | 10 | (1,4m)-CMA-ES [5] |
| (1,4ms)-CMA-ES | 3.2 | 38 | 28 | 5.3 | **2.7** | **4.6** | 8.3 | 8.3 | 8.3 | 12 | (1,4ms)-CMA-ES [1, 5] |
| (1,4s)-CMA-ES | **1** | 24 | 12 | 5.1 | 4.3 | 17 | 9.1 | 9.1 | 9.1 | **5.7** | (1,4s)-CMA-ES [3] |
| avg NEWUOA | **1.0** | 36 | 26 | 4.3 | 16 | 29 | 40 | 40 | 40 | 25 | avg NEWUOA [15] |
| CMA-EGS (IPOP,r1) | 441 | 329 | 187 | 52 | 37 | 45 | 25 | 25 | 25 | 54 | CMA-EGS (IPOP,r1) [7] |
| IPOP-aCMA-ES | **1.3** | 7.5 | 7.6 | **2.7** | **1.7** | **2.3** | **2.0** | **2.0** | **2.0** | **1.6** | IPOP-aCMA-ES [11] |
| IPOP-CMA-ES | **1.4** | **2.3** | **2.3** | **1.5** | **1** | **1** | **1** | **1** | **1** | **1** | IPOP-CMA-ES [14] |
| CMA+DE-MOS | **1** | **1.5** | **1.2** | **1** | 5.5 | 5.8 | **2.7** | **2.7** | **2.7** | 6.1 | CMA+DE-MOS [12] |
| NEWUOA | **1.4** | 22 | 61 | 14 | 23 | 97 | 39 | 39 | 39 | *21e-2/6e3* | NEWUOA [15] |
| Basic RCGA | **1.3** | **1** | **1** | **1.7** | 11 | 30 | 24 | 24 | 24 | 21 | Basic RCGA [16] |
| SPSA | 71 | 147 | 95 | 49 | 50 | 120 | 141 | 141 | 141 | *63e-4/1e5* | SPSA [8] |

Table 15: 02-D, running time excess ERT/$\mathrm{ERT}_{\mathrm{best}}$ 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**

| $\Delta$ftarget | 1e+03 | 1e+02 | 1e+01 | 1e+00 | 1e-01 | 1e-02 | 1e-03 | 1e-04 | 1e-05 | 1e-07 | $\Delta$ftarget |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $\mathrm{ERT}_{\mathrm{best}}$/D | 0.60 | 1.9 | 5.0 | 25 | 100 | 183 | 203 | 203 | 203 | 274 | $\mathrm{ERT}_{\mathrm{best}}$/D |
| (1,2)-CMA-ES | **1.7** | **2.0** | **1.6** | **1.8** | **2.1** | 4.2 | 6.7 | 6.7 | 6.7 | 19 | (1,2)-CMA-ES [4, 2] |
| (1,2m)-CMA-ES | **1** | **1.3** | **2.0** | **1.3** | **1.8** | **2.3** | 5.3 | 5.3 | 5.3 | 16 | (1,2m)-CMA-ES [4] |
| (1,2ms)-CMA-ES | **1.6** | **1.1** | **1.7** | **1.3** | **1.6** | **2.9** | 5.8 | 5.8 | 5.8 | 13672.92m2658.876650.68818.265672.92m2818.266650.68S0G10001000cmBT/R276.97 | |

Table 16: 02-D, running time excess ERT/$\mathrm{ERT}_{\mathrm{best}}$ on $f_{116}$, in italics is given the median final function value and the median number of function evaluations to reach this value divided by dimension

**116 Ellipsoid Gauss**

| Δftarget | 1e+03 | 1e+02 | 1e+01 | 1e+00 | 1e-01 | 1e-02 | 1e-03 | 1e-04 | 1e-05 | 1e-07 | Δftarget |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $\mathrm{ERT}_{\mathrm{best}}$/D | 4.7 | 15 | 114 | 527 | 1491 | 1573 | 1917 | 1974 | 2050 | 2169 | $\mathrm{ERT}_{\mathrm{best}}$/D |
| (1,2)-CMA-ES | 8.3 | 5.6 | **2.8** | **2.2** | **1.6** | 4.6 | 7.4 | 16 | 33 | 66 | (1,2)-CMA-ES [4, 2] |
| (1,2m)-CMA-ES | **1.4** | 4.3 | 4.8 | **2.6** | **2.5** | 8.4 | 8.3 | 13 | 16 | 21 | (1,2m)-CMA-ES [4] |
| (1,2ms)-CMA-ES | **1** | **2.0** | **2.4** | **1** | **1.8** | 4.5 | 6.4 | 16 | 34 | 69 | (1,2ms)-CMA-ES [4] |
| (1,2s)-CMA-ES | 9.2 | 18 | 3.4 | **2.5** | **2.0** | 11 | *12e-3/1e4* | . | . | . | (1,2s)-CMA-ES [2] |
| (1,4)-CMA-ES | **1.3** | **1** | 3.3 | **1.9** | **1.8** | **2.9** | 3.0 | **3.0** | 4.1 | 3.9 | (1,4)-CMA-ES [5, 3] |
| (1,4m)-CMA-ES | **1.3** | **1.1** | **2.1** | **2.4** | **1.8** | 3.2 | 3.5 | 3.8 | 4.5 | 5.0 | (1,4m)-CMA-ES [5] |
| (1,4ms)-CMA-ES | **2.0** | 3.7 | 3.1 | **1.9** | **1.1** | **2.2** | **2.5** | 3.1 | 3.5 | 3.9 | (1,4ms)-CMA-ES [1, 5] |
| (1,4s)-CMA-ES | **1.8** | **1.1** | **1.4** | **2.3** | **1.6** | 3.2 | 3.6 | 4.2 | 4.9 | 5.9 | (1,4s)-CMA-ES [3] |
| avg NEWUOA | 5.5 | **2.9** | **2.7** | **1.4** | **1.7** | 6.4 | 9.0 | 40 | *14e-3/5e3* | . | avg NEWUOA [15] |
| CMA-EGS (IPOP,r1) | 46 | 61 | 110 | 103 | 187 | 416 | 733 | *34e-2/1e5* | . | . | CMA-EGS (IPOP,r1) [7] |
| IPOP-aCMA-ES | **2.2** | **1.3** | 5.3 | **2.1** | **1** | **1** | **1** | **1** | **1** | **1** | IPOP-aCMA-ES [11] |
| IPOP-CMA-ES | **1.2** | **1.8** | 6.0 | 4.0 | **1.9** | **2.3** | **2.2** | **2.2** | **2.1** | **2.1** | IPOP-CMA-ES [14] |
| CMA+DE-MOS | **1.5** | **1.7** | 7.2 | 7.9 | 3.6 | 3.6 | 3.1 | 3.2 | **3.2** | **3.3** | CMA+DE-MOS [12] |
| NEWUOA | 3.8 | **2.1** | **1.4** | **1.7** | **2.0** | 7.0 | 41 | *50e-3/5e3* | . | . | NEWUOA [15] |
| Basic RCGA | **1.3** | **2.1** | **1** | 10 | 25 | 56 | 116 | 176 | 170 | 337 | Basic RCGA [16] |
| SPSA | 14 | 8.8 | 13 | 29 | 60 | 297 | 780 | *43e-3/1e5* | . | . | SPSA [8] |

Table 17: 02-D, running time excess ERT/$\mathrm{ERT}_{\mathrm{best}}$ on $f_{117}$, in italics is given the median final function value and the median number of function evaluations to reach this value divided by dimension

