

Modyfikacje/hybrydyzacje algorytmu PSO w zadaniu optymalizacji globalnej wielowymiarowej funkcji ciągłej

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ABSTRACT

Dokumentacja uzyskanych wyników hybrydy PSO-DE

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, PSODE, Optymalizacja wielowymiarowej funkcji ciągłej

1. CPU TIMING

In order to evaluate the CPU timing of the algorithm, we have run the **PSO-DE Hybrid** on the function f_8 with restarts for at least 30 seconds and until a maximum budget equal to $400(D + 2)$ is reached. The code was run on a **Mac Intel(R) Core(TM) i5-2400S CPU @ 2.50GHz** with 1 processor and 4 cores. The time per function evaluation for dimensions 2, 3, 5, 10, 20, 40 equals $8,3e^{-11}$, $1,0e^{-10}$, $1,4e^{-10}$, $2,2e^{-10}$, $3,8e^{-10}$, and $7,2e^{-10}$ seconds respectively.

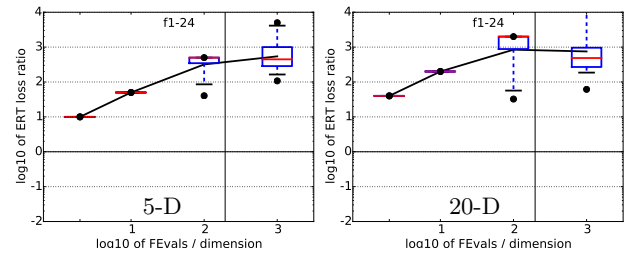
2. RESULTS

Results of PSO DE from experiments according to [?] on the benchmark functions given in [?, ?] are presented in Figures 1, 2, 3, and 4 and in Tables 1.

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f_1-f_{24} in 5-D, maxFE/D=193						
#FEs/D	best	10%	25%	med	75%	90%
2	10	10	10	10	10	10
10	50	50	50	50	50	50
100	40	69	3.3e2	5.0e2	5.0e2	5.0e2
1e3	1.1e2	1.5e2	2.7e2	4.5e2	1.0e3	5.0e3
RLUS/D	2e2	2e2	2e2	2e2	2e2	2e2
f_1-f_{24} in 20-D, maxFE/D=197						
#FEs/D	best	10%	25%	med	75%	90%
2	40	40	40	40	40	40
10	2.0e2	2.0e2	2.0e2	2.0e2	2.0e2	2.0e2
100	32	49	6.5e2	2.0e3	2.0e3	2.0e3
1e3	62	1.7e2	2.7e2	4.9e2	9.9e2	2.0e4
RLUS/D	2e2	2e2	2e2	2e2	2e2	2e2

Figure 3: ERT loss ratio versus the budget in number of f -evaluations divided by dimension. For each given budget FEvals, the target value f_t is computed as the best target f -value reached within the budget by the given algorithm. Shown is then the ERT to reach f_t for the given algorithm or the budget, if the GECCO-BBOB-2009 best algorithm reached a better target within the budget, divided by the best ERT seen in GECCO-BBOB-2009 to reach f_t . Line: geometric mean. Box-Whisker error bar: 25-75%-ile with median (box), 10-90%-ile (caps), and minimum and maximum ERT loss ratio (points). The vertical line gives the maximal number of function evaluations in a single trial in this function subset. See also Figure 4 for results on each function subgroup.

