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, $f_t = f_{opt} + \Delta f$, 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_t, summed over all trials and divided by the number of trials that actually reached f_t [**?**, **?**]. **Statistical significance** is tested with the rank-sum test for a given target Δf_t using, for each trial, either the number of needed function evaluations to reach Δf_t (inverted and multiplied by -1), or, if the target was not reached, the best Δf-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 ERT_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 $\text{ERT}(10^{-7}) = \infty$. #succ is the number of trials that reached the final target $f_{opt} + 10^{-8}$. 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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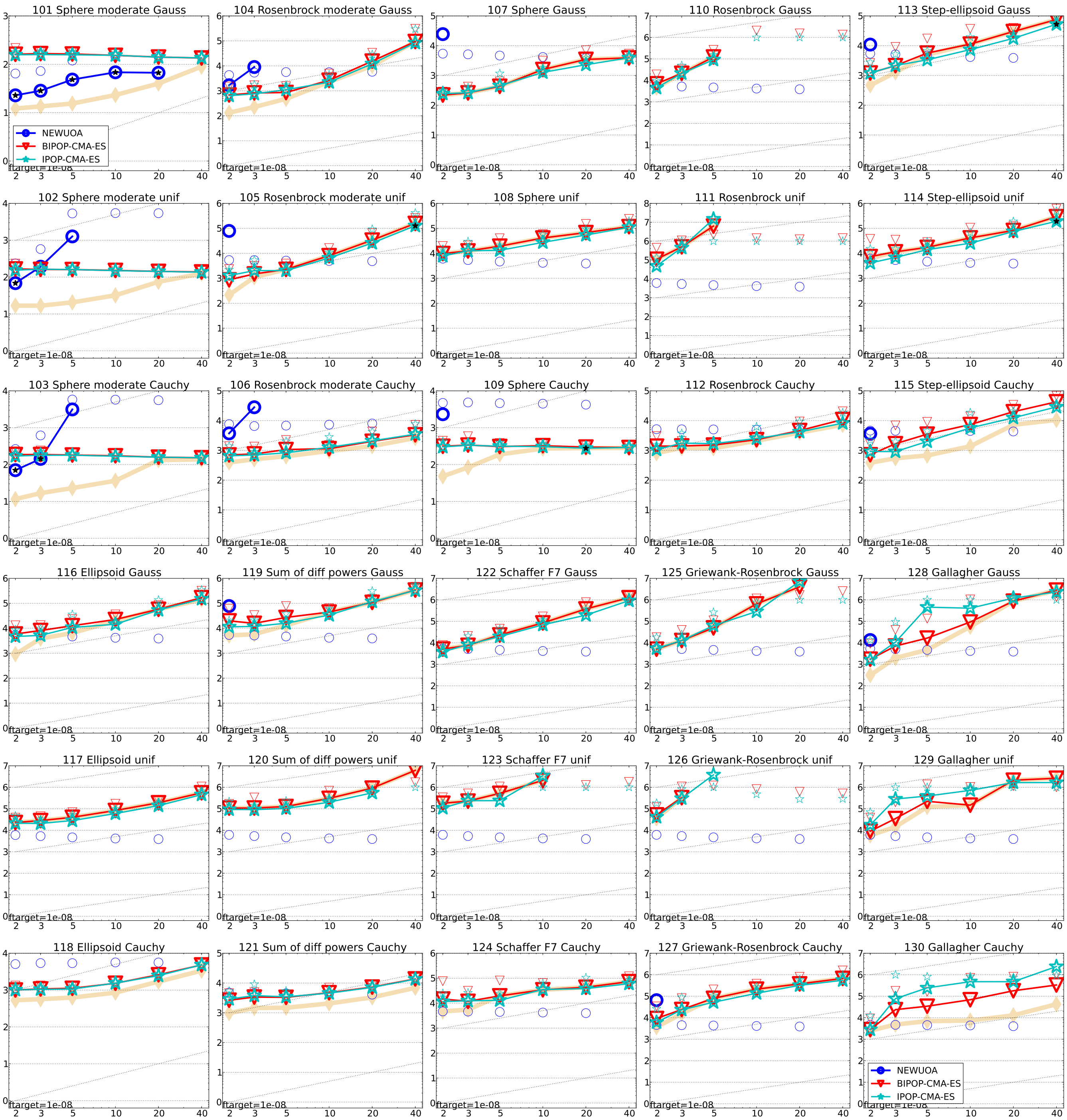

Figure 1: Expected running time (ERT) divided by dimension for target function value 10^{-8} as $\log_{10}$ values versus dimension. Different symbols correspond to different algorithms given in legend of f_{101} and f_{130}. Light symbols give the maximum number of function evaluations from all trials divided by the dimension. Horizontal lines give linear scaling, the slanted dotted lines give quadratic scaling. Legend: ○: NEWUOA, ▽: BIPOP-CMA-ES, ⋆: IPOP-CMA-ES