**117 Ellipsoid unif**

| Δftarget | 1e+03 | 1e+02 | 1e+01 | 1e+00 | 1e-01 | 1e-02 | 1e-03 | 1e-04 | 1e-05 | 1e-07 | Δftarget |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $\mathrm{ERT}_{\mathrm{best}}$/D | 5.3 | 21 | 137 | 2224 | 5898 | 6907 | 9411 | 10034 | 11058 | 13526 | $\mathrm{ERT}_{\mathrm{best}}$/D |
| (1,2)-CMA-ES | 8.3 | 7.1 | 5.4 | **1.8** | 3.0 | *12e-2/1e4* | . | . | . | . | (1,2)-CMA-ES [4, 2] |
| (1,2m)-CMA-ES | 5.9 | 6.2 | 4.9 | **1.6** | 3.1 | 22 | 16 | *11e-2/1e4* | . | . | (1,2m)-CMA-ES [4] |
| (1,2ms)-CMA-ES | 8.0 | 6.4 | 6.0 | **1.1** | 3.8 | *14e-2/1e4* | . | . | . | . | (1,2ms)-CMA-ES [4] |
| (1,2s)-CMA-ES | 9.2 | 7.0 | 5.8 | **2.6** | 7.3 | *31e-2/1e4* | . | . | . | . | (1,2s)-CMA-ES [2] |
| (1,4)-CMA-ES | 10 | 7.7 | 6.0 | **1.2** | **1.1** | 10 | *36e-3/1e4* | . | . | . | (1,4)-CMA-ES [5, 3] |
| (1,4m)-CMA-ES | 13 | 5.1 | 4.4 | **1** | 3.3 | 10 | *12e-2/1e4* | . | . | . | (1,4m)-CMA-ES [5] |
| (1,4ms)-CMA-ES | 13 | 11 | 5.8 | **1.4** | **1.8** | 6.1 | 15 | *59e-3/1e4* | . | . | (1,4ms)-CMA-ES [1, 5] |
| (1,4s)-CMA-ES | 7.1 | 7.2 | **2.9** | **1.4** | **1.5** | **3.9** | 16 | *33e-3/1e4* | . | . | (1,4s)-CMA-ES [3] |
| avg NEWUOA | 14 | 27 | 15 | 3.1 | 4.6 | *78e-2/6e3* | . | . | . | . | avg NEWUOA [15] |
| CMA-EGS (IPOP,r1) | 45 | 93 | 70 | 10 | 34 | 104 | 154 | *17e-2/1e5* | . | . | CMA-EGS (IPOP,r1) [7] |
| IPOP-aCMA-ES | 4.9 | 4.6 | **3.1** | **1.1** | **1** | **1** | **1** | **1** | **1** | **1** | IPOP-aCMA-ES [11] |
| IPOP-CMA-ES | **2.9** | **3.9** | 6.2 | **1.4** | **1.1** | **1.5** | **1.4** | **1.4** | **1.6** | **1.5** | IPOP-CMA-ES [14] |
| CMA+DE-MOS | **1** | **1** | **1** | **1.1** | **2.3** | 4.3 | **3.6** | **3.9** | **3.9** | **4.6** | CMA+DE-MOS [12] |
| NEWUOA | 39 | 21 | 18 | 3.7 | 14 | *97e-2/6e3* | . | . | . | . | NEWUOA [15] |
| Basic RCGA | **1.6** | **1.3** | 3.6 | 6.7 | 8.5 | 13 | 17 | *73e-3/5e4* | . | . | Basic RCGA [16] |
| SPSA | 52 | 34 | 48 | 39 | 72 | 216 | 158 | *35e-2/1e5* | . | . | SPSA [8] |

Table 18: 02-D, running time excess ERT/$\mathrm{ERT}_{\mathrm{best}}$ on $f_{118}$, in italics is given the median final function value and the median number of function evaluations to reach this value divided by dimension

**118 Ellipsoid Cauchy**

| Δftarget | 1e+03 | 1e+02 | 1e+01 | 1e+00 | 1e-01 | 1e-02 | 1e-03 | 1e-04 | 1e-05 | 1e-07 | Δftarget |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $\mathrm{ERT}_{\mathrm{best}}$/D | 4.4 | 5.8 | 29 | 105 | 143 | 172 | 189 | 213 | 232 | 273 | $\mathrm{ERT}_{\mathrm{best}}$/D |
| (1,2)-CMA-ES | 3.6 | 5.3 | 20 | 9.3 | 8.5 | 7.9 | 7.9 | 8.5 | 8.5 | 8.2 | (1,2)-CMA-ES [4, 2] |
| (1,2m)-CMA-ES | **1.3** | **2.4** | 16 | 8.8 | 7.8 | 6.9 | 6.6 | 6.1 | 6.1 | 5.7 | (1,2m)-CMA-ES [4] |
| (1,2ms)-CMA-ES | **2.1** | 4.8 | 7.3 | 4.1 | 3.6 | 4.1 | 4.2 | 4.2 | 4.0 | 3.7 | (1,2ms)-CMA-ES [4] |
| (1,2s)-CMA-ES | **1.5** | 5.9 | 47 | 26 | 30 | 35 | 38 | 35 | 33 | 29 | (1,2s)-CMA-ES [2] |
| (1,4)-CMA-ES | **1.7** | **2.8** | 4.4 | **2.3** | **1.9** | **2.0** | **2.0** | **1.8** | **1.9** | **1.8** | (1,4)-CMA-ES [5, 3] |
| (1,4m)-CMA-ES | **1.7** | **2.8** | 3.2 | **1.7** | **1.8** | **1.7** | **1.7** | **1.8** | **1.7** | **1.8** | (1,4m)-CMA-ES [5] |
| (1,4ms)-CMA-ES | **1.7** | 3.1 | **2.1** | **1** | **1** | **1** | **1** | **1** | **1** | **1** | (1,4ms)-CMA-ES [1, 5] |
| (1,4s)-CMA-ES | **1.1** | **1.7** | **1.7** | **1.4** | **1.5** | **1.4** | **1.4** | **1.4** | **1.4** | **1.3** | (1,4s)-CMA-ES [3] |
| avg NEWUOA | **1.1** | **1** | **1** | **1.9** | 5.7 | 13 | 32 | 338 | *90e-5/5e3* | . | avg NEWUOA [15] |
| CMA-EGS (IPOP,r1) | 20 | 61 | 22 | 22 | 247 | 897 | 2123 | 1886 | 6047 | 5147 | CMA-EGS (IPOP,r1) [7] |
| IPOP-aCMA-ES | **1.4** | 3.5 | **2.8** | **1.6** | **1.7** | **1.6** | **1.8** | **1.8** | **1.8** | **1.9** | IPOP-aCMA-ES [11] |
| IPOP-CMA-ES | **1.8** | **2.8** | 4.4 | **2.4** | **2.6** | 3.5 | 3.8 | 3.6 | 3.6 | 3.5 | IPOP-CMA-ES [14] |
| CMA+DE-MOS | **1.2** | 4.4 | 3.1 | **2.3** | **2.8** | **2.9** | 3.4 | 3.8 | 4.2 | 5.1 | CMA+DE-MOS [12] |
| NEWUOA | **1** | **1.1** | **2.0** | **2.0** | 5.1 | 15 | 54 | 109 | 312 | *11e-4/5e3* | NEWUOA [15] |
| Basic RCGA | **1.9** | **2.3** | 27 | 49 | 214 | 370 | 432 | 1652 | 1517 | *16e-3/5e4* | Basic RCGA [16] |
| SPSA | 29 | 171 | 434 | 369 | 2051 | 8144 | *20e-2/1e5* | . | . | . | SPSA [8] |

Table 19: 02-D, running time excess ERT/$\mathrm{ERT}_{\mathrm{best}}$ on $f_{119}$, in italics is given the median final function value and the median number of function evaluations to reach this value divided by dimension