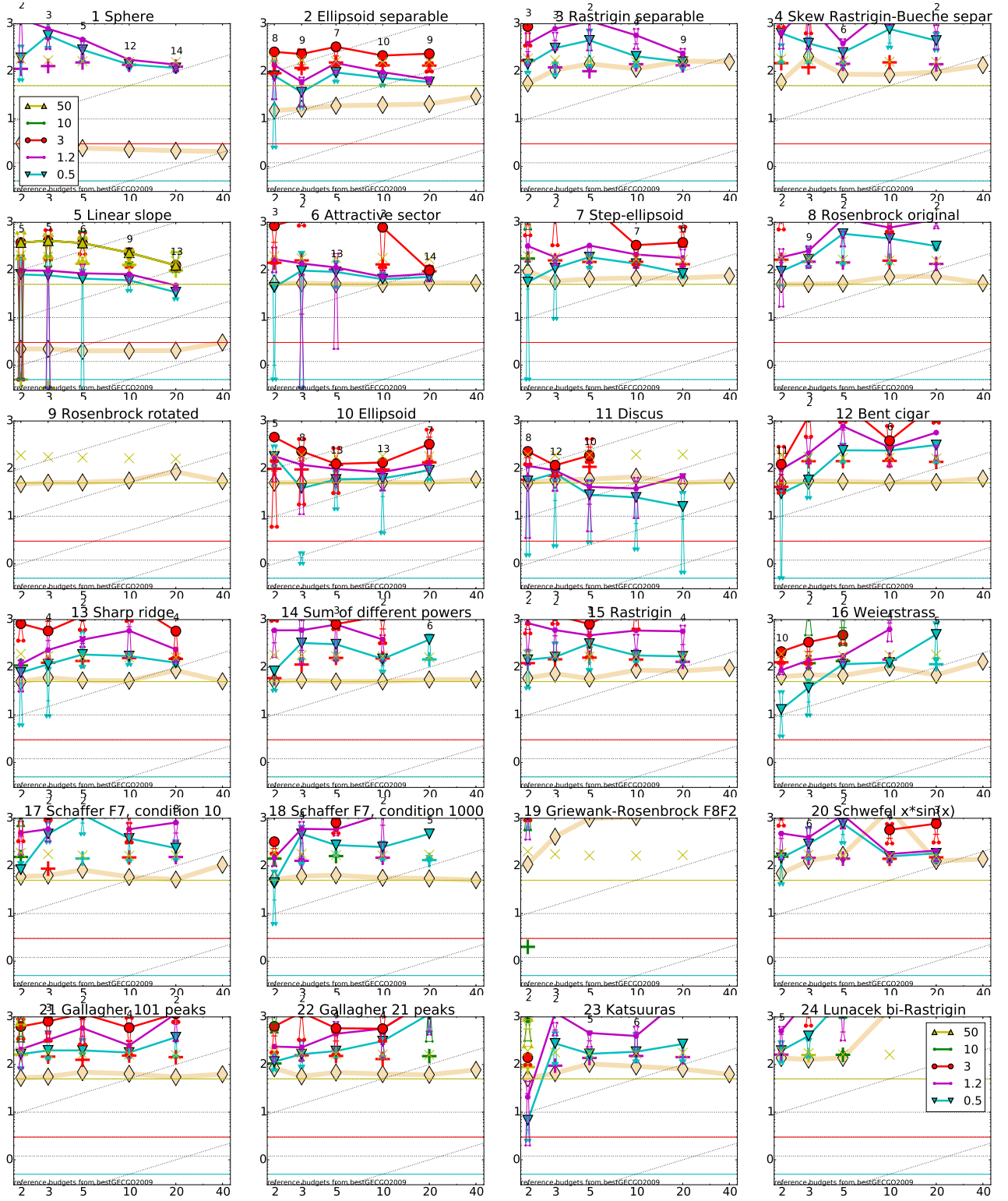


Figure 1: Expected number of f -evaluations (ERT, lines) to reach $f_{\text{opt}} + \Delta f$; median number of f -evaluations (+) to reach the most difficult target that was reached not always but at least once; maximum number of f -evaluations in any trial (\times); interquartile range with median (notched boxes) of simulated runlengths to reach $f_{\text{opt}} + \Delta f$; all values are divided by dimension and plotted as \log_{10} values versus dimension. Shown is the ERT for targets just not reached by the artificial GECCO-BBOB-2009 best algorithm within the given budget $k \times \text{DIM}$, where k is shown in the legend. Numbers above ERT-symbols indicate the number of trials reaching the respective target. The light thick line with diamonds indicates the respective best result from BBOB-2009 for the most difficult target. Slanted grid lines indicate a scaling with $\mathcal{O}(\text{DIM})$ compared to $\mathcal{O}(1)$ when using the respective 2009 best algorithm.