Δf_{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)*	**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
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
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
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
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
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	3.1(1)	2.5(1)	**2.2**(0.6)	**1.2**(0.2)	**1.3**(0.2)	**1.3**(0.2)	15/15
f107	40	228	453	940	1376	1850	15/15
NEWUOA	60(50)	194(204)	∞	∞	∞	∞ *2e4*	0/15
BIPOP-C	**1.7**(2)	1(0.7)	**1**(0.5)	**1**(0.3)	**1**(0.2)	**1**(0.2)	15/15
IPOP-CM	2.1(3)	**0.98**(0.4)	1.1(0.7)	1.3(1)	1.2(1.0)	1.1(0.7)	15/15
f108	87	5144	14469	30935	58628	80667	15/15
NEWUOA	77(89)	64(74)	∞	∞	∞	∞ *2e4*	0/15
BIPOP-C	**6.1**(10)	1.0(0.9)	1(0.8)	1(0.6)	1(0.4)	1(0.3)	15/15
IPOP-CM	9.1(13)	**0.80**(0.5)	**0.67**(0.4)	**0.77**(0.3)	**0.62**(0.2)$_{\downarrow}$	**0.69**(0.3)	15/15
f109	11	57	216	572	873	946	15/15
NEWUOA	4.8(10)	13(10)	83(108)	∞	∞	∞ *2e4*	0/15
BIPOP-C	3.5(2)	2.2(0.9)	**1.1**(0.3)	1.1(0.2)	1.1(0.3)	**1.5**(0.3)	15/15
IPOP-CM	**2.9**(3)	**2.2**(0.9)	1.2(0.5)	**1.0**(0.3)	**1.1**(0.2)	1.5(0.3)	15/15
f110	949	33625	1.2e5	5.9e5	6.0e5	6.1e5	15/15
NEWUOA	118(111)	10(12)	∞	∞	∞	∞ *2e4*	0/15
BIPOP-C	1(1)	**4.8**(7)	3.7(4)	1(0.7)	1(0.7)	1(0.6)	15/15
IPOP-CM	**0.73**(0.8)	8.3(6)	**3.4**(2)	**0.72**(0.4)	**0.73**(0.4)	**0.74**(0.4)	15/15
f111	6856	6.1e5	8.8e6	2.3e7	3.1e7	3.1e7	3/15
NEWUOA	∞	∞	∞	∞	∞	∞ *2e4*	0/15
BIPOP-C	1(1.0)	**2.5**(3)	**1**(1)	**1**(0.9)	**1**(1.0)	**1**(1.0)	3/15
IPOP-CM	**0.78**(0.8)	15(19)	3.9(5)	3.2(3)	2.4(3)	2.4(3)	1/15
f112	107	1684	3421	4502	5132	5596	15/15
NEWUOA	**1.9**(3)	7.7(9)	105(112)	∞	∞	∞ *2e4*	0/15
BIPOP-C	4.0(2)	**1**(0.6)	**1.2**(0.2)	**1.3**(0.2)	**1.3**(0.2)	**1.3**(0.2)	15/15
IPOP-CM	2.1(1)	1.4(0.5)	1.4(0.2)	1.5(0.2)	1.5(0.2)	1.5(0.2)	15/15
f113	133	1883	8081	24128	24128	24402	15/15
NEWUOA	13(16)	44(43)	∞	∞	∞	∞ *2e4*	0/15
BIPOP-C	**1.5**(1.0)	**1.3**(2)	1.7(2)	1.1(1)	1.1(1)	1.1(1)	15/15
IPOP-CM	3.7(8)	1.4(1)	**1.4**(1)	**0.67**(0.4)	**0.67**(0.4)	**0.67**(0.4)	15/15
f114	767	14720	56311	83272	83272	84949	15/15
NEWUOA	43(40)	∞	∞	∞	∞	∞ *2e4*	0/15
BIPOP-C	**2.2**(2)	1(0.6)	1(0.7)	1(0.7)	1(0.7)	1(0.7)	15/15
IPOP-CM	3.2(4)	**0.45**(0.5)	**0.48**(0.3)	**0.79**(0.7)	**0.79**(0.7)	**0.80**(0.7)	15/15
f115	64	485	1829	2550	2550	2970	15/15
NEWUOA	2.9(3)	14(20)	42(48)	∞	∞	∞ *2e4*	0/15
BIPOP-C	**1.5**(0.8)	2.6(2)	6.5(7)	5.9(6)	5.9(6)	5.7(5)	15/15
IPOP-CM	1.7(2)	**2.4**(4)	**2.7**(4)	**3.1**(3)	**3.1**(3)	**2.7**(3)	15/15

