Computational results for an automatically tuned CMA-ES with increasing population size on the CEC'05 benchmark set: Supplementary material

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Abstract. This document is the supplementary material for the article: Computational results for an automatically tuned CMA-ES with increasing population size on the CEC'05 benchmark set.

1. The qualified run-length distributions (RLDs, for short) over 100 independent runs obtained by iCMA-ES-dp and iCMA-ES-tsc on the 50 dimensional versions of functions f_{cec4}, f_{cec5}, f_{cec11}, f_{cec12}, f_{cec16} and f_{cec17}.

2. The average errors obtained by Sep-iCMA-ES-tsc and iCMA-ES-tsc over 25 independent runs for CEC'05 functions.

3. The data obtained by different variations of the tuning setups over 25 independent runs for CEC'05 functions of dimension 50.

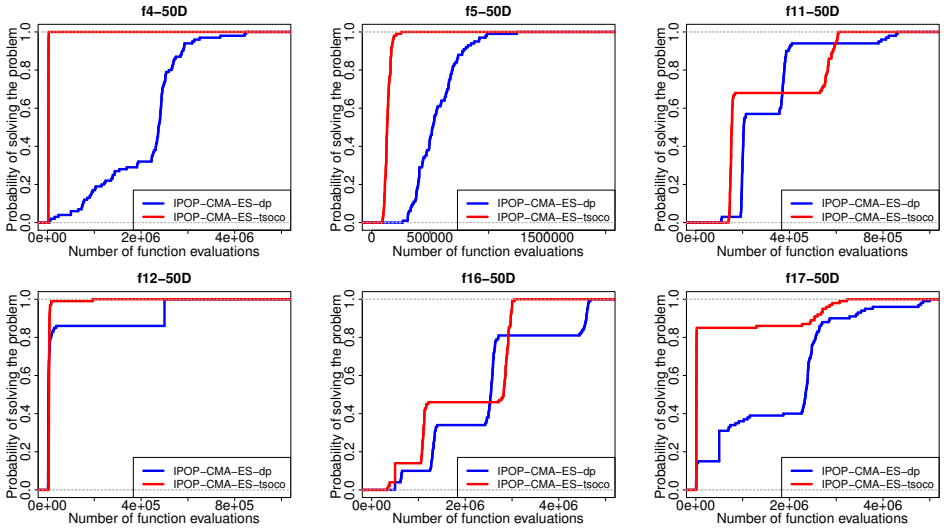

Fig. 1. The qualified run-length distributions (RLDs, for short) over 100 independent runs obtained by iCMA-ES-dp and iCMA-ES-tsc on the 50 dimensional versions of functions f_{cec4}, f_{cec5}, f_{cec11}, f_{cec12}, f_{cec16} and f_{cec17}. The required solution qualities are 1.00E+03, 1.00E−08, 1.00E−08, 1.00E+05, 1.00E+00 and 1.00E+02, respectively.

Table 1. The average errors obtained by Sep-iCMA-ES-tsc and iCMA-ES-tsc over 25 independent runs for CEC'05 functions. The numbers in parenthesis represent the times of $<$, $=$, and $>$, respectively, when the corresponding algorithms are compared with iCMA-ES-tsc on the average errors.

f_{cec}	10 dimensions		30 dimensions		50 dimensions	
	Mean Errors		Mean Errors		Mean Errors	
	Sep-iCMA-ES-tsc	iCMA-ES-tsc	Sep-iCMA-ES-tsc	iCMA-ES-tsc	Sep-iCMA-ES-tsc	iCMA-ES-tsc
f_1	1.00E−08	1.00E−08	1.00E−08	1.00E−08	1.00E−08	1.00E−08
f_2	1.00E−08	1.00E−08	1.00E−08	1.00E−08	1.00E−08	1.00E−08
f_3	3.45E+04	1.00E−08	1.07E+05	1.00E−08	1.17E+05	1.00E−08
f_4	1.00E−08	1.00E−08	1.40E+03	1.00E−08	1.54E+04	1.00E−08
f_5	1.00E−08	1.00E−08	1.03E+03	1.00E−08	2.80E+03	1.00E−08
f_6	2.62E−06	1.00E−08	4.78E−01	1.00E−08	7.97E−01	1.00E−08
f_7	5.81E−03	1.00E−08	1.00E−08	1.00E−08	1.00E−08	1.00E−08
f_8	2.00E+01	2.02E+01	2.00E+01	2.08E+01	2.00E+01	2.10E+01
f_9	2.78E−07	4.81E−02	5.57E−01	1.99E+00	2.23E+00	4.18E+00
f_{10}	1.81E−05	3.73E−03	1.27E+00	1.59E+00	1.31E+00	2.71E+00
f_{11}	2.22E+00	1.00E−08	3.55E+00	5.09E−05	3.82E+00	6.03E−02
f_{12}	4.46E+02	1.00E−08	5.40E+03	4.22E+02	1.54E+04	4.69E+03
f_{13}	6.95E−01	7.14E−01	2.72E+00	2.53E+00	4.95E+00	4.70E+00
f_{14}	3.47E+00	2.03E+00	1.25E+01	1.10E+01	2.16E+01	2.09E+01
f_{15}	2.04E+02	3.32E+02	2.16E+02	2.00E+02	2.12E+02	2.00E+02
f_{16}	1.07E+02	8.86E+01	5.17E+01	1.11E+01	4.15E+01	5.34E+00
f_{17}	2.31E+02	9.34E+01	3.06E+02	2.08E+02	2.61E+02	6.36E+01
f_{18}	7.11E+02	3.60E+02	9.06E+02	9.04E+02	9.19E+02	9.13E+02
f_{19}	7.19E+02	3.20E+02	9.06E+02	9.04E+02	9.19E+02	9.13E+02
f_{20}	7.18E+02	3.40E+02	9.06E+02	9.04E+02	9.19E+02	9.13E+02
f_{21}	9.59E+02	5.00E+02	5.00E+02	5.00E+02	9.05E+02	7.05E+02
f_{22}	7.84E+02	7.28E+02	8.40E+02	8.17E+02	8.61E+02	8.19E+02
f_{23}	5.92E+02	5.59E+02	5.34E+02	5.34E+02	8.99E+02	7.30E+02
f_{24}	2.43E+02	2.00E+02	2.00E+02	2.00E+02	2.00E+02	2.00E+02
f_{25}	4.06E+02	4.03E+02	2.11E+02	2.09E+02	2.16E+02	2.13E+02
V.S.	(5, 4, 16)†		(3, 6, 16)†		(3, 4, 18)†	