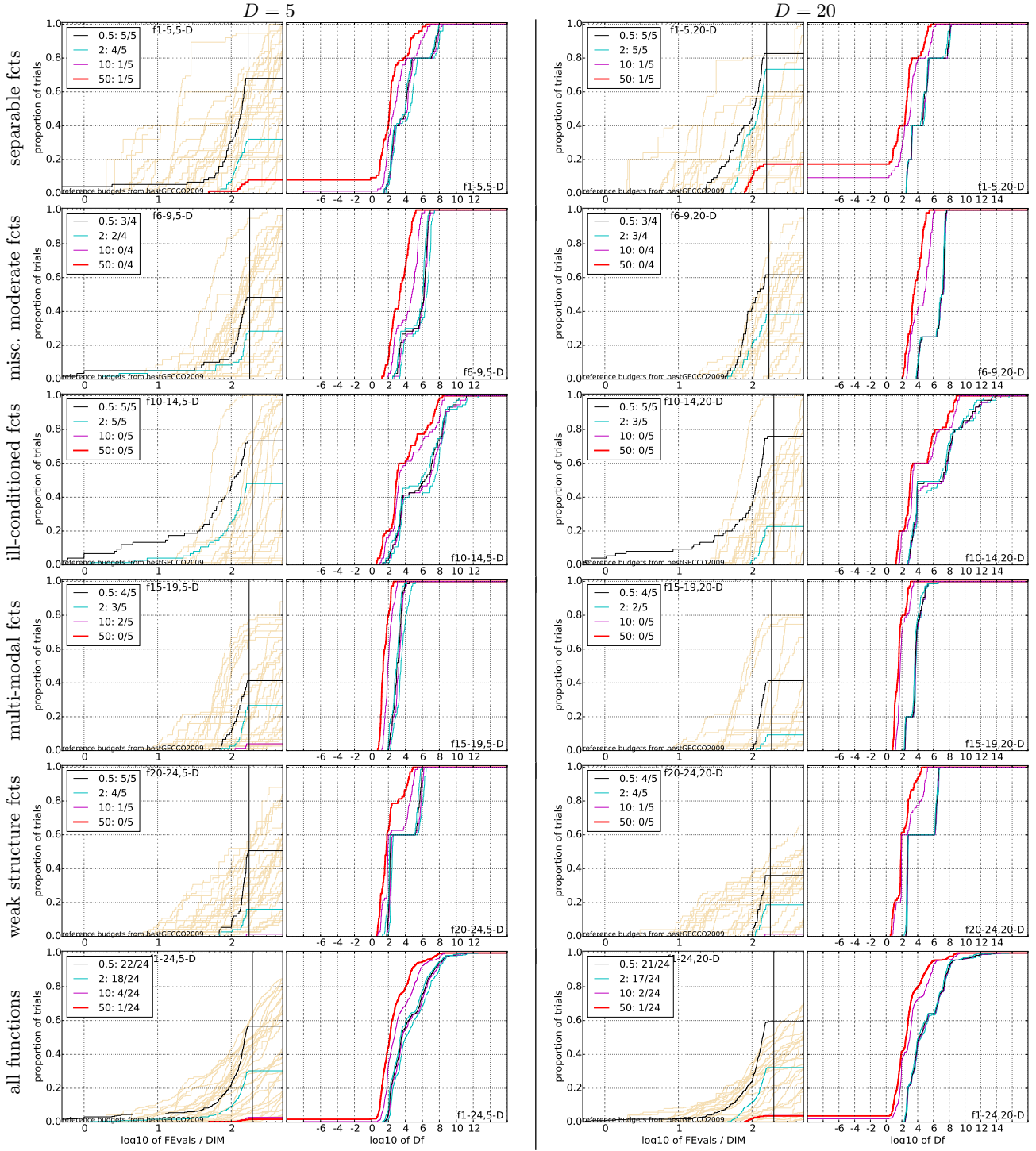


Figure 2: Empirical cumulative distribution functions (ECDF), plotting the fraction of trials with an outcome not larger than the respective value on the x -axis. Left subplots: ECDF of number of function evaluations (FEvals) divided by search space dimension D , to fall below $f_{\text{opt}} + \Delta f$ where Δf is the target just not reached by the GECCO-BBOB-2009 best algorithm within a budget of $k \times \text{DIM}$ evaluations, where k is the first value in the legend. Legends indicate for each target the number of functions that were solved in at least one trial within the displayed budget. Right subplots: ECDF of the best achieved Δf for running times of $0.5D, 1.2D, 3D, 10D, 100D, 1000D, \dots$ function evaluations (from right to left cycling cyan-magenta-black...) and final Δf -value (red), where Δf and Df denote the difference to the optimal function value. Light brown lines in the background show ECDFs for the most difficult target of all algorithms benchmarked during BBOB-2009.