**119 Sum of diff powers Gauss**

| Δftarget | 1e+03 | 1e+02 | 1e+01 | 1e+00 | 1e-01 | 1e-02 | 1e-03 | 1e-04 | 1e-05 | 1e-07 | Δftarget |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $\mathrm{ERT}_{\mathrm{best}}$/D | 0.50 | 0.53 | 0.97 | 12 | 50 | 117 | 366 | 1153 | 1602 | 2770 | $\mathrm{ERT}_{\mathrm{best}}$/D |
| (1,2)-CMA-ES | **1** | **1.1** | **1.8** | **1.8** | 4.5 | 5.0 | 5.5 | 6.1 | 11 | 52 | (1,2)-CMA-ES [4, 2] |
| (1,2m)-CMA-ES | **1** | **1.9** | **2.3** | 3.8 | **2.9** | **2.1** | **1.7** | **1.8** | 4.9 | 25 | (1,2m)-CMA-ES [4] |
| (1,2ms)-CMA-ES | **1** | **1.1** | **1.4** | **2.4** | **2.0** | **1.8** | **2.9** | **2.5** | 4.3 | 16 | (1,2ms)-CMA-ES [4] |
| (1,2s)-CMA-ES | **1** | **1.5** | **1.6** | **2.2** | 3.1 | 5.2 | 6.8 | 12 | 91 | *90e-6/1e4* | (1,2s)-CMA-ES [2] |
| (1,4)-CMA-ES | **1** | **2.0** | **2.4** | **1.8** | **2.8** | **1.4** | **1.6** | **1.2** | **2.8** | 16 | (1,4)-CMA-ES [5, 3] |
| (1,4m)-CMA-ES | **1** | **1** | **1.5** | 3.1 | **1.6** | **1.1** | **2.1** | **1.7** | **2.4** | 11 | (1,4m)-CMA-ES [5] |
| (1,4ms)-CMA-ES | **1** | **1.8** | **2.1** | **2.5** | **1** | **1.2** | **1** | **1.1** | **1.9** | 25 | (1,4ms)-CMA-ES [1, 5] |
| (1,4s)-CMA-ES | **1** | **1.3** | **2.1** | 5.8 | **2.6** | **2.3** | **1.4** | **1.8** | 3.2 | 16 | (1,4s)-CMA-ES [3] |
| avg NEWUOA | **1** | **1.3** | **2.1** | 8.1 | 5.7 | 11 | 8.4 | 5.4 | 10 | *67e-6/5e3* | avg NEWUOA [15] |
| CMA-EGS (IPOP,r1) | 12 | 19 | 12 | **1.7** | **1.3** | 10 | 115 | 68 | 273 | *34e-6/1e5* | CMA-EGS (IPOP,r1) [7] |
| IPOP-aCMA-ES | **1** | **1** | **1.2** | **3.0** | **1.2** | **1** | **1.1** | **1.4** | **1.5** | **1.4** | IPOP-aCMA-ES [11] |
| IPOP-CMA-ES | **1** | **1.6** | **2.8** | 3.6 | **1.6** | **1.1** | **1.6** | **2.1** | **2.4** | **3.4** | IPOP-CMA-ES [14] |
| CMA+DE-MOS | **1** | **1.1** | **1.4** | **1.3** | 3.6 | 4.3 | **2.2** | **1** | **1** | **1** | CMA+DE-MOS [12] |
| NEWUOA | **1** | **2.4** | **2.2** | 6.9 | 6.1 | 17 | 10 | 16 | 48 | 28 | NEWUOA [15] |
| Basic RCGA | **1** | **1.1** | **1** | **1** | **2.3** | 6.6 | 6.5 | 8.8 | 15 | 35 | Basic RCGA [16] |
| SPSA | 15 | 30 | 25 | 418 | 820 | 1984 | 1191 | *21e-3/1e5* | . | . | SPSA [8] |

Table 20: 02-D, running time excess ERT/$\mathrm{ERT}_{\mathrm{best}}$ 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**

| Δftarget | 1e+03 | 1e+02 | 1e+01 | 1e+00 | 1e-01 | 1e-02 | 1e-03 | 1e-04 | 1e-05 | 1e-07 | Δftarget |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $\mathrm{ERT}_{\mathrm{best}}$/D | 0.50 | 0.50 | 1.1 | 9.1 | 445 | 1182 | 3214 | 8792 | 16925 | 53115 | $\mathrm{ERT}_{\mathrm{best}}$/D |
| (1,2)-CMA-ES | **1** | **1.7** | 12 | 21 | **2.5** | 8.0 | *76e-4/1e4* | . | . | . | (1,2)-CMA-ES [4, 2] |
| (1,2m)-CMA-ES | **1** | **1.1** | 12 | 12 | **2.0** | 15 | *12e-3/1e4* | . | . | . | (1,2m)-CMA-ES [4] |
| (1,2ms)-CMA-ES | **1** | **2.9** | 13 | 12 | **2.1** | 8.7 | *52e-4/1e4* | . | . | . | (1,2ms)-CMA-ES [4] |
| (1,2s)-CMA-ES | **1** | **1.1** | 7.4 | 20 | 3.9 | 14 | 46 | *15e-3/1e4* | . | . | (1,2s)-CMA-ES [2] |
| (1,4)-CMA-ES | **1** | **1.3** | **1.6** | 26 | **1.9** | 7.8 | **13** | *56e-4/1e4* | . | . | (1,4)-CMA-ES [5, 3] |
| (1,4m)-CMA-ES | **1** | **1.5** | 22 | 16 | **2.1** | **4.6** | 44 | *25e-4/1e4* | . | . | (1,4m)-CMA-ES [5] |
| (1,4ms)-CMA-ES | **1** | **1.5** | 10 | 16 | **2.1** | 4.6 | *54e-4/1e4* | . | . | . | (1,4ms)-CMA-ES [1, 5] |
| (1,4s)-CMA-ES | **1** | **1** | **1** | 5.9 | **1.6** | 8.4 | *79e-4/1e4* | . | . | . | (1,4s)-CMA-ES [3] |
| avg NEWUOA | **1** | 9.5 | 23 | 46 | 17 | 16 | *94e-3/6e3* | . | . | . | avg NEWUOA [15] |
| CMA-EGS (IPOP,r1) | 423 | 709 | 383 | 139 | 15 | 70 | 220 | *53e-4/1e5* | . | . | CMA-EGS (IPOP,r1) [7] |
| IPOP-aCMA-ES | **1** | **1.2** | **1.2** | **5.4** | **1** | **1** | **1** | **1** | **1.2** | **1** | IPOP-aCMA-ES [11] |
| IPOP-CMA-ES | **1** | **1.5** | **2.2** | 15 | **1.5** | **1.6** | **1.3** | **1.1** | **1** | **1.1** | IPOP-CMA-ES [14] |
| CMA+DE-MOS | **1** | **1.3** | **1.2** | **2.8** | **1.3** | 4.7 | 15 | **16** | **9.2** | **10** | CMA+DE-MOS [12] |
| NEWUOA | **1** | 3.1 | 30 | 38 | 17 | 36 | *98e-3/6e3* | . | . | . | NEWUOA [15] |
| Basic RCGA | **1** | **1.3** | **1.3** | **1** | **2.9** | 14 | 17 | 24 | 42 | *31e-5/5e4* | Basic RCGA [16] |
| SPSA | 57 | 173 | 94 | 94 | 45 | 270 | *13e-3/1e5* | . | . | . | SPSA [8] |