Δf_{opt}	1e1	1e0	1e-1	1e-3	1e-5	1e-7	#succ
f116	5730	14472	22311	26868	30329	31661	15/15
NEWUOA	∞	∞	∞	∞	∞	∞ *2e4*	0/15
BIPOP-C	**1.2**(1)	**2.0**(2)	1.9(2)	2.1(2)	2.0(2)	2.0(2)	15/15
IPOP-CM	3.1(3)	2.3(2)	**1.9**(2)	**1.8**(1)	**1.7**(1)	**1.7**(1)	15/15
f117	26686	76052	1.1e5	1.4e5	1.7e5	1.9e5	15/15
NEWUOA	∞	∞	∞	∞	∞	∞ *2e4*	0/15
BIPOP-C	**1**(0.7)	1(0.8)	1(0.7)	1(0.6)	1(0.6)	1(0.5)	15/15
IPOP-CM	1.1(1)	**0.95**(0.8)	**0.77**(0.6)	**0.73**(0.5)	**0.67**(0.5)	**0.69**(0.5)	15/15
f118	429	1217	1555	1998	2430	2913	15/15
NEWUOA	4.3(6)	10(11)	116(134)	∞	∞	∞ *3e4*	0/15
BIPOP-C	3.2(1)	**2.0**(0.7)	1.9(0.7)	2.1(0.4)	2.0(0.4)	1.8(0.3)	15/15
IPOP-CM	**3.2**(1)	2.0(0.9)	**1.9**(0.8)	**2.0**(0.4)	**1.9**(0.3)	**1.7**(0.2)	15/15
f119	12	657	1136	10372	35296	49747	15/15
NEWUOA	26(40)	35(41)	∞	∞	∞	∞ *2e4*	0/15
BIPOP-C	1.9(3)	1(2)	1(2)	1(0.6)	1.5(0.8)	2.3(1)	15/15
IPOP-CM	**1.1**(1)	**0.35**(0.2)	**0.70**(1.0)	**0.83**(0.7)	**1.0**(0.4)	**1.4**(0.7)	15/15
f120	16	2900	18698	72438	3.3e5	5.5e5	15/15
NEWUOA	130(196)	55(67)	∞	∞	∞	∞ *2e4*	0/15
BIPOP-C	17(16)	**1.1**(1)	1(0.6)	1(0.8)	1(0.5)	1(0.4)	15/15
IPOP-CM	**6.0**(8)	1.6(2)	**0.68**(0.4)	**0.69**(0.5)	**0.55**(0.4)$_{\downarrow}$	**0.83**(0.5)	15/15
f121	8.6	111	273	1583	3870	6195	15/15
NEWUOA	4.8(13)	15(24)	76(82)	∞	∞	∞ *2e4*	0/15
BIPOP-C	2.7(3)	**1.1**(0.4)	**1**(0.2)	1.1(0.5)	**2.0**(0.2)	**2.2**(0.2)	15/15
IPOP-CM	**1.9**(2)	1.1(0.5)	1.0(0.3)	**1.1**(0.4)	2.1(0.4)	2.3(0.4)	15/15
f122	10	1727	9190	30087	53743	1.1e5	15/15
NEWUOA	14(23)	91(104)	∞	∞	∞	∞ *2e4*	0/15
BIPOP-C	**2.2**(2)	1(1)	1(0.8)	1(0.5)	1(0.6)	1(0.6)	15/15
IPOP-CM	4.8(5)	**0.94**(0.7)	**0.44**(0.3)	**0.56**(0.3)$_{\downarrow}$	**0.68**(0.3)	**0.67**(0.5)$_{\downarrow}$	15/15
f123	11	16066	81505	3.4e5	6.7e5	2.2e6	15/15
NEWUOA	65(85)	∞	∞	∞	∞	∞ *2e4*	0/15
BIPOP-C	**8.1**(11)	1(0.8)	1(0.6)	1(0.6)	1(0.6)	1(0.9)	15/15
IPOP-CM	23(38)	**0.62**(0.5)	**0.52**(0.3)	**0.74**(0.5)	**0.65**(0.4)	**0.45**(0.3)	15/15
f124	10	202	1040	20478	45337	95200	15/15
NEWUOA	3.0(1)	158(177)	∞	∞	∞	∞ *2e4*	0/15
BIPOP-C	**1.5**(2)	**1.1**(0.4)	**1**(0.3)	**1.1**(0.7)	1.2(1.0)	1(0.5)	15/15
IPOP-CM	2.8(3)	1.3(0.6)	4.0(8)	1.2(0.8)	**0.93**(0.2)	**0.65**(0.4)	15/15
f125	1	1	1	2.4e5	2.4e5	2.5e5	15/15
NEWUOA	3.9(6)	**15**(6)	6088(8822)	∞	∞	∞ *2e4*	0/15
BIPOP-C	1.1(0)	17(18)	3443(2609)	1(0.7)	**1**(0.7)	**1**(0.7)	15/15
IPOP-CM	**1**(0)	27(28)	**2599**(2294)	**0.78**(0.3)	1.3(0.6)	1.3(0.6)	15/15
f126	1	1	1	∞	∞	∞	0
NEWUOA	1.2(0)	1053(1172)	3.5e5(3e5)	.	.	.	0/15
BIPOP-C	**1**(0)	160(130)	1.3e4(1e4)	.	.	.	0/15
IPOP-CM	**1**(0)	**63**(59)	**1.0e4**(7819)	**1.2e7**(1e7)	**1.9e7**(2e7)	**1.9e7**(2e7)	2/15
f127	1	1	1	3.4e5	3.9e5	4.0e5	15/15
NEWUOA	2.5(6)	**14**(4)	7248(1e4)	∞	∞	∞ *2e4*	0/15
BIPOP-C	**1**(0)	19(24)	2136(1530)	1(1.0)	1(0.8)	1(0.8)	15/15
IPOP-CM	**1**(0)	15(18)	**1542**(1498)	**0.58**(0.6)	**0.64**(0.5)	**0.65**(0.5)	15/15
f128	111	4248	7808	12447	17217	21162	15/15
NEWUOA	12(22)	17(19)	43(49)	∞	∞	∞ *2e4*	0/15
BIPOP-C	2.2(2)	**6.9**(9)	**10**(17)	**6.6**(11)	**4.8**(8)	**3.9**(6)	15/15
IPOP-CM	**1.0**(0.7)	14(27)	166(314)	183(335)	132(150)	108(196)	10/15
f129	64	10710	59443	2.8e5	5.1e5	5.8e5	15/15
NEWUOA	124(124)	16(16)	∞	∞	∞	∞ *2e4*	0/15
BIPOP-C	12(15)	**7.1**(8)	**9.2**(2)	**3.9**(12)	**2.2**(7)	**1.9**(6)	13/15
IPOP-CM	**8.5**(10)	13(18)	18(35)	6.7(9)	3.8(5)	3.3(4)	11/15
f130	55	812	3034	32823	33889	34528	10/15
NEWUOA	2.3(4)	**11**(10)	**10**(10)	∞	∞	∞ *2e4*	0/15
BIPOP-C	1.9(1)	57(82)	55(101)	**5.1**(9)	**5.0**(9)	**5.0**(9)	15/15
IPOP-CM	**1.2**(1)	59(10)	321(634)	37(62)	36(60)	35(59)	12/15