5-D						
#FEs/D	0.5	1.2	3	10	50	#succ
f₁	<i>2.5e+1:4.8</i> 294(81)	<i>1.6e+1:7.6</i> 306(341)	<i>1.0e-8:12</i> ∞	<i>1.0e-8:12</i> ∞	<i>1.0e-8:12</i> ∞ 790	15/15 0/15
f₂	<i>1.6e+6:2.9</i> 165(133)	<i>4.0e+5:11</i> 67(27)	<i>4.0e+4:15</i> 108(41)	<i>6.3e+2:58</i> ∞	<i>1.0e-8:95</i> ∞ 800	15/15 0/15
f₃	<i>1.6e+2:4.1</i> 539(454)	<i>1.0e+2:15</i> 389(492)	<i>6.3e+1:23</i> ∞	<i>2.5e+1:73</i> ∞	<i>1.0e+1:716</i> ∞ 800	15/15 0/15
f₄	<i>2.5e+2:2.6</i> 475(470)	<i>1.6e+2:10</i> 200(107)	<i>1.0e+2:19</i> ∞	<i>4.0e+1:65</i> ∞	<i>1.6e+1:434</i> ∞ 800	15/15 0/15
f₅	<i>6.3e+1:4.0</i> 82(75)	<i>4.0e+1:10</i> 43(29)	<i>1.0e-8:10</i> 184(187)	<i>1.0e-8:10</i> 184(70)	<i>1.0e-8:10</i> 184(259)	15/15 6/15
f₆	<i>1.0e+5:3.0</i> 152(253)	<i>2.5e+4:8.4</i> 67(54)	<i>1.0e+2:16</i> ∞	<i>2.5e+1:54</i> ∞	<i>2.5e-1:254</i> ∞ 800	15/15 0/15
f₇	<i>1.6e+2:4.2</i> 221(174)	<i>1.0e+2:6.2</i> 263(302)	<i>2.5e+1:20</i> 606(771)	<i>4.0e+0:54</i> ∞	<i>1.0e+0:324</i> ∞ 830	15/15 0/15
f₈	<i>1.0e+4:4.6</i> 625(600)	<i>6.3e+3:6.8</i> 870(1031)	<i>1.0e+3:18</i> ∞	<i>6.3e+1:54</i> ∞	<i>1.6e+0:258</i> ∞ 800	15/15 0/15
f₉	<i>2.5e+1:20</i> ∞	<i>1.6e+1:26</i> ∞	<i>1.0e+1:35</i> ∞	<i>4.0e+0:62</i> ∞	<i>1.6e-2:256</i> ∞ 810	15/15 0/15
f₁₀	<i>2.5e+6:2.9</i> 103(182)	<i>6.3e+5:7.0</i> 70(47)	<i>2.5e+5:17</i> 37(21)	<i>6.3e+3:54</i> ∞	<i>2.5e+1:297</i> ∞ 850	15/15 0/15
f₁₁	<i>1.0e+6:3.0</i> 47(43)	<i>6.3e+4:6.2</i> 33(35)	<i>6.3e+2:16</i> 59(38)	<i>6.3e+1:74</i> ∞	<i>6.3e-1:298</i> ∞ 860	15/15 0/15
f₁₂	<i>4.0e+7:3.6</i> 336(209)	<i>1.6e+7:7.6</i> 509(567)	<i>4.0e+6:19</i> 633(1085)	<i>1.6e+4:52</i> ∞	<i>1.0e+0:268</i> ∞ 820	15/15 0/15