Table 21: 02-D, running time excess ERT/$\mathrm{ERT}_{\mathrm{best}}$ 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**

| $\Delta$ftarget | 1e+03 | 1e+02 | 1e+01 | 1e+00 | 1e-01 | 1e-02 | 1e-03 | 1e-04 | 1e-05 | 1e-07 | $\Delta$ftarget |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $\mathrm{ERT}_{\mathrm{best}}$/D | 0.50 | 0.60 | 1.2 | 7.0 | 20 | 49 | 113 | 270 | 398 | 601 | $\mathrm{ERT}_{\mathrm{best}}$/D |
| (1,2)-CMA-ES | **1** | **1.3** | **1.4** | **1.9** | **2.6** | 6.0 | 9.5 | 8.2 | 11 | 14 | (1,2)-CMA-ES [4, 2] |
| (1,2m)-CMA-ES | **1** | **1.1** | **1.3** | **1.3** | **2.1** | **1.6** | **2.2** | 4.1 | 5.0 | 7.0 | (1,2m)-CMA-ES [4] |
| (1,2ms)-CMA-ES | **1** | **1.1** | **1.5** | **1.7** | **1.0** | **1.6** | **1.9** | **2.4** | 3.1 | 3.9 | (1,2ms)-CMA-ES [4] |
| (1,2s)-CMA-ES | **1** | **1.1** | **2.5** | **2.5** | **1.8** | 5.0 | 23 | 25 | 42 | 119 | (1,2s)-CMA-ES [2] |
| (1,4)-CMA-ES | **1** | **1** | **1.9** | **1.6** | **1.5** | **1.5** | **1.3** | **1.2** | **1.5** | **2.0** | (1,4)-CMA-ES [5, 3] |
| (1,4m)-CMA-ES | **1** | **1.3** | **1.7** | **1.6** | **1.6** | **1.9** | **1.9** | **2.0** | **1.8** | **2.0** | (1,4m)-CMA-ES [5] |
| (1,4ms)-CMA-ES | **1** | **1** | **1.3** | **1** | **1** | **1** | **1.0** | **1** | **1** | **1** | (1,4ms)-CMA-ES [1, 5] |
| (1,4s)-CMA-ES | **1** | **1.4** | **1.6** | **1.4** | **1.1** | **1.1** | **1** | **1.0** | **1.0** | **1.1** | (1,4s)-CMA-ES [3] |
| avg NEWUOA | **1** | **1.3** | **1.6** | **2.9** | 4.5 | 9.3 | 31 | 49 | *31e-5/5e3* | . | avg NEWUOA [15] |
| CMA-EGS (IPOP,r1) | 15 | 21 | 13 | 16 | 10 | 15 | 88 | 472 | 3535 | *13e-5/1e5* | CMA-EGS (IPOP,r1) [7] |
| IPOP-aCMA-ES | **1** | **1.1** | **1.6** | **1.6** | **1.5** | **1.7** | **1.9** | **1.6** | **1.7** | **1.9** | IPOP-aCMA-ES [11] |
| IPOP-CMA-ES | **1** | **1.7** | **2.5** | **1.9** | **1.6** | **1.5** | **2.3** | **2.8** | 3.1 | 3.7 | IPOP-CMA-ES [14] |
| CMA+DE-MOS | **1** | **1** | **1.3** | **2.1** | 5.9 | 5.5 | 5.6 | 4.1 | 4.1 | 4.6 | CMA+DE-MOS [12] |
| NEWUOA | **1** | **1.3** | **1.6** | **2.2** | 3.1 | 11 | 20 | 80 | 170 | *40e-5/5e3* | NEWUOA [15] |
| Basic RCGA | **1** | **1.1** | **1** | **1.0** | 8.3 | 9.1 | 20 | 21 | 51 | 147 | Basic RCGA [16] |
| SPSA | 33 | 50 | 76 | 407 | 2835 | 2575 | 2803 | *13e-3/1e5* | . | . | SPSA [8] |

Table 22: 02-D, running time excess $\mathrm{ERT}/\mathrm{ERT}_{\mathrm{best}}$ on $f_{122}$, in italics is given the median final function value and the median number of function evaluations to reach this value divided by dimension

**122 Schaffer F7 Gauss**

| $\Delta$ftarget | 1e+03 | 1e+02 | 1e+01 | 1e+00 | 1e-01 | 1e-02 | 1e-03 | 1e-04 | 1e-05 | 1e-07 | $\Delta$ftarget |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $\mathrm{ERT}_{\mathrm{best}}$/D | 0.50 | 0.50 | 3.1 | 56 | 212 | 548 | 840 | 1164 | 1950 | 2867 | $\mathrm{ERT}_{\mathrm{best}}$/D |
| (1,2)-CMA-ES | **1** | **2.9** | 6.8 | 4.3 | 6.0 | 15 | 81 | *53e-4/1e4* | . | . | (1,2)-CMA-ES [4, 2] |
| (1,2m)-CMA-ES | **1** | **1.3** | **1.1** | **2.8** | **2.0** | 6.2 | 13 | 27 | 36 | *98e-5/1e4* | (1,2m)-CMA-ES [4] |
| (1,2ms)-CMA-ES | **1** | **1.7** | 5.8 | 3.2 | 3.9 | 5.3 | 50 | *32e-4/1e4* | . | . | (1,2ms)-CMA-ES [4] |
| (1,2s)-CMA-ES | **1** | **1.6** | 11 | 3.6 | 8.7 | 28 | *16e-3/1e4* | . | . | . | (1,2s)-CMA-ES [2] |
| (1,4)-CMA-ES | **1** | **1.3** | **2.7** | 5.1 | 4.1 | 4.0 | 6.3 | 20 | 36 | *23e-5/1e4* | (1,4)-CMA-ES [5, 3] |
| (1,4m)-CMA-ES | **1** | **1.1** | **2.2** | 3.2 | 3.1 | 3.6 | **4.4** | 8.6 | 8.5 | 52 | (1,4m)-CMA-ES [5] |
| (1,4ms)-CMA-ES | **1** | **1.4** | 15 | **1.9** | **2.6** | **3.1** | 7.8 | 20 | 22 | *38e-5/1e4* | (1,4ms)-CMA-ES [1, 5] |
| (1,4s)-CMA-ES | **1** | **1.9** | 17 | 3.8 | 7.0 | 9.4 | 26 | 39 | 75 | *32e-4/1e4* | (1,4s)-CMA-ES [3] |
| avg NEWUOA | **1** | **1.3** | 6.7 | 8.3 | 40 | 70 | *11e-2/5e3* | . | . | . | avg NEWUOA [15] |
| CMA-EGS (IPOP,r1) | 12 | 16 | 7.6 | 18 | 46 | 117 | 261 | *53e-4/1e5* | . | . | CMA-EGS (IPOP,r1) [7] |
| IPOP-aCMA-ES | **1** | **1.3** | **1.7** | **1** | **1** | **1** | **1** | **1** | **1** | **1** | IPOP-aCMA-ES [11] |
| IPOP-CMA-ES | **1** | **1.3** | 14 | 3.3 | 3.0 | **1.5** | **1.4** | **1.4** | **1.1** | **1.2** | IPOP-CMA-ES [14] |
| CMA+DE-MOS | **1** | **1.4** | **1** | 26 | 25 | 13 | 10 | **8.4** | **5.7** | **4.8** | CMA+DE-MOS [12] |
| NEWUOA | **1** | **1.7** | 4.7 | 14 | 37 | 70 | *99e-3/5e3* | . | . | . | NEWUOA [15] |
| Basic RCGA | **1** | **1** | **1.1** | 8.6 | 27 | 18 | 28 | 36 | 50 | *25e-6/5e4* | Basic RCGA [16] |
| SPSA | 21 | 38 | 29 | 688 | *44e-2/1e5* | . | . | . | . | . | SPSA [8] |