Table 1: Expected running time (ERT in number of function evaluations) divided by the respective best ERT measured during BBOB-2009 (given in the respective first row) for different Δf values in dimension 5. The inter-80%tile range divided by two is given in braces. 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 $f_{\mathrm{opt}} + 10^{-8}$. Best results are printed in bold.

$\Delta f_{\rm opt}$	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

$\Delta f_{\rm opt}$	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

$\Delta f_{\rm opt}$	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

$\Delta f_{\rm opt}$	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

$\Delta f_{\rm opt}$	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

$\Delta f_{\rm opt}$	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

$\Delta f_{\rm opt}$	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

$\Delta f_{\rm opt}$	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

$\Delta f_{\rm opt}$	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(0.3)	1.2(0.2)	1.1(0.2)	1.1(0.1)	1.1(0.1)	1.0(0.1)	15/15
IPOP-CM	**1.1**(0.2)	**1.2**(0.1)	**1.1**(0.1)	**1.1**(0.1)	**1.0**(0.1)	**1.00**(0.1)	15/15

$\Delta f_{\rm opt}$	1e1	1e0	1e-1	1e-3	1e-5	1e-7	#succ
f110	∞	∞	∞	∞	∞	∞	0
NEWUOA	.	.	.	.	.	.	0/15
BIPOP-C	.	.	.	.	.	.	0/15
IPOP-CM	.	.	.	.	.	.	0/15

$\Delta f_{\rm opt}$	1e1	1e0	1e-1	1e-3	1e-5	1e-7	#succ
f111	∞	∞	∞	∞	∞	∞	0
NEWUOA	.	.	.	.	.	.	0/15
BIPOP-C	.	.	.	.	.	.	0/15
IPOP-CM	.	.	.	.	.	.	0/15

$\Delta f_{\rm opt}$	1e1	1e0	1e-1	1e-3	1e-5	1e-7	#succ
f112	25552	64124	69621	73557	76137	78238	15/15
NEWUOA	∞	∞	∞	∞	∞	∞ *1e5*	0/15
BIPOP-C	1(0.3)	1.1(0.8)	1.1(0.8)	1.2(0.7)	1.2(0.7)	1.2(0.7)	15/15
IPOP-CM	**0.95**(0.4)	**0.94**(0.2)	**1.0**(0.1)	**1.1**(0.1)	**1.1**(0.1)	**1.1**(0.1)	15/15

$\Delta f_{\rm opt}$	1e1	1e0	1e-1	1e-3	1e-5	1e-7	#succ
f113	50123	3.6e5	5.6e5	5.9e5	5.9e5	5.9e5	15/15
NEWUOA	∞	∞	∞	∞	∞	∞ *8e4*	0/15
BIPOP-C	**1**(1.0)	1(0.7)	1(0.4)	1(0.4)	1(0.4)	1(0.4)	15/15
IPOP-CM	1.0(0.8)	**0.53**(0.4)	**0.58**(0.3)$_{\downarrow}$	**0.59**(0.2)$_{\downarrow}$	**0.59**(0.2)$_{\downarrow}$	**0.59**(0.2)$_{\downarrow}$	15/15