f₁₃	<i>1.0e+3:2.8</i> 331(393)	<i>6.3e+2:8.4</i> 226(249)	<i>4.0e+2:17</i> 353(145)	<i>6.3e+1:52</i> ∞	<i>6.3e-2:264</i> ∞ 800	15/15 0/15
f₁₄	<i>1.6e+1:3.0</i> 507(350)	<i>1.0e+1:10</i> 402(297)	<i>6.3e+0:15</i> 262(335)	<i>2.5e-1:53</i> ∞	<i>1.0e-5:251</i> ∞ 820	15/15 0/15
f₁₅	<i>1.6e+2:3.0</i> 523(499)	<i>1.0e+2:13</i> 180(236)	<i>6.3e+1:24</i> 166(126)	<i>4.0e+1:55</i> ∞	<i>1.6e+1:289</i> ∞ 820	5/5 0/15
f₁₆	<i>4.0e+1:4.8</i> 121(42)	<i>2.5e+1:16</i> 55(65)	<i>1.6e+1:46</i> 51(52)	<i>1.0e+1:120</i> 52(48)	<i>4.0e+0:334</i> ∞ 860	15/15 0/15
f₁₇	<i>1.0e+1:5.2</i> 1152(1329)	<i>6.3e+0:26</i> ∞	<i>4.0e+0:57</i> ∞	<i>2.5e+0:110</i> ∞	<i>6.3e-1:412</i> ∞ 810	15/15 0/15
f₁₈	<i>6.3e+1:3.4</i> 402(336)	<i>4.0e+1:7.2</i> 405(419)	<i>2.5e+1:20</i> 203(205)	<i>1.6e+1:58</i> 210(438)	<i>1.6e+0:318</i> ∞ 820	15/15 0/15
f₁₉	<i>1.6e-1:172</i> ∞	<i>1.0e-1:242</i> ∞	<i>6.3e-2:675</i> ∞	<i>4.0e-2:3078</i> ∞	<i>2.5e-2:4946</i> ∞ 800	15/15 0/15
f₂₀	<i>6.3e+3:5.1</i> 758(454)	<i>4.0e+3:8.4</i> 700(522)	<i>4.0e+1:15</i> ∞	<i>2.5e+0:69</i> ∞	<i>1.0e+0:851</i> ∞ 800	15/15 0/15
f₂₁	<i>4.0e+1:3.9</i> 252(36)	<i>2.5e+1:11</i> 276(240)	<i>1.6e+1:31</i> 190(170)	<i>6.3e+0:73</i> ∞	<i>1.6e+0:347</i> ∞ 800	5/5 0/15
f₂₂	<i>6.3e+1:3.6</i> 266(172)	<i>4.0e+1:15</i> 149(319)	<i>2.5e+1:32</i> 90(75)	<i>1.0e+1:71</i> ∞	<i>1.6e+0:341</i> ∞ 810	5/5 0/15
f₂₃	<i>1.0e+1:3.0</i> 280(124)	<i>6.3e+0:9.0</i> 255(174)	<i>4.0e+0:33</i> ∞	<i>2.5e+0:84</i> ∞	<i>1.0e+0:518</i> ∞ 840	15/15 0/15
f₂₄	<i>6.3e+1:15</i> 828(815)	<i>4.0e+1:37</i> 329(251)	<i>4.0e+1:37</i> 329(340)	<i>2.5e+1:118</i> 102(81)	<i>1.6e+1:692</i> ∞ 810	15/15 0/15