Table 23: 02-D, running time excess ERT/$\mathrm{ERT}_{\mathrm{best}}$ on $f_{123}$, in italics is given the median final function value and the median number of function evaluations to reach this value divided by dimension

**123 Schaffer F7 unif**

| Δftarget<br>$\mathrm{ERT}_{\mathrm{best}}$/D | 1e+03<br>0.50 | 1e+02<br>0.50 | 1e+01<br>3.0 | 1e+00<br>386 | 1e-01<br>2371 | 1e-02<br>6690 | 1e-03<br>13816 | 1e-04<br>22782 | 1e-05<br>33525 | 1e-07<br>78413 | Δftarget<br>$\mathrm{ERT}_{\mathrm{best}}$/D |
|---|---|---|---|---|---|---|---|---|---|---|---|
| (1,2)-CMA-ES | **1** | **1.8** | 13 | **1.9** | 62 | *24e-2/1e4* | . | . | . | . | (1,2)-CMA-ES [4, 2] |
| (1,2m)-CMA-ES | **1.2** | **2.8** | 9.3 | **1.3** | 10 | *13e-2/1e4* | . | . | . | . | (1,2m)-CMA-ES [4] |
| (1,2ms)-CMA-ES | **1.1** | 6.1 | 16 | **2.0** | 61 | *23e-2/1e4* | . | . | . | . | (1,2ms)-CMA-ES [4] |
| (1,2s)-CMA-ES | **1** | **1.2** | 25 | **2.7** | 30 | *18e-2/1e4* | . | . | . | . | (1,2s)-CMA-ES [2] |
| (1,4)-CMA-ES | **1** | **1.8** | 11 | **2.3** | **4.7** | *83e-3/1e4* | . | . | . | . | (1,4)-CMA-ES [5, 3] |
| (1,4m)-CMA-ES | **1** | **1.3** | **3.8** | **1.3** | 14 | *13e-2/1e4* | . | . | . | . | (1,4m)-CMA-ES [5] |
| (1,4ms)-CMA-ES | **1** | **2.0** | 15 | **1.7** | 6.0 | **22** | *98e-3/1e4* | . | . | . | (1,4ms)-CMA-ES [1, 5] |
| (1,4s)-CMA-ES | **1** | **2.8** | 40 | **1.9** | 15 | *11e-2/1e4* | . | . | . | . | (1,4s)-CMA-ES [3] |
| avg NEWUOA | **1** | 10 | 34 | 6.6 | 38 | *46e-2/6e3* | . | . | . | . | avg NEWUOA [15] |
| CMA-EGS (IPOP,r1) | 261 | 1354 | 288 | 34 | 27 | 46 | *48e-3/1e5* | . | . | . | CMA-EGS (IPOP,r1) [7] |
| IPOP-aCMA-ES | **1** | **2.0** | 10 | **1.5** | **1.2** | **1** | **1** | **1** | **1** | **1.1** | IPOP-aCMA-ES [11] |
| IPOP-CMA-ES | **1** | **1.6** | 9.0 | **1** | **1** | **1.3** | **1.4** | **1.1** | **1.1** | **1** | IPOP-CMA-ES [14] |
| CMA+DE-MOS | **1** | **1.5** | **1** | 11 | 52 | 33 | **21** | **13** | **12** | **7.2** | CMA+DE-MOS [12] |
| NEWUOA | **1** | **1** | 29 | 8.8 | 38 | *44e-2/6e3* | . | . | . | . | NEWUOA [15] |
| Basic RCGA | **1** | **1.5** | **1.5** | 5.8 | 31 | *11e-2/5e4* | . | . | . | . | Basic RCGA [16] |
| SPSA | 32 | 64 | 71 | 21 | 296 | *22e-2/1e5* | . | . | . | . | SPSA [8] |

Table 24: 02-D, running time excess $\mathrm{ERT}/\mathrm{ERT}_{\mathrm{best}}$ 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**

| Δftarget | 1e+03 | 1e+02 | 1e+01 | 1e+00 | 1e-01 | 1e-02 | 1e-03 | 1e-04 | 1e-05 | 1e-07 | Δftarget |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $\mathrm{ERT}_{\mathrm{best}}$/D | 0.50 | 0.53 | 2.1 | 33 | 108 | 274 | 1110 | 1849 | 4139 | 9115 | $\mathrm{ERT}_{\mathrm{best}}$/D |
| (1,2)-CMA-ES | **1** | **2.0** | 3.3 | 13 | 20 | 32 | 62 | *60e-4/1e4* | . | . | (1,2)-CMA-ES [4, 2] |
| (1,2m)-CMA-ES | **1** | **1.7** | **2.5** | 3.3 | **2.8** | 5.6 | 11 | *98e-5/1e4* | . | . | (1,2m)-CMA-ES [4] |
| (1,2ms)-CMA-ES | **1** | **1.8** | **2.6** | **2.7** | 6.6 | 6.8 | 7.6 | 77 | *89e-5/1e4* | . | (1,2ms)-CMA-ES [4] |
| (1,2s)-CMA-ES | **1** | **1.6** | 13 | 11 | 19 | 55 | *16e-3/1e4* | . | . | . | (1,2s)-CMA-ES [2] |
| (1,4)-CMA-ES | **1** | 3.6 | **2.8** | 7.5 | 6.5 | 7.9 | 7.2 | 24 | *23e-5/1e4* | . | (1,4)-CMA-ES [5, 3] |
| (1,4m)-CMA-ES | **1** | **1.3** | **2.7** | 4.4 | **2.1** | 3.4 | **2.9** | 10 | 34 | *23e-5/1e4* | (1,4m)-CMA-ES [5] |
| (1,4ms)-CMA-ES | **1** | **1.7** | 22 | 4.9 | **2.6** | **2.0** | **1.5** | 11 | 35 | *23e-5/1e4* | (1,4ms)-CMA-ES [1, 5] |
| (1,4s)-CMA-ES | **1.1** | **1.4** | **1.6** | 10 | 6.7 | 6.2 | 7.2 | 79 | *42e-5/1e4* | . | (1,4s)-CMA-ES [3] |
| avg NEWUOA | **1** | **1.6** | 10 | 9.0 | 32 | 76 | *98e-3/5e3* | . | . | . | avg NEWUOA [15] |
| CMA-EGS (IPOP,r1) | 14 | 19 | 30 | 11 | 55 | 176 | 203 | 764 | *19e-4/1e5* | . | CMA-EGS (IPOP,r1) [7] |
| IPOP-aCMA-ES | **1** | **1.7** | **1.9** | **1** | **1.3** | **1.9** | **1** | **1** | **1** | **1** | IPOP-aCMA-ES [11] |
| IPOP-CMA-ES | **1** | **1.3** | **3.0** | **1.2** | **1** | **1** | **1.1** | **1.3** | **1.3** | **1.2** | IPOP-CMA-ES [14] |
| CMA+DE-MOS | **1** | **1.4** | **1.6** | 3.0 | 21 | 25 | 9.1 | **5.8** | **5.3** | **3.6** | CMA+DE-MOS [12] |
| NEWUOA | **1** | **2.1** | 4.7 | 6.3 | 20 | 57 | *33e-3/5e3* | . | . | . | NEWUOA [15] |
| Basic RCGA | **1** | **1** | **1** | **2.9** | 33 | 31 | 29 | 52 | 88 | *19e-5/5e4* | Basic RCGA [16] |
| SPSA | 48 | 84 | 3825 | 818 | 683 | 2545 | *37e-3/1e5* | . | . | . | SPSA [8] |

