# Example paper: Black-Box Optimization Benchmarking Template for the Comparison of More than Two Algorithms on the NoisyTestbed

Draft version *

BBOBies

## ABSTRACT

## Categories and Subject Descriptors

G.1.6 [**Numerical Analysis**]: Optimization—*global optimization, unconstrained optimization*; F.2.1 [**Analysis of Algorithms and Problem Complexity**]: Numerical Algorithms and Problems

## General Terms

Algorithms

## Keywords

Benchmarking, Black-box optimization

## 1. RESULTS

Results from experiments according to [**?**] on the benchmark functions given in [**?**, **?**] are presented in Figures 2 and 3, and Figure 1. The **expected running time (**ERT**)**, used in the figures and table, depends on a given target function value, $f_{\mathrm{t}} = f_{\mathrm{opt}} + \Delta f$, and is computed over all relevant trials as the number of function evaluations executed during each trial while the best function value did not reach $f_{\mathrm{t}}$, summed over all trials and divided by the number of trials that actually reached $f_{\mathrm{t}}$ [**?**, **?**]. **Statistical significance** is tested with the rank-sum test for a given target $\Delta f_{\mathrm{t}}$ using, for each trial, either the number of needed function evaluations to reach $\Delta f_{\mathrm{t}}$ (inverted and multiplied by $-1$), or, if the target was not reached, the best $\Delta f$-value achieved, measured only up to the smallest number of overall function evaluations for any unsuccessful trial under consideration if available. Tables 1 and 2 give the Expected Running Time (ERT) for targets $10^{1,-1,-3,-5,-7}$ divided by the best ERT obtained during BBOB-2009 (given in the $\mathrm{ERT}_{\mathrm{best}}$ row), respectively in 5-D and 20-D. Bold entries correspond to the best (or 3-best if there are more than 3 algorithms) values. The median number of conducted function evaluations is additionally given in *italics*, if $\mathrm{ERT}(10^{-7}) = \infty$. #succ is the number of trials that reached the final target $f_{\mathrm{opt}} + 10^{-8}$. Entries with the ↓ symbol are statistically significantly better (according to the rank-sum test) compared to the best algorithm in BBOB-2009, with $p = 0.05$ or $p = 10^{-k}$ where $k > 1$ is the number following the ↓ symbol, with Bonferroni correction of 30.

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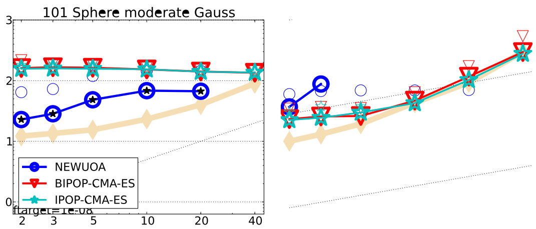

101 Sphere moderate Gauss
3
2
1
0
NEWUOA
BIPOP-CMA-ES
IPOP-CMA-ES
ftarget=1e-08
2
3
5
10
20
40

| $\Delta f_{opt}$ | 1e1 | 1e0 | 1e-1 | 1e-3 | 1e-5 | 1e-7 | #succ |
|---|---|---|---|---|---|---|---|
| **f101** | 11 | 37 | 44 | 62 | 69 | 75 | 15/15 |
| NEWUOA | **2.5**(1) | **1.6**(0.7)$^{\star}$ | **2.1**(0.9)$^{\star 2}$ | **2.6**(2)$^{\star 2}$ | **3.0**(2)$^{\star 3}$ | **3.1**(2)$^{\star 4}$ | 15/15 |
| BIPOP-C | 3.2(2) | 3.1(0.8) | 4.6(0.9) | 6.1(0.5) | 8.0(0.4) | 10(0.7) | 15/15 |
| IPOP-CM | 3.3(3) | 3.4(1) | 4.7(1) | 6.0(1) | 7.8(1) | 9.3(0.5) | 15/15 |

| $\Delta f_{opt}$ | 1e1 | 1e0 | 1e-1 | 1e-3 | 1e-5 | 1e-7 | #succ |
|---|---|---|---|---|---|---|---|
| **f102** | 11 | 35 | 50 | 72 | 86 | 99 | 15/15 |
| NEWUOA | 6.3(11) | 6.0(7) | 7.0(9) | 20(19) | 33(32) | 41(57) | 15/15 |
| BIPOP-C | **2.7**(2) | **3.0**(1) | **4.0**(0.6) | 5.1(0.5) | **6.3**(0.5) | **7.2**(0.7) | 15/15 |
| IPOP-CM | 3.4(2) | 3.1(2) | 4.1(0.9) | **5.1**(0.8) | 6.5(0.9) | 7.3(0.6) | 15/15 |

