Comparison of optimization results submitted for the CEC 2017 Competition of Single Objective Numerical Optimization methods based on empirical runtime distributions

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CEC'2017 Competition conditions

Test functions are minimization problems defined as following:

min
$$F_P(x)$$
, $x = [x_1, x_2, ..., x_D]^D$

D: Dimension = 10,30,50,100 **P:** Problem Number = 1,...,30 **Search range** = $[-100,100]^D$ **Budget:** f-evals = $10000 \cdot D$ **Initialization:** Uniform random initialization within the search range. Random seed is based on time.

Global Optimum: $F_P(x^*) = 100 \cdot P$

Full specification of CEC'2017 competition conditions:



Recording results for CEC'2017

Function error value is defined as:

$$ERR_P = F_P(x^{best}) - F_P(x^*)$$

The accuracy of finding the optimum is 10^{-8} :

$$ERR_P \le 10^{-8} \implies ERR_P = 0$$

Tuning search method parameters for each problem or dimension is **not allowed.**

Number of runs: For each problem and each dimension, 51 independent runs of the method.

Progress reporting: For each run, record the smallest-so-far error after exceeding (0.01, 0.02, 0.03, 0.05, 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 1.0) $\cdot Budget_D$.



Results of the competition

- 12 competing teams,
- 14 optimization methods,
- detailed results for 13 optimization methods were published in the format required by the organizers: Link
- for details see summary of methods and results: Link

ECDF empirical runtime distributions

Runlength-based target quality indicator corresponds to the function P value to be reached, and is defined as:

$$I_P^t = F_P(x^*) + \Delta I_P^t$$
 $F_P(x^{best}) \leq \Delta I_P^t \leq F_P(x^{worst})$ $rac{\Delta I_P^{t+1}}{\Delta I_P^t} = 10^{0.2} \; , \; t \in T_P$

The ratio between two neighboring ΔI_P target precision values is $10^{0.2}$. The largest ΔI_P value is the error value chosen such that the worst algorithm reaches the first budget step. Smallest ΔI_P value is related to the best algorithm error value on the last budget step.

Budget steps: 14 moments on which error values are reported

ECDF performance assessment: • Link





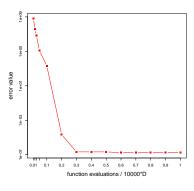
ECDF empirical runtime distributions

ECDF plot displays the proportion of problems solved within a specified budget, where the budget is given on the x-axis. The y-axis shows the fraction of target quality indicators which have been reached. The fraction is defined as:

$$P_P(b) = rac{\sum_{t=1}^{|T_P|} [ERR_P(b) \le I_P^t]}{|T_P|} \;,\; b \in \{1,..,14\}$$

The $P_P(b)$ ratio can be considered as **probability of achieving** success for a given budget b.

ECDF plot example



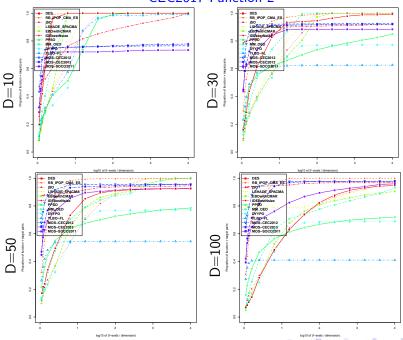
Proportion of function + larger pairs s

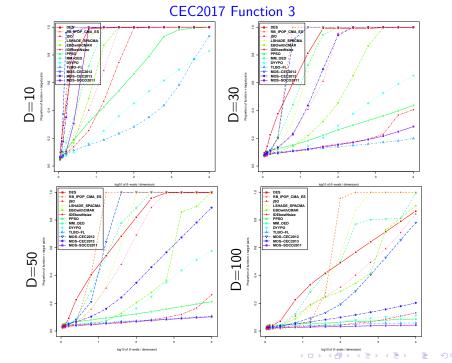
Convergence curve for a single run, with 14 budget steps on which error values have been reported.

ECDF plot aggregated for 51 runs, for a single problem.

Interpretation of the ECDF curve: About 90 percent of the error levels were achieved within budget of $10^2 \cdot D$ function evaluations.

CEC2017 Function 1 RB IPOP CMA ES RB IPOP CMA ES -- JSO jso LSHADE SPACMA LSHADE SPACMA FROwith CMAR FBOwithCMAR ◆ IDEbestNsize IDEbestNsize PPSO. PPSO MM_OED MM_OED DYYPO DYYPO TLBO-FL TLBO-FL MOS-CEC2012 MOS-CEC2012 MOS-CEC2013 MOS-SPC02011 MO\$-CEC2013 MQS-SOC02011 =30-- RB IPOP CMA ES - RB IPOP CMA ES jso JSO LSHADE SPACMA LSHADE SPACMA EBOwith CMAR ● EBOwithCMAR IDEbestNsize - IDEbestNsize PPSO MM.DED MM_OED DYYPO DYYPO TLBO-FL TLBO-FL MOS-CEC2012 MOS-CEC2012 MOS-CEC2013 MOS-CEC2013 MOS-SOCO2011 MOS-SOCO2011 D = 10050 log10 of (F-evals / dimension) log10 of (f-evals / dimension)

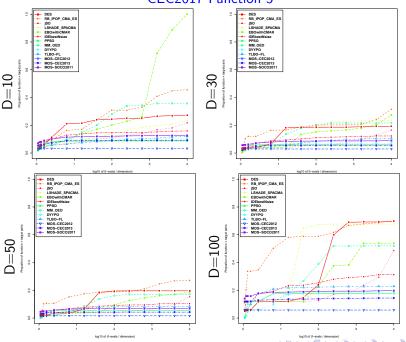




CEC2017 Function 4 RB IPOP CMA ES RB IPOP CMA ES -- JSO jso LSHADE SPACMA LSHADE SPACMA EBOwith CMAR EBOwithCMAR ◆ IDEbestNsize IDEbestNsize PPSO PPSO MM_OED MM_OED DYYPÓ DYYPO TLBO-FL TLBO-FL MOS-GEC2012 MOS-CEC2012 * MOS-CEC2013 MOS-CEC2013 MOS-SOCO2011 MOS-SOCO2011 D = 30log10 of (I-evals / dimen log10 of (f-evals / dime RB IPOP CMA ES --- RB_IPOP_CMA_ES JSO LSHADE SPACMA JSO LSHADE SPACMA EBOwithCMAR ● EBOwithCMAR IDEbestNsize PPSO - IDEbestNsize PPSO MM_OED MM_OED DYYPO DYYPO TLBO-FL TLBO-FL MOS-CEC2012 MOS-CEC2012 MOS-CEC2013 MOS-SOCO2011 MOS-CEC2013 MOS-SOCO2011 D = 100=50

log10 of (f-evals / dimension)