Table 25: 02-D, running time excess ERT/$\mathrm{ERT}_{\mathrm{best}}$ 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**

| Δftarget | 1e+03 | 1e+02 | 1e+01 | 1e+00 | 1e-01 | 1e-02 | 1e-03 | 1e-04 | 1e-05 | 1e-07 | Δftarget |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $\mathrm{ERT}_{\mathrm{best}}$/D | 0.50 | 0.50 | 0.50 | 1.9 | 12 | 86 | 269 | 1246 | 2703 | 3541 | $\mathrm{ERT}_{\mathrm{best}}$/D |
| (1,2)-CMA-ES | **1** | **1** | 5.6 | 3.7 | 4.2 | 3.8 | 8.7 | 4.0 | 4.3 | *63e-7/1e4* | (1,2)-CMA-ES [4, 2] |
| (1,2m)-CMA-ES | **1** | **1** | **1** | **1.5** | **2.1** | **1.4** | 6.0 | 3.0 | 3.9 | 13 | (1,2m)-CMA-ES [4] |
| (1,2ms)-CMA-ES | **1** | **1** | **1** | **1** | **1.4** | **2.3** | 7.3 | 4.4 | 5.0 | 20 | (1,2ms)-CMA-ES [4] |
| (1,2s)-CMA-ES | **1** | **1** | **1.1** | **2.8** | 5.5 | **2.7** | 12 | 4.4 | 5.4 | 41 | (1,2s)-CMA-ES [2] |
| (1,4)-CMA-ES | **1** | **1** | **1** | **1.2** | **1** | **1.6** | 12 | 5.1 | 5.7 | 13 | (1,4)-CMA-ES [5, 3] |
| (1,4m)-CMA-ES | **1** | **1** | **1.1** | **1.5** | **2.0** | **2.2** | 8.5 | 3.5 | **2.7** | 4.3 | (1,4m)-CMA-ES [5] |
| (1,4ms)-CMA-ES | **1** | **1** | **1** | **1.4** | **2.4** | **2.7** | 7.3 | **2.1** | **2.2** | 6.9 | (1,4ms)-CMA-ES [1, 5] |
| (1,4s)-CMA-ES | **1** | **1** | **1.2** | **1.3** | **1.3** | **1.6** | 13 | 5.9 | 4.4 | 19 | (1,4s)-CMA-ES [3] |
| avg NEWUOA | **1** | **1** | **2.3** | **1.8** | **1.9** | **1.6** | 5.7 | **2.4** | **1.6** | 6.6 | avg NEWUOA [15] |
| CMA-EGS (IPOP,r1) | 14 | 20 | 25 | 8.9 | 3.5 | 4.3 | 12 | 6.7 | 10 | 43 | CMA-EGS (IPOP,r1) [7] |
| IPOP-aCMA-ES | **1** | **1** | **1.1** | **1.2** | **2.1** | **1.2** | **3.3** | **1** | **1** | **1** | IPOP-aCMA-ES [11] |
| IPOP-CMA-ES | **1** | **1** | **1.2** | **1.5** | **1.4** | **1.8** | **4.2** | **1.3** | **1.3** | **1.5** | IPOP-CMA-ES [14] |
| CMA+DE-MOS | **1** | **1** | **1.1** | **1.5** | **1.8** | **1** | **1** | 3.3 | **1.5** | **1.2** | CMA+DE-MOS [12] |
| NEWUOA | **1** | **1** | **2.0** | **1.6** | 3.1 | **1.2** | 5.7 | **2.1** | **1.8** | 11 | NEWUOA [15] |
| Basic RCGA | **1** | **1** | **1.2** | **1.7** | **2.3** | **1.6** | 5.8 | 4.6 | 3.6 | 14 | Basic RCGA [16] |
| SPSA | 22 | 32 | 37 | 16 | 6.8 | **1.9** | 209 | 227 | 246 | *45e-5/1e5* | SPSA [8] |

Table 26: 02-D, running time excess ERT/$\mathrm{ERT}_{\mathrm{best}}$ 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**

| Δftarget | 1e+03 | 1e+02 | 1e+01 | 1e+00 | 1e-01 | 1e-02 | 1e-03 | 1e-04 | 1e-05 | 1e-07 | Δftarget |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $\mathrm{ERT}_{\mathrm{best}}$/D | 0.50 | 0.50 | 0.50 | 1.7 | 23 | 88 | 1671 | 3483 | 5350 | 27651 | $\mathrm{ERT}_{\mathrm{best}}$/D |
| (1,2)-CMA-ES | **1** | **1** | **2.3** | 15 | 6.4 | 12 | 7.0 | 19 | 27 | *75e-5/1e4* | (1,2)-CMA-ES [4, 2] |
| (1,2m)-CMA-ES | **1** | **1** | **1.1** | **1.2** | 3.0 | 11 | 4.9 | 5.9 | 8.2 | *23e-5/1e4* | (1,2m)-CMA-ES [4] |
| (1,2ms)-CMA-ES | **1** | **1** | **1** | **1** | 5.0 | 6.8 | 9.1 | 7.7 | 28 | *81e-5/1e4* | (1,2ms)-CMA-ES [4] |
| (1,2s)-CMA-ES | **1** | **1** | **1.1** | 11 | 5.3 | 16 | 8.6 | 12 | 26 | *12e-4/1e4* | (1,2s)-CMA-ES [2] |
| (1,4)-CMA-ES | **1** | **1** | **1** | **1.8** | 7.2 | 7.6 | 3.7 | 8.8 | 12 | 5.1 | (1,4)-CMA-ES [5, 3] |
| (1,4m)-CMA-ES | **1** | **1** | **1** | **2.1** | **2.4** | 5.7 | 4.0 | 3.7 | 5.8 | *64e-6/1e4* | (1,4m)-CMA-ES [5] |
| (1,4ms)-CMA-ES | **1** | **1** | **1.1** | 12 | **2.4** | 3.9 | 3.1 | 3.5 | 5.7 | 5.2 | (1,4ms)-CMA-ES [1, 5] |
| (1,4s)-CMA-ES | **1** | **1** | **1** | 3.5 | 5.5 | 5.9 | 4.9 | 4.6 | *18e-5/1e4* | . | (1,4s)-CMA-ES [3] |
| avg NEWUOA | **1** | **1** | 26 | 27 | 14 | 26 | 12 | 7.6 | *18e-4/6e3* | . | avg NEWUOA [15] |
| CMA-EGS (IPOP,r1) | 284 | 472 | 608 | 203 | 34 | 99 | 23 | 40 | 38 | *32e-6/1e5* | CMA-EGS (IPOP,r1) [7] |
| IPOP-aCMA-ES | **1** | **1** | **1** | **1.3** | 4.9 | 3.3 | **1.4** | **1** | **1** | **1** | IPOP-aCMA-ES [11] |
| IPOP-CMA-ES | **1** | **1** | **1** | **1.2** | **1.6** | **3.2** | **1.1** | **1.9** | **2.2** | **1.0** | IPOP-CMA-ES [14] |
| CMA+DE-MOS | **1** | **1** | **1.1** | **1.1** | **1.0** | **1** | 12 | 17 | 21 | 13 | CMA+DE-MOS [12] |
| NEWUOA | **1** | **1** | **2.1** | 58 | 13 | 26 | 54 | *32e-4/6e3* | . | . | NEWUOA [15] |
| Basic RCGA | **1** | **1** | **1.1** | **1.3** | **1** | **1.2** | **1** | **1.3** | **1.5** | **1.3** | Basic RCGA [16] |
| SPSA | 16 | 50 | 86 | 56 | 40 | 151 | 113 | 93 | 83 | *18e-4/1e5* | SPSA [8] |