† denotes there is a significant difference over the distribution of average errors between Sep-iCMA-ES-tsc with iCMA-ES-tsc by a two-sided Wilcoxon matched-pairs signed-ranks test at 0,05 α-level.

Table 2. The average errors obtained by iCMA-ES-$\oplus$, iCMA-ES-uni,multi, iCMA-ES-uni and iCMA-ES-multi for each CEC'05 function. Error values lower than 10^{-8} are approximated to 10^{-8}. The lowest average errors values are highlighted.

f_{cec}	iCMA-ES-$\oplus$	iCMA-ES-uni,multi	iCMA-ES-uni	iCMA-ES-multi
f_1	1.00E−08	1.00E−08	1.00E−08	1.00E−08
f_2	1.00E−08	1.00E−08	1.00E−08	1.00E−08
f_3	1.00E−08	1.00E−08	1.00E−08	1.00E−08
f_4	1.27E−08	1.82E+03	1.00E−08	2.05E+04
f_5	4.88E−07	1.00E−08	1.00E−08	4.51E+01
f_6	1.79E−01	1.00E−08	1.00E−08	1.59E−01
f_7	1.00E−08	1.00E−08	1.00E−08	1.00E−08
f_8	2.08E+01	2.08E+01	2.09E+01	2.07E+01
f_9	3.66E+00	6.92E+00	3.38E+00	7.80E+00
f_{10}	2.19E+00	5.57E+00	1.59E+00	7.28E+00
f_{11}	4.45E−04	3.47E−05	8.50E−02	8.91E−04
f_{12}	3.45E+03	6.03E+03	3.58E+03	2.94E+04
f_{13}	4.72E+00	4.44E+00	4.23E+00	4.47E+00
f_{14}	1.79E+01	2.10E+01	2.00E+01	2.26E+01
f_{15}	2.00E+02	2.00E+02	2.00E+02	2.00E+02
f_{16}	5.12E+00	8.36E+00	5.23E+00	1.81E+01
f_{17}	1.36E+02	2.30E+02	1.24E+02	2.55E+02
f_{18}	9.13E+02	9.15E+02	9.15E+02	9.12E+02
f_{19}	9.13E+02	9.14E+02	9.16E+02	9.16E+02
f_{20}	9.13E+02	9.15E+02	9.16E+02	9.17E+02
f_{21}	7.25E+02	9.67E+02	8.57E+02	8.44E+02
f_{22}	8.21E+02	8.64E+02	8.49E+02	8.44E+02
f_{23}	7.49E+02	9.23E+02	8.78E+02	9.26E+02
f_{24}	2.00E+02	2.00E+02	2.00E+02	2.00E+02
f_{25}	2.13E+02	2.13E+02	2.13E+02	2.15E+02

Table 3. The average errors obtained by iCMA-ES-uni+, iCMA-ES-multi+ and iCMA-ES-tsc++ for each CEC'05 function. Error values lower than 10^{-8} are approximated to 10^{-8}. The lowest average errors values are highlighted.