$\Delta f_{\rm opt}$	1e1	1e0	1e-1	1e-3	1e-5	1e-7	#succ
f114	2.1e5	1.1e6	1.4e6	1.6e6	1.6e6	1.6e6	15/15
NEWUOA	∞	∞	∞	∞	∞	∞ *8e4*	0/15
BIPOP-C	1(0.4)	1(0.5)	1(0.5)	1(0.5)	1(0.5)	1(0.5)	15/15
IPOP-CM	**0.59**(0.3)$_{\downarrow}$	**0.68**(0.5)	**0.84**(0.3)	**0.91**(0.3)	**0.91**(0.3)	**0.92**(0.4)	15/15

$\Delta f_{\rm opt}$	1e1	1e0	1e-1	1e-3	1e-5	1e-7	#succ
f115	2405	30268	91749	1.3e5	1.3e5	1.3e5	15/15
NEWUOA	236(283)	∞	∞	∞	∞	∞ *8e4*	0/15
BIPOP-C	**1**(1)	6.5(7)	3.9(2)	3.0(1)	3.0(1)	3.0(2)	15/15
IPOP-CM	1.1(2)	**4.8**(3)	**2.2**(1.0)	**1.8**(0.8)	**1.8**(0.8)	**1.9**(0.8)	15/15

$\Delta f_{\rm opt}$	1e1	1e0	1e-1	1e-3	1e-5	1e-7	#succ
f116	5.0e5	6.9e5	8.9e5	1.0e6	1.1e6	1.1e6	15/15
NEWUOA	∞	∞	∞	∞	∞	∞ *8e4*	0/15
BIPOP-C	1.4(0.9)	1.2(0.6)	1.1(0.5)	1(0.4)	1(0.4)	1(0.4)	15/15
IPOP-CM	**1.2**(0.5)	**1.1**(0.5)	**1.00**(1)	**0.92**(1.0)	**0.93**(0.9)	**0.93**(0.9)	15/15

$\Delta f_{\rm opt}$	1e1	1e0	1e-1	1e-3	1e-5	1e-7	#succ
f117	1.8e6	2.5e6	2.6e6	2.9e6	3.2e6	3.6e6	15/15
NEWUOA	∞	∞	∞	∞	∞	∞ *8e4*	0/15
BIPOP-C	1(0.5)	1(0.2)	1(0.2)	1(0.2)	1(0.2)	1(0.2)	15/15
IPOP-CM	**0.55**(0.3)$_{\downarrow}$	**0.61**(0.3)$_{\downarrow 3}$	**0.66**(0.3)$_{\downarrow 2}$	**0.69**(0.3)$_{\downarrow 2}$	**0.71**(0.2)$_{\downarrow 2}$	**0.72**(0.3)$_{\downarrow 2}$	15/15

$\Delta f_{\rm opt}$	1e1	1e0	1e-1	1e-3	1e-5	1e-7	#succ
f118	6908	11786	17514	26342	30062	32659	15/15
NEWUOA	∞	∞	∞	∞	∞	∞ *1e5*	0/15
BIPOP-C	**1.9**(0.4)	**1.8**(0.4)	**1.6**(0.2)	1.5(0.1)	1.6(0.1)	1.6(0.1)	15/15
IPOP-CM	2.0(0.4)	1.8(0.5)	1.7(0.2)	**1.5**(0.1)	**1.5**(0.2)	**1.5**(0.1)	15/15

$\Delta f_{\rm opt}$	1e1	1e0	1e-1	1e-3	1e-5	1e-7	#succ
f119	2771	29365	35930	4.1e5	1.4e6	1.9e6	15/15
NEWUOA	398(463)	∞	∞	∞	∞	∞ *8e4*	0/15
BIPOP-C	**1.6**(1)	1(1)	1(1)	1(0.5)	1.3(0.3)	1.1(0.2)	15/15
IPOP-CM	1.9(0.6)	**0.58**(0.4)	**0.69**(0.3)	**0.58**(0.3)	**0.59**(0.4)$_{\downarrow 2}$	**0.97**(0.5)	15/15

$\Delta f_{\rm opt}$	1e1	1e0	1e-1	1e-3	1e-5	1e-7	#succ
f120	36040	1.8e5	2.8e5	1.6e6	6.7e6	1.4e7	13/15
NEWUOA	∞	∞	∞	∞	∞	∞ *8e4*	0/15
BIPOP-C	1(0.6)	1(0.9)	1(0.6)	1(0.6)	1(0.4)	1(0.4)	13/15
IPOP-CM	**0.69**(0.4)	**0.60**(0.4)	**0.74**(0.5)	**0.67**(0.4)$_{\downarrow}$	**0.69**(0.4)	**0.69**(0.3)	15/15