Table 27: 02-D, running time excess ERT/$\mathrm{ERT}_{\mathrm{best}}$ 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**

| Δftarget | 1e+03 | 1e+02 | 1e+01 | 1e+00 | 1e-01 | 1e-02 | 1e-03 | 1e-04 | 1e-05 | 1e-07 | Δftarget |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $\mathrm{ERT}_{\mathrm{best}}$/D | 0.50 | 0.50 | 0.50 | 1.6 | 8.3 | 83 | 520 | 1883 | 2428 | 2506 | $\mathrm{ERT}_{\mathrm{best}}$/D |
| (1,2)-CMA-ES | **1** | **1** | **1** | **3.0** | 3.2 | **2.8** | 5.9 | 3.0 | 3.8 | 7.2 | (1,2)-CMA-ES [4, 2] |
| (1,2m)-CMA-ES | **1** | **1** | **1.1** | **2.0** | **2.4** | **1.3** | **2.3** | **1.0** | **1.2** | **2.3** | (1,2m)-CMA-ES [4] |
| (1,2ms)-CMA-ES | **1** | **1** | **1** | **1.5** | **2.0** | **1.3** | 3.1 | **1.7** | **1.9** | **2.3** | (1,2ms)-CMA-ES [4] |
| (1,2s)-CMA-ES | **1** | **1** | **1.2** | 3.3 | 5.1 | **2.8** | 9.3 | 3.8 | 5.2 | 28 | (1,2s)-CMA-ES [2] |
| (1,4)-CMA-ES | **1** | **1** | **1** | **1.1** | **1** | 3.0 | 4.0 | **2.3** | **1.8** | **2.3** | (1,4)-CMA-ES [5, 3] |
| (1,4m)-CMA-ES | **1** | **1** | **1** | **1.3** | **1.2** | **2.9** | 3.5 | **1.8** | **1.9** | **2.1** | (1,4m)-CMA-ES [5] |
| (1,4ms)-CMA-ES | **1** | **1** | **1.1** | **1.3** | **1.2** | 3.1 | 3.0 | **1.3** | **1.1** | **1.4** | (1,4ms)-CMA-ES [1, 5] |
| (1,4s)-CMA-ES | **1** | **1** | **1** | **1** | 4.9 | **2.4** | **2.8** | **1** | **1.0** | **1** | (1,4s)-CMA-ES [3] |
| avg NEWUOA | **1** | **1** | **1.3** | **2.2** | 4.3 | **1.8** | 4.0 | **1.9** | 3.4 | *16e-6/5e3* | avg NEWUOA [15] |
| CMA-EGS (IPOP,r1) | 12 | 17 | 19 | 8.6 | 4.2 | **1.7** | **2.5** | 5.0 | 16 | 96 | CMA-EGS (IPOP,r1) [7] |
| IPOP-aCMA-ES | **1** | **1** | **1.4** | **1.9** | **2.3** | **2.7** | 3.0 | **1.2** | **1.1** | **1.2** | IPOP-aCMA-ES [11] |
| IPOP-CMA-ES | **1** | **1** | **1** | **1.3** | 4.7 | **1.3** | **1.9** | **1.1** | **1** | **2.3** | IPOP-CMA-ES [14] |
| CMA+DE-MOS | **1** | **1** | **1.1** | **1.2** | **1.9** | **1** | **1** | **1.6** | 3.6 | 5.1 | CMA+DE-MOS [12] |
| NEWUOA | **1** | **1** | **2.1** | **1.9** | 5.7 | **2.0** | 5.6 | 4.1 | 3.9 | 13 | NEWUOA [15] |
| Basic RCGA | **1** | **1** | **1.2** | **1.1** | **2.5** | **1.6** | 4.6 | **2.8** | 3.5 | 42 | Basic RCGA [16] |
| SPSA | 26 | 39 | 94 | 195 | 296 | 140 | 206 | 176 | *40e-5/1e5* | . | SPSA [8] |

Table 28: 02-D, running time excess ERT/$\mathrm{ERT}_{\mathrm{best}}$ on $f_{128}$, in italics is given the median final function value and the median number of function evaluations to reach this value divided by dimension

**128 Gallagher Gauss**

| $\Delta$ftarget | 1e+03 | 1e+02 | 1e+01 | 1e+00 | 1e-01 | 1e-02 | 1e-03 | 1e-04 | 1e-05 | 1e-07 | $\Delta$ftarget |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $\mathrm{ERT}_{\mathrm{best}}$/D | 0.50 | 0.50 | 0.70 | 37 | 247 | 618 | 706 | 759 | 771 | 783 | $\mathrm{ERT}_{\mathrm{best}}$/D |
| (1,2)-CMA-ES | **1** | **1** | 5.3 | 5.4 | **2.6** | **1.6** | **1.9** | **2.0** | **2.1** | **2.7** | (1,2)-CMA-ES [4, 2] |
| (1,2m)-CMA-ES | **1** | **1** | **1.2** | **3.1** | **1.7** | **1.4** | **1.7** | **1.6** | **1.8** | **2.2** | (1,2m)-CMA-ES [4] |
| (1,2ms)-CMA-ES | **1** | **1** | **2.1** | **1.5** | **1** | **1.0** | **1.3** | **1.5** | **1.7** | **1.9** | (1,2ms)-CMA-ES [4] |
| (1,2s)-CMA-ES | **1** | **1** | 9.4 | 4.9 | **1.5** | **1** | **1.9** | **2.7** | 4.0 | 4.2 | (1,2s)-CMA-ES [2] |
| (1,4)-CMA-ES | **1** | **1** | **2.1** | 12 | 3.9 | **1.6** | **1.9** | **1.8** | **1.8** | **1.8** | (1,4)-CMA-ES [5, 3] |
| (1,4m)-CMA-ES | **1** | **1** | **2.7** | 6.8 | 3.2 | **1.8** | **1.7** | **1.6** | **1.5** | **1.8** | (1,4m)-CMA-ES [5] |
| (1,4ms)-CMA-ES | **1** | **1** | **2.3** | 8.0 | **2.7** | **1.1** | **1** | **1** | **1** | **1** | (1,4ms)-CMA-ES [1, 5] |
| (1,4s)-CMA-ES | **1** | **1** | **1.6** | 3.7 | **2.7** | **1.5** | **1.4** | **2.0** | **2.2** | **2.1** | (1,4s)-CMA-ES [3] |
| avg NEWUOA | **1** | **1** | 3.8 | 12 | **2.5** | **2.0** | **2.0** | **2.4** | 3.7 | 13 | avg NEWUOA [15] |
| CMA-EGS (IPOP,r1) | 13 | 19 | 20 | 9.1 | 12 | 5.0 | 13 | 21 | 94 | 223 | CMA-EGS (IPOP,r1) [7] |
| IPOP-aCMA-ES | **1** | **1** | **2.6** | 14 | 4.3 | **2.0** | 3.1 | 5.1 | 5.1 | 5.4 | IPOP-aCMA-ES [11] |
| IPOP-CMA-ES | **1** | **1** | **1** | 5.2 | **2.9** | **2.3** | **2.0** | **2.0** | **2.0** | **2.1** | IPOP-CMA-ES [14] |
| CMA+DE-MOS | **1** | **1** | **1.8** | 20 | 23 | 13 | 11 | 11 | 11 | 11 | CMA+DE-MOS [12] |
| NEWUOA | **1** | **1** | **2.4** | 9.5 | **2.6** | **2.5** | **2.7** | 4.4 | 5.3 | 8.0 | NEWUOA [15] |
| Basic RCGA | **1** | **1** | **1.4** | **1** | 4.9 | 4.0 | 8.1 | 18 | 22 | 59 | Basic RCGA [16] |
| SPSA | 10 | 22 | 45 | 173 | 179 | 206 | 609 | 567 | *83e-4/1e5* | . | SPSA [8] |