f_{cec}	iCMA-ES-uni+	iCMA-ES-multi+	iCMA-ES-tsc++
f_1	1.00E−08	1.00E−08	1.00E−08
f_2	1.00E−08	1.00E−08	1.00E−08
f_3	1.00E−08	1.00E−08	1.00E−08
f_4	1.00E−08	1.70E+04	1.00E−08
f_5	1.01E−08	9.30E−01	1.00E−08
f_6	1.00E−08	1.00E−08	1.00E−08
f_7	1.00E−08	1.00E−08	1.00E−08
f_8	2.10E+01	2.06E+01	2.10E+01
f_9	7.00E+00	5.33E+00	3.70E+00
f_{10}	5.01E+00	4.78E+00	1.79E+00
f_{11}	4.35E−02	1.00E−08	3.63E−03
f_{12}	5.86E+03	1.46E+04	1.44E+04
f_{13}	4.30E+00	4.68E+00	4.51E+00
f_{14}	2.06E+01	2.28E+01	2.15E+01
f_{15}	2.00E+02	2.00E+02	2.00E+02
f_{16}	1.55E+01	8.75E+00	3.14E+00
f_{17}	1.48E+02	2.34E+02	7.77E+01
f_{18}	9.16E+02	9.20E+02	9.13E+02
f_{19}	9.15E+02	9.22E+02	9.13E+02
f_{20}	9.15E+02	9.20E+02	9.13E+02
f_{21}	9.66E+02	5.41E+02	7.06E+02
f_{22}	8.18E+02	8.71E+02	8.55E+02
f_{23}	9.05E+02	6.21E+02	8.68E+02
f_{24}	2.00E+02	2.00E+02	2.00E+02
f_{25}	2.13E+02	2.14E+02	2.13E+02

Table 4. The average and median errors obtained by tuning setup (i) t-test and (ii) 25000 runs over 25 independent runs for CEC'05 functions of dimension 50. The numbers in parenthesis represent the times of $<$, $=$, and $>$, respectively, when the iCMA-ES-dp are compared with iCMA-ES-(i), iCMA-ES-(ii) on the average and median errors.

f_{cec}	iCMA-ES-dp Mean and Median		iCMA-ES-(i) Mean and Median		iCMA-ES-(ii) Mean and Median	
f_1	1.00E−08	1.00E−08	1.00E−08	1.00E−08	1.00E−08	1.00E−08
f_2	1.00E−08	1.00E−08	1.00E−08	1.00E−08	1.00E−08	1.00E−08
f_3	1.00E−08	1.00E−08	1.00E−08	1.00E−08	1.00E−08	1.00E−08
f_4	1.43E+04	1.27E+04	1.00E−08	1.00E−08	1.00E−08	1.00E−08
f_5	7.41E−02	8.61E−08	1.00E−08	1.00E−08	1.00E−08	1.00E−08
f_6	1.00E−08	1.00E−08	2.79E−03	1.00E−08	1.59E−01	1.00E−08
f_7	1.00E−08	1.00E−08	1.00E−08	1.00E−08	1.00E−08	1.00E−08
f_8	2.09E+01	2.11E+01	2.10E+01	2.11E+01	2.10E+01	2.11E+01
f_9	4.36E+00	3.98E+00	4.10E+00	3.98E+00	2.92E+00	2.99E+00
f_{10}	2.89E+00	1.99E+00	2.55E+00	2.98E+00	2.40E+00	1.99E+00
f_{11}	9.94E−02	1.00E−08	4.17E−04	1.00E−08	6.00E−02	5.33E−07
f_{12}	4.25E+04	2.78E+04	3.34E+03	2.27E+03	3.95E+03	3.40E+03
f_{13}	4.44E+00	4.37E+00	4.64E+00	4.70E+00	4.59E+00	4.60E+00
f_{14}	2.28E+01	2.30E+01	2.06E+01	2.09E+01	2.09E+01	2.11E+01
f_{15}	2.00E+02	2.00E+02	2.00E+02	2.00E+02	2.00E+02	2.00E+02
f_{16}	1.10E+01	1.14E+01	5.14E+00	5.54E+00	8.78E+00	8.66E+00
f_{17}	1.91E+02	1.62E+02	5.47E+01	4.81E+01	1.34E+02	5.28E+01
f_{18}	9.13E+02	9.16E+02	9.13E+02	9.13E+02	9.14E+02	9.13E+02
f_{19}	9.13E+02	9.15E+02	9.13E+02	9.13E+02	9.14E+02	9.13E+02
f_{20}	9.15E+02	9.15E+02	9.13E+02	9.13E+02	9.14E+02	9.13E+02
f_{21}	6.64E+02	5.00E+02	8.07E+02	1.01E+03	6.63E+02	5.00E+02
f_{22}	8.19E+02	8.18E+02	8.60E+02	8.63E+02	8.22E+02	8.21E+02
f_{23}	6.97E+02	5.40E+02	6.55E+02	5.40E+02	6.55E+02	5.40E+02
f_{24}	2.00E+02	2.00E+02	2.00E+02	2.00E+02	2.00E+02	2.00E+02
f_{25}	2.14E+02	2.14E+02	2.13E+02	2.13E+02	2.13E+02	2.13E+02
Mean: iCMA-ES-dp vs.			($<$, $=$, $>$): (5, 8, 12)†		($<$, $=$, $>$): (6, 6, 13)†	
Median: iCMA-ES-dp vs.			($<$, $=$, $>$): (4, 11, 10)†		($<$, $=$, $>$): (3, 11, 11)†	

† denotes there is a significant difference over the distribution of mean or median errors between iCMA-ES-dp with the corresponding algorithm by a two-sided Wilcoxon matched-pairs signed-ranks test at the 0,05 α-level.