| $\Delta f_{opt}$ | 1e1 | 1e0 | 1e-1 | 1e-3 | 1e-5 | 1e-7 | #succ |
|---|---|---|---|---|---|---|---|
| **f103** | 11 | 28 | 30 | 31 | 35 | 115 | 15/15 |
| NEWUOA | **2.4**(1.0) | **1.9**(0.7)$^{\star 2}$ | **5.7**(9) | 60(66) | 178(172) | 136(176) | 12/15 |
| BIPOP-C | 3.5(4) | 4.7(1) | 7.4(1) | 13(1) | **17**(2) | **6.9**(0.9) | 15/15 |
| IPOP-CM | 3.6(2) | 4.0(2) | 6.6(1) | **12**(2) | 17(3) | 7.1(0.6) | 15/15 |

| $\Delta f_{opt}$ | 1e1 | 1e0 | 1e-1 | 1e-3 | 1e-5 | 1e-7 | #succ |
|---|---|---|---|---|---|---|---|
| **f104** | 173 | 773 | 1287 | 1768 | 2040 | 2284 | 15/15 |
| NEWUOA | **1.2**(2) | 3.4(4) | 6.0(8) | 24(27) | ∞ | ∞ *3e4* | 0/15 |
| BIPOP-C | 1.4(0.3) | **1.9**(0.6) | **2.0**(0.3) | **2.0**(0.2) | **1.9**(0.2) | **1.8**(0.2) | 15/15 |
| IPOP-CM | 1.4(0.4) | 3.4(3) | 2.9(2) | 2.7(1) | 2.5(1) | 2.4(1) | 15/15 |

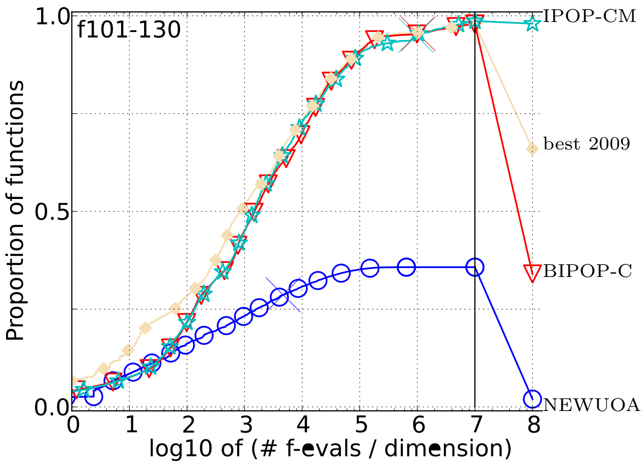
| $\Delta f_{opt}$ | 1e1 | 1e0 | 1e-1 | 1e-3 | 1e-5 | 1e-7 | #succ |
|---|---|---|---|---|---|---|---|
| **f105** | 167 | 1436 | 5174 | 10388 | 10824 | 11202 | 15/15 |
| NEWUOA | 1.7(2) | **2.7**(3) | 3.3(4) | ∞ | ∞ | ∞ *3e4* | 0/15 |
| BIPOP-C | 1.7(0.4) | 3.7(2) | 1.7(0.9) | 1(0.4) | 1(0.4) | 1(0.4) | 15/15 |
| IPOP-CM | **1.6**(0.7) | 3.8(3) | **1.6**(0.7) | **0.90**(0.3) | **0.90**(0.3) | **0.90**(0.3) | 15/15 |

| $\Delta f_{opt}$ | 1e1 | 1e0 | 1e-1 | 1e-3 | 1e-5 | 1e-7 | #succ |
|---|---|---|---|---|---|---|---|
| **f106** | 92 | 529 | 1050 | 2666 | 2887 | 3087 | 15/15 |
| NEWUOA | **0.93**(0.7)$^{\star 3}$ | **2.2**(3) | 5.0(6) | 59(63) | ∞ | ∞ *3e4* | 0/15 |
| BIPOP-C | 3.3(0.9) | 4.3(5) | 3.2(3) | 1.6(1) | 1.7(1) | 1.7(1) | 15/15 |
| IPOP-CM | | | | | | | |