Table 29: 02-D, running time excess ERT/$\mathrm{ERT}_{\mathrm{best}}$ on $f_{129}$, in italics is given the median final function value and the median number of function evaluations to reach this value divided by dimension

**129 Gallagher unif**

| Δftarget | 1e+03 | 1e+02 | 1e+01 | 1e+00 | 1e-01 | 1e-02 | 1e-03 | 1e-04 | 1e-05 | 1e-07 | Δftarget |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $\mathrm{ERT}_{\mathrm{best}}$/D | 0.50 | 0.50 | 0.73 | 21 | 621 | 1124 | 2090 | 3863 | 9428 | 17273 | $\mathrm{ERT}_{\mathrm{best}}$/D |
| (1,2)-CMA-ES | **1** | **1** | 11 | 13 | **2.4** | 3.0 | 4.5 | 7.0 | 4.9 | 8.5 | (1,2)-CMA-ES [4, 2] |
| (1,2m)-CMA-ES | **1** | **1** | **2.2** | 17 | **1.7** | **1.8** | **2.1** | 6.2 | 15 | *12e-5/1e4* | (1,2m)-CMA-ES [4] |
| (1,2ms)-CMA-ES | **1** | **1** | **1.6** | 17 | **1.9** | **2.5** | **1.8** | 5.1 | **2.6** | 8.5 | (1,2ms)-CMA-ES [4] |
| (1,2s)-CMA-ES | **1** | **1** | 22 | 13 | **1.1** | **2.5** | 3.9 | **2.6** | 3.3 | *60e-6/1e4* | (1,2s)-CMA-ES [2] |
| (1,4)-CMA-ES | **1** | **1** | **1.5** | 13 | **1.6** | **1.9** | **1.8** | **1.9** | **1.0** | **2.0** | (1,4)-CMA-ES [5, 3] |
| (1,4m)-CMA-ES | **1** | **1** | **2.0** | **11** | **1.0** | **1** | **1.3** | **2.0** | **1.2** | **2.6** | (1,4m)-CMA-ES [5] |
| (1,4ms)-CMA-ES | **1** | **1** | **2.0** | 17 | **1.6** | **1.2** | **1.9** | **2.2** | **1.8** | 4.1 | (1,4ms)-CMA-ES [1, 5] |
| (1,4s)-CMA-ES | **1** | **1** | **1** | 12 | **1** | **1.7** | **1.7** | **2.1** | 3.5 | *31e-6/1e4* | (1,4s)-CMA-ES [3] |
| avg NEWUOA | **1** | **1** | 63 | 40 | 5.6 | 6.3 | 4.3 | 11 | 9.3 | 5.1 | avg NEWUOA [15] |
| CMA-EGS (IPOP,r1) | 288 | 439 | 335 | 144 | 9.4 | 22 | 18 | 29 | 18 | 85 | CMA-EGS (IPOP,r1) [7] |
| IPOP-aCMA-ES | **1** | **1** | **1.9** | 21 | **2.3** | **1.5** | **1** | **1** | **1** | **1.7** | IPOP-aCMA-ES [11] |
| IPOP-CMA-ES | **1** | **1** | **2.1** | 12 | **2.2** | **2.2** | **2.5** | 3.4 | **1.5** | **1** | IPOP-CMA-ES [14] |
| CMA+DE-MOS | **1** | **1** | **1.8** | **2.2** | **2.3** | 11 | 13 | 8.5 | 3.6 | **2.1** | CMA+DE-MOS [12] |
| NEWUOA | **1** | **1** | 30 | 36 | 3.7 | 6.0 | 8.7 | 11 | 10 | *37e-4/6e3* | NEWUOA [15] |
| Basic RCGA | **1** | **1** | **1.0** | **1** | **2.4** | 3.6 | 5.8 | 4.5 | 7.4 | 42 | Basic RCGA [16] |
| SPSA | 5.1 | 48 | 118 | 156 | 12 | 25 | 25 | 34 | 47 | *86e-6/1e5* | SPSA [8] |

Table 30: 02-D, running time excess ERT/$\mathrm{ERT}_{\mathrm{best}}$ 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**

| $\Delta$ftarget | 1e+03 | 1e+02 | 1e+01 | 1e+00 | 1e-01 | 1e-02 | 1e-03 | 1e-04 | 1e-05 | 1e-07 | $\Delta$ftarget |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $\mathrm{ERT}_{\mathrm{best}}$/D | 0.50 | 0.50 | 0.93 | 24 | 97 | 637 | 1328 | 1341 | 1365 | 1392 | $\mathrm{ERT}_{\mathrm{best}}$/D |
| (1,2)-CMA-ES | **1** | **1** | **1.6** | 38 | 34 | 7.1 | 3.8 | 3.8 | 5.0 | 5.1 | (1,2)-CMA-ES [4, 2] |
| (1,2m)-CMA-ES | **1** | **1** | **1.2** | 29 | 16 | 3.4 | **1.7** | **1.7** | **1.8** | **1.8** | (1,2m)-CMA-ES [4] |
| (1,2ms)-CMA-ES | **1** | **1** | **1.2** | 13 | 15 | 4.2 | **2.2** | **2.8** | **2.7** | **2.8** | (1,2ms)-CMA-ES [4] |
| (1,2s)-CMA-ES | **1** | **1** | **2.1** | 39 | 55 | 12 | 5.9 | 6.0 | 6.2 | 6.9 | (1,2s)-CMA-ES [2] |
| (1,4)-CMA-ES | **1** | **1** | **1.6** | 20 | 13 | **2.4** | **1.3** | **1.3** | **1.3** | **1.3** | (1,4)-CMA-ES [5, 3] |
| (1,4m)-CMA-ES | **1** | **1** | **2.0** | 15 | 10 | **2.7** | **1.4** | **1.4** | **1.4** | **1.4** | (1,4m)-CMA-ES [5] |
| (1,4ms)-CMA-ES | **1** | **1** | **1.2** | **6.1** | 9.1 | **2.0** | **1** | **1** | **1.2** | **1.2** | (1,4ms)-CMA-ES [1, 5] |
| (1,4s)-CMA-ES | **1** | **1** | **1.1** | 8.6 | 13 | **2.1** | **1.0** | **1.0** | **1** | **1** | (1,4s)-CMA-ES [3] |
| avg NEWUOA | **1** | **1** | **2.6** | 7.8 | **3.8** | **1** | **1.1** | **2.4** | 4.9 | 11 | avg NEWUOA [15] |
| CMA-EGS (IPOP,r1) | 8.8 | 12 | 9.0 | 7.4 | 23 | 7.1 | 9.0 | 44 | 84 | 202 | CMA-EGS (IPOP,r1) [7] |
| IPOP-aCMA-ES | **1** | **1** | **1.2** | 6.3 | 6.7 | 15 | 7.8 | 7.7 | 7.8 | 53 | IPOP-aCMA-ES [11] |
| IPOP-CMA-ES | **1** | **1** | **1** | 7.9 | 18 | 3.4 | **1.7** | **1.9** | **1.9** | **1.9** | IPOP-CMA-ES [14] |
| CMA+DE-MOS | **1** | **1** | **1.4** | **1** | **1** | 3.9 | 7.1 | 12 | 12 | 25 | CMA+DE-MOS [12] |
| NEWUOA | **1** | **1** | **2.3** | 9.3 | **5.5** | **1.4** | **1.1** | **2.2** | 3.0 | 10 | NEWUOA [15] |
| Basic RCGA | **1** | **1** | **1.7** | **1.1** | 8.7 | 8.0 | 11 | 27 | 41 | 121 | Basic RCGA [16] |
| SPSA | 22 | 34 | 69 | 630 | 523 | 116 | 73 | 175 | 315 | 496 | SPSA [8] |

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