$\Delta f_{\rm opt}$	1e1	1e0	1e-1	1e-3	1e-5	1e-7	#succ
f121	249	769	1426	9304	34434	57404	15/15
NEWUOA	31(63)	∞	∞	∞	∞	∞ *8e4*	0/15
BIPOP-C	**1.2**(0.5)	**1.0**(0.2)	1.2(0.3)	**1.1**(0.2)	**1.3**(0.1)	1.9(0.1)	15/15
IPOP-CM	1.3(0.4)	1.1(0.2)	**1.1**(0.2)	1.1(0.1)	1.4(0.1)	**1.9**(0.2)	15/15

$\Delta f_{\rm opt}$	1e1	1e0	1e-1	1e-3	1e-5	1e-7	#succ
f122	692	52008	1.4e5	7.9e5	2.0e6	5.8e6	15/15
NEWUOA	82(114)	∞	∞	∞	∞	∞ *8e4*	0/15
BIPOP-C	**1.8**(2)	1(0.5)	1(0.7)	1(0.7)	1(0.5)	1(0.8)	15/15
IPOP-CM	2.0(2)	**0.92**(0.5)	**0.74**(0.2)	**0.63**(0.5)	**0.95**(0.5)	**0.64**(0.4)	15/15

$\Delta f_{\rm opt}$	1e1	1e0	1e-1	1e-3	1e-5	1e-7	#succ
f123	1063	5.3e5	1.5e6	5.3e6	2.7e7	1.6e8	0
NEWUOA	174(196)	∞	∞	∞	∞	∞ *8e4*	0/15
BIPOP-C	**5.7**(4)	1(0.8)	1(0.7)	1(0.6)	1(0.8)	**1**(1)	0/15
IPOP-CM	7.2(5)	**0.72**(0.4)	**0.61**(0.3)	**0.80**(0.6)	**0.62**(0.4)	∞ *2e7*	0/15

$\Delta f_{\rm opt}$	1e1	1e0	1e-1	1e-3	1e-5	1e-7	#succ
f124	192	1959	40840	1.3e5	3.9e5	8.0e5	15/15
NEWUOA	91(187)	∞	∞	∞	∞	∞ *8e4*	0/15
BIPOP-C	**1.1**(0.5)	1.0(0.5)	1(1.0)	1(0.9)	1(0.8)	1(0.4)	15/15
IPOP-CM	1.1(0.5)	**0.99**(0.7)	**0.75**(0.7)	**0.98**(0.5)	**0.84**(0.4)	**0.78**(0.3)	15/15

$\Delta f_{\rm opt}$	1e1	1e0	1e-1	1e-3	1e-5	1e-7	#succ
f125	1	1	1	2.5e7	8.0e7	8.1e7	4/15
NEWUOA	**1**(0)	414(426)	∞	∞	∞	∞ *8e4*	0/15
BIPOP-C	**1**(0)	**383**(356)	9.8e6(7e6)	1(0.9)	**1**(1)	**1**(1.0)	4/15
IPOP-CM	**1**(0)	957(1360)	**7.1e6**(5e6)	**0.79**(0.6)	1.8(2)	1.8(2)	2/15

$\Delta f_{\rm opt}$	1e1	1e0	1e-1	1e-3	1e-5	1e-7	#succ
f126	1	1	1	∞	∞	∞	0
NEWUOA	4.2(0)	1.3e5(1e5)	∞	.	.	.	0/15
BIPOP-C	**1**(0)	5781(4226)	∞	.	.	.	0/15
IPOP-CM	**1**(0)	**5759**(3156)	∞	.	.	.	0/15

$\Delta f_{\rm opt}$	1e1	1e0	1e-1	1e-3	1e-5	1e-7	#succ
f127	1	1	1	4.4e6	7.3e6	7.4e6	15/15
NEWUOA	3.7(0)	253(389)	∞	∞	∞	∞ *8e4*	0/15
BIPOP-C	**1**(0)	**176**(91)	**9.0e5**(1e6)	1(0.6)	1(0.7)	1(0.7)	15/15
IPOP-CM	**1**(0)	267(132)	9.6e5(1e6)	**0.81**(0.6)	**0.84**(0.5)	**0.85**(0.5)	15/15

$\Delta f_{\rm opt}$	1e1	1e0	1e-1	1e-3	1e-5	1e-7	#succ
f128	1.4e5	1.3e7	1.7e7	1.7e7	1.7e7	1.7e7	9/15
NEWUOA	∞	∞	∞	∞	∞	∞ *8e4*	0/15
BIPOP-C	**1**(2)	**1**(2)	**1**(1)	**1**(1)	**1**(1)	**1**(1)	9/15
IPOP-CM	12(4)	1.0(1)	1.4(2)	1.4(2)	1.4(2)	1.4(2)	6/15