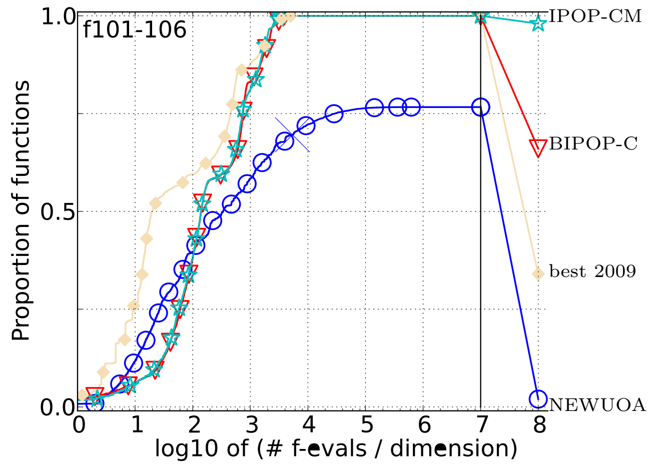
| $\Delta f_{opt}$ | 1e1 | 1e0 | 1e-1 | 1e-3 | 1e-5 | 1e-7 | #succ |
|---|---|---|---|---|---|---|---|
| **f101** | 59 | 425 | 571 | 700 | 739 | 783 | 15/15 |
| NEWUOA | **3.1**(0.8)$^{\star 3}$ | **0.85**(0.2)$^{\star 3}$ | **0.90**(0.2)$^{\star 4}$ | **1.1**(0.2)$^{\star 4}$ | **1.5**(0.3)$^{\star 2}$ | **1.6**(0.4)$^{\star 2}$ | 15/15 |
| BIPOP-C | 6.1(1) | 1.5(0.2) | 1.6(0.1) | 2.1(0.1) | 2.7(0.1) | 3.3(0.2) | 15/15 |
| IPOP-CM | 6.0(2) | 1.5(0.2) | 1.5(0.2) | 2.0(0.2) | 2.6(0.2) | 3.2(0.2) | 15/15 |
| $\Delta f_{opt}$ | 1e1 | 1e0 | 1e-1 | 1e-3 | 1e-5 | 1e-7 | #succ |
| **f102** | 231 | 399 | 579 | 921 | 1157 | 1407 | 15/15 |
| NEWUOA | 2.9(4) | 6.1(9) | 6.3(7) | 45(49) | ∞ | ∞ *1e5* | 0/15 |
| BIPOP-C | **1.6**(0.3) | 1.6(0.2) | 1.6(0.2) | 1.6(0.1) | 1.8(0.1) | **1.8**(0.1) | 15/15 |
| IPOP-CM | 1.6(0.2) | **1.6**(0.3) | **1.6**(0.2) | **1.6**(0.1) | **1.7**(0.1) | 1.8(0.1) | 15/15 |
| $\Delta f_{opt}$ | 1e1 | 1e0 | 1e-1 | 1e-3 | 1e-5 | 1e-7 | #succ |
| **f103** | 65 | 417 | 629 | 1313 | 1893 | 2464 | 14/15 |
| NEWUOA | **2.3**(0.9)$^{\star 4}$ | **1.00**(0.2)$^{\star 2}$ | 5.9(6) | 1231(1324) | ∞ | ∞ *1e5* | 0/15 |
| BIPOP-C | 5.5(1) | 1.6(0.1) | 1.5(0.1) | 1.2(0.1) | 1.2(0.1) | **1.2**(0.1) | 15/15 |
| IPOP-CM | 5.5(1) | 1.5(0.2) | **1.4**(0.2) | **1.2**(0.1) | **1.2**(0.1) | 1.2(0.1) | 15/15 |
| $\Delta f_{opt}$ | 1e1 | 1e0 | 1e-1 | 1e-3 | 1e-5 | 1e-7 | #succ |
| **f104** | 23690 | 85656 | 1.7e5 | 1.8e5 | 1.9e5 | 2.0e5 | 15/15 |
| NEWUOA | 68(78) | ∞ | ∞ | ∞ | ∞ | ∞ *1e5* | 0/15 |
| BIPOP-C | 10(7) | 3.2(2) | 1.7(1) | 1.6(1) | 1.6(1.0) | 1.6(0.9) | 15/15 |
| IPOP-CM | **7.5**(6) | **2.5**(2) | **1.3**(0.9) | **1.3**(0.9) | **1.3**(0.9) | **1.2**(0.8) | 15/15 |
| $\Delta f_{opt}$ | 1e1 | 1e0 | 1e-1 | 1e-3 | 1e-5 | 1e-7 | #succ |
| **f105** | 1.9e5 | 6.1e5 | 6.3e5 | 6.5e5 | 6.6e5 | 6.7e5 | 15/15 |
| NEWUOA | ∞ | ∞ | ∞ | ∞ | ∞ | ∞ *9e4* | 0/15 |
| BIPOP-C | 2.7(2) | 1(0.6) | 1(0.6) | 1(0.6) | 1(0.6) | 1(0.6) | 15/15 |
| IPOP-CM | **1.9**(0.9) | **0.76**(0.3) | **0.76**(0.3) | **0.77**(0.3) | **0.77**(0.3) | **0.76**(0.2) | 15/15 |
| $\Delta f_{opt}$ | 1e1 | 1e0 | 1e-1 | 1e-3 | 1e-5 | 1e-7 | #succ |
| **f106** | 11480 | 21668 | 23746 | 25470 | 26492 | 27360 | 15/15 |
| NEWUOA | 7.0(5) | 31(32) | ∞ | ∞ | ∞ | ∞ *2e5* | 0/15 |
| BIPOP-C | **1.0**(0.3) | **1.3**(0.3) | **1.4**(1) | **1.5**(1) | **1.5**(1) | **1.5**(1) | 15/15 |
| IPOP-CM | 1.0(0.4) | 1.4(1) | 1.5(1.0) | 1.5(0.9) | 1.5(0.9) | 1.5(0.9) | 15/15 |
| $\Delta f_{opt}$ | 1e1 | 1e0 | 1e-1 | 1e-3 | 1e-5 | 1e-7 | #succ |
| **f107** | 8571 | 13582 | 16226 | 27357 | 52486 | 65052 | 15/15 |
| NEWUOA | ∞ | ∞ | ∞ | ∞ | ∞ | ∞ *8e4* | 0/15 |
| BIPOP-C | **1**(0.4) | 1(0.7) | **1**(0.6) | 1(0.4) | 1(0.8) | 1(0.8) | 15/15 |
| IPOP-CM | 1.1(0.6) | **0.95**(0.4) | 1.1(0.7) | **0.96**(0.5) | **0.68**(0.3) | **0.65**(0.3) | 15/15 |
| $\Delta f_{opt}$ | 1e1 | 1e0 | 1e-1 | 1e-3 | 1e-5 | 1e-7 | #succ |
| **f108** | 58063 | 97228 | 2.0e5 | 4.5e5 | 6.3e5 | 9.0e5 | 15/15 |
| NEWUOA | ∞ | ∞ | ∞ | ∞ | ∞ | ∞ *8e4* | 0/15 |
| BIPOP-C | 1(0.5) | 1(0.4) | 1(0.5) | 1(0.5) | 1(0.5) | **1**(0.4) | 15/15 |
| IPOP-CM | **0.72**(0.2) | **0.87**(0.6) | **0.66**(0.3) | **0.77**(0.4) | **0.94**(0.4) | 1.0(0.6) | 15/15 |
| $\Delta f_{opt}$ | 1e1 | 1e0 | 1e-1 | 1e-3 | 1e-5 | 1e-7 | #succ |
| **f109** | 333 | 632 | 1138 | 2287 | 3583 | 4952 | 15/15 |
| NEWUOA | 17(23) | ∞ | ∞ | ∞ | ∞ | ∞ *8e4* | 0/15 |
| BIPOP-C | 1.2(0.441(.)-0.904257(116.74(1)0.66847.3526206.67847.3526266.521000101(.)-0.906708(2)-1.14441())-1.16.74(1)0.66847.3526206.678-1.14686(()-1.02433(0)-1.14441(.)-0.906708(7)- | | | | | | |