20-D						
#FEs/D	0.5	1.2	3	10	50	#succ
f₁	<i>6.3e+1:24</i> 97(21)	<i>4.0e+1:42</i> 66(24)	<i>1.0e-8:43</i> ∞	<i>1.0e-8:43</i> ∞	<i>1.0e-8:43</i> ∞ 3100	15/15 0/15
f₂	<i>4.0e+6:29</i> 42(9)	<i>2.5e+6:42</i> 32(7)	<i>1.0e+5:65</i> 72(62)	<i>1.0e+4:207</i> ∞	<i>1.0e-8:412</i> ∞ 3100	15/15 0/15
f₃	<i>6.3e+2:33</i> 96(10)	<i>4.0e+2:44</i> 108(94)	<i>1.6e+2:109</i> ∞	<i>1.0e+2:255</i> ∞	<i>2.5e+1:3277</i> ∞ 3100	15/15 0/15
f₄	<i>6.3e+2:22</i> 409(429)	<i>4.0e+2:91</i> 252(213)	<i>2.5e+2:250</i> ∞	<i>1.6e+2:332</i> ∞	<i>6.3e+1:1927</i> ∞ 3100	15/15 0/15
f₅	<i>2.5e+2:19</i> 36(11)	<i>1.6e+2:34</i> 28(6)	<i>1.0e-8:41</i> 62(13)	<i>1.0e-8:41</i> 62(24)	<i>1.0e-8:41</i> 62(51)	15/15 13/15
f₆	<i>2.5e+5:16</i> 89(44)	<i>6.3e+4:43</i> 38(13)	<i>1.6e+4:62</i> 32(10)	<i>1.6e+2:353</i> ∞	<i>1.6e+1:1078</i> ∞ 3300	15/15 0/15
f₇	<i>1.0e+3:11</i> 160(43)	<i>4.0e+2:39</i> 92(43)	<i>2.5e+2:74</i> 102(99)	<i>6.3e+1:319</i> ∞	<i>1.0e+1:1351</i> ∞ 3200	15/15 0/15
f₈	<i>4.0e+4:19</i> 338(539)	<i>2.5e+4:35</i> 647(660)	<i>4.0e+3:67</i> ∞	<i>2.5e+2:231</i> ∞	<i>1.6e+1:1470</i> ∞ 3100	15/15 0/15
f₉	<i>1.0e+2:357</i> ∞	<i>6.3e+1:560</i> ∞	<i>4.0e+1:684</i> ∞	<i>2.5e+1:756</i> ∞	<i>1.0e+1:1716</i> ∞ 3100	15/15 0/15
f₁₀	<i>1.6e+6:15</i> 123(45)	<i>1.0e+6:27</i> 94(102)	<i>4.0e+5:70</i> 93(131)	<i>6.3e+4:231</i> ∞	<i>4.0e+3:1015</i> ∞ 3500	15/15 0/15
f₁₁	<i>4.0e+4:11</i> 29(26)	<i>2.5e+3:27</i> 52(48)	<i>1.6e+2:313</i> ∞	<i>1.0e+2:481</i> ∞	<i>1.0e+1:1002</i> ∞ 3800	15/15 0/15
f₁₂	<i>1.0e+8:23</i> 270(194)	<i>6.3e+7:39</i> 290(339)	<i>2.5e+7:76</i> 617(476)	<i>4.0e+6:209</i> ∞	<i>1.0e+1:1042</i> ∞ 3100	15/15 0/15
f₁₃	<i>1.6e+3:28</i> 90(40)	<i>1.0e+3:64</i> 74(48)	<i>6.3e+2:79</i> 147(70)	<i>4.0e+1:211</i> ∞	<i>2.5e+0:1724</i> ∞ 3200	15/15 0/15
f₁₄	<i>2.5e+1:15</i> 521(331)	<i>1.6e+1:42</i> ∞	<i>1.0e+1:75</i> ∞	<i>1.6e+0:219</i> ∞	<i>6.3e-4:1106</i> ∞ 3200	15/15 0/15
f₁₅	<i>6.3e+2:15</i> 220(133)	<i>4.0e+2:67</i> 168(155)	<i>2.5e+2:292</i> ∞	<i>1.6e+2:846</i> ∞	<i>1.0e+2:1671</i> ∞ 3200	15/15 0/15
f₁₆	<i>4.0e+1:26</i> 370(523)	<i>2.5e+1:127</i> ∞	<i>1.6e+1:540</i> ∞	<i>1.6e+1:540</i> ∞	<i>1.0e+1:1384</i> ∞ 3600	15/15 0/15
f₁₇	<i>1.6e+1:11</i> 445(171)	<i>1.0e+1:63</i> 258(105)	<i>6.3e+0:305</i> ∞	<i>4.0e+0:468</i> ∞	<i>1.0e+0:1030</i> ∞ 3300	15/15 0/15
f₁₈	<i>4.0e+1:116</i> 81(65)	<i>2.5e+1:252</i> ∞	<i>1.6e+1:430</i> ∞	<i>1.0e+1:621</i> ∞	<i>4.0e+0:1090</i> ∞ 3300	15/15 0/15
f₁₉	<i>1.6e-1:2.5e5</i> ∞	<i>1.0e-1:3.4e5</i> ∞	<i>6.3e-2:3.4e5</i> ∞	<i>4.0e-2:3.4e5</i> ∞	<i>2.5e-2:3.4e5</i> ∞ 3300	3/15 0/15
f₂₀	<i>1.6e+4:38</i> 96(25)	<i>1.0e+4:42</i> 100(41)	<i>2.5e+2:62</i> 247(149)	<i>2.5e+0:250</i> ∞	<i>1.6e+0:2536</i> ∞ 3100	15/15 0/15
f₂₁	<i>6.3e+1:36</i> 209(352)	<i>4.0e+1:77</i> 305(226)	<i>4.0e+1:77</i> 305(269)	<i>1.6e+1:456</i> ∞	<i>4.0e+0:1094</i> ∞ 3100	15/15 0/15
f₂₂	<i>6.3e+1:45</i> 508(396)	<i>4.0e+1:68</i> 681(359)	<i>4.0e+1:68</i> 681(510)	<i>1.6e+1:231</i> 203(214)	<i>6.3e+0:1219</i> ∞ 3100	15/15 0/15
f₂₃	<i>6.3e+0:29</i> 188(155)	<i>4.0e+0:118</i> 437(405)	<i>2.5e+0:306</i> ∞	<i>2.5e+0:306</i> ∞	<i>1.0e+0:1614</i> ∞ 3500	15/15 0/15
f₂₄	<i>2.5e+2:208</i> ∞	<i>1.6e+2:918</i> ∞	<i>1.0e+2:6628</i> ∞	<i>6.3e+1:9885</i> ∞	<i>4.0e+1:31629</i> ∞ 3200	15/15 0/15