$\Delta f_{\rm opt}$	1e1	1e0	1e-1	1e-3	1e-5	1e-7	#succ
f129	7.8e6	4.1e7	4.2e7	4.2e7	4.2e7	4.2e7	5/15
NEWUOA	∞	∞	∞	∞	∞	∞ *8e4*	0/15
BIPOP-C	1(1)	1(1)	1(1)	1(1)	1(1)	1(1)	5/15
IPOP-CM	**0.29**(0.3)	**0.30**(0.4)	**0.77**(1.0)	**0.77**(0.9)	**0.77**(1.0)	**0.77**(0.9)	4/15

$\Delta f_{\rm opt}$	1e1	1e0	1e-1	1e-3	1e-5	1e-7	#succ
f130	4904	93149	2.5e5	2.5e5	2.6e5	2.6e5	7/15
NEWUOA	9.1(9)	∞	∞	∞	∞	∞ *8e4*	0/15
BIPOP-C	**1.9**(4)	**33**(75)	**14**(28)	**14**(27)	**14**(27)	**14**(27)	15/15
IPOP-CM	4.9(5)	76(149)	37(57)	37(56)	37(57)	37(55)	9/15

Table 2: Expected running time (ERT in number of function evaluations) divided by the respective best ERT measured during BBOB-2009 (given in the respective first row) for different Δf values in dimension 20. The inter-80%tile range divided by two is given in braces. 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 $f_{\rm opt} + 10^{-8}$. Best results are printed in bold.