f1009 847.352 5404.484 847.352 5234.842 10 0 0 10 0 0 124 4.98132 f 1 0 0 1 86.1121 4334363 5 f 5484751 1 1.84772 1 1.84751 1 1.84751 1 1.84772 1 1514618 2893.54 04.4

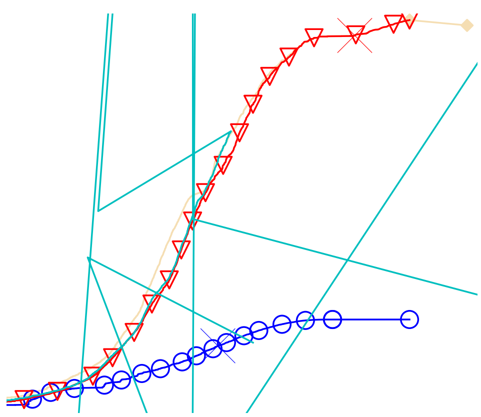
all functions




moderate noise

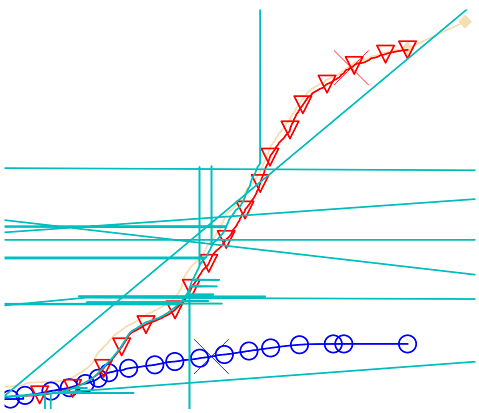



severe noise



severe noise multimod.

all functions



moderate noise