Table 1: Expected running time (ERT in number of function evaluations) divided by the best ERT measured during BBOB-2009. The ERT and in braces, as dispersion measure, the half difference between 90 and 10%-tile of bootstrapped run lengths appear in the second row of each cell, the best ERT (preceded by the target Δf -value in *italics*) in the first. #succ is the number of trials that reached the target value of the last column. The median number of conducted function evaluations is additionally given in *italics*, if the target in the last column was never reached. Bold entries are statistically significantly better (according to the rank-sum test) compared to the best algorithm in BBOB-2009, with $p = 0.05$ or $p = 10^{-k}$ when the number $k > 1$ is following the \downarrow symbol, with Bonferroni correction by the number of functions.

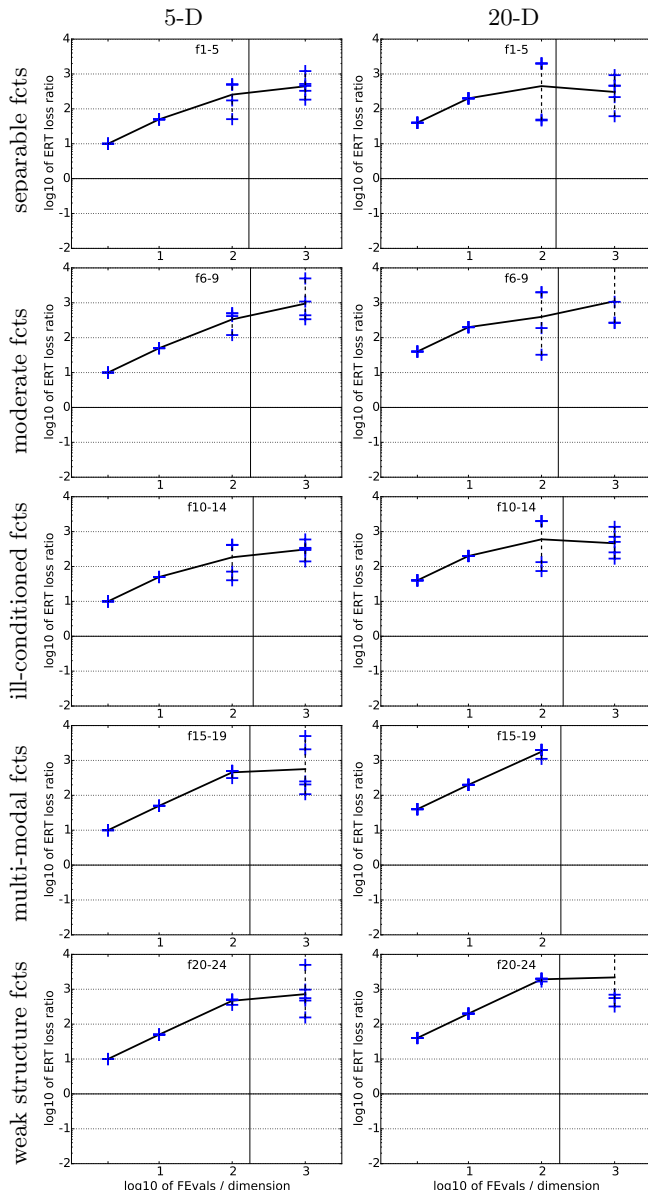


Figure 4: ERT loss ratios (see Figure 3 for details). Each cross (+) represents a single function, the line is the geometric mean.