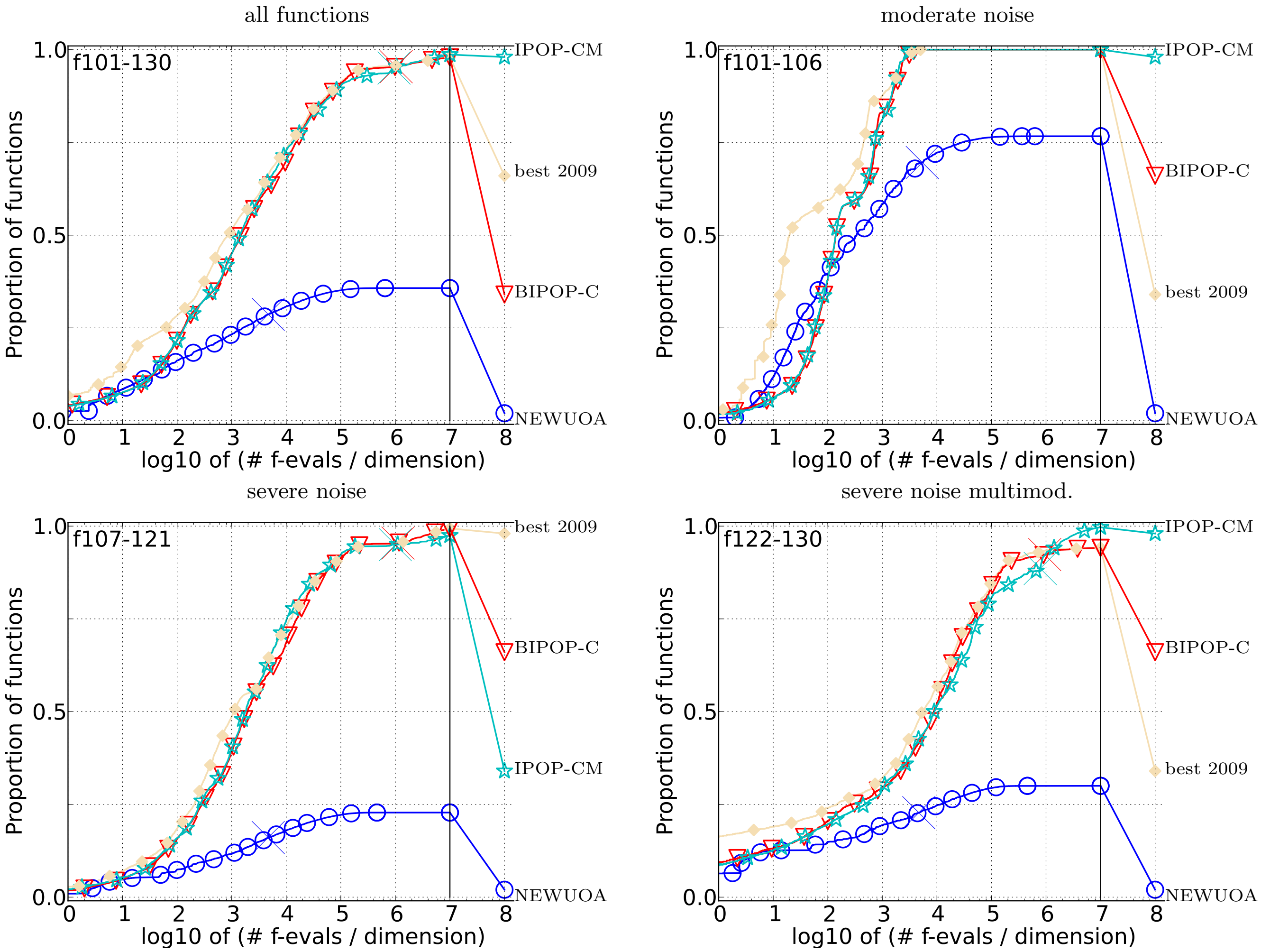

Figure 2: Bootstrapped empirical cumulative distribution of the number of objective function evaluations divided by dimension (FEvals/D) for 50 targets in $10^{[-8..2]}$ for all functions and subgroups in 5-D. The "best 2009" line corresponds to the best ERT observed during BBOB 2009 for each single target.

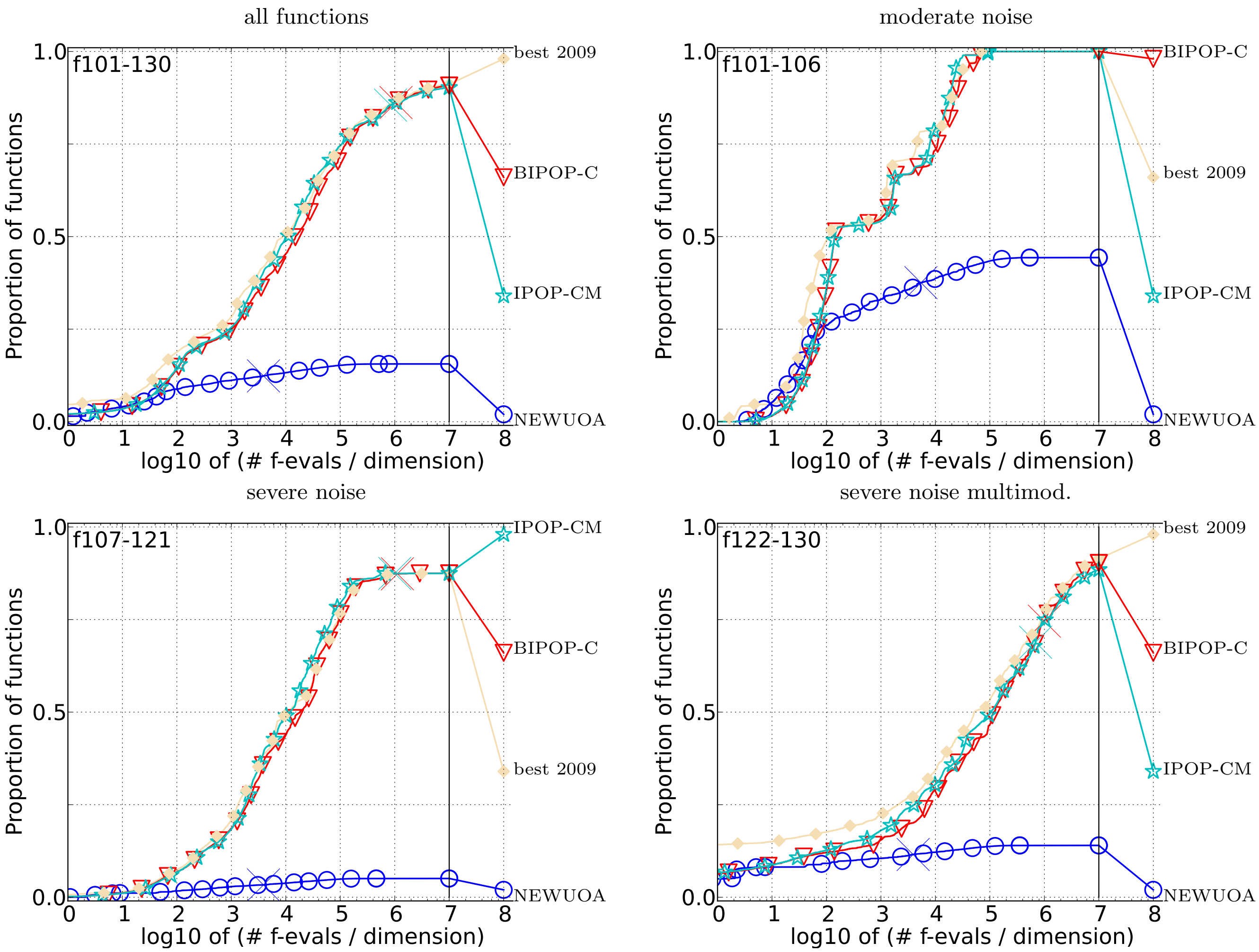

Figure 3: Bootstrapped empirical cumulative distribution of the number of objective function evaluations divided by dimension (FEvals/D) for 50 targets in $10^{[-8..2]}$ for all functions and subgroups in 20-D. The "best 2009" line corresponds to the best ERT observed during BBOB 2009 for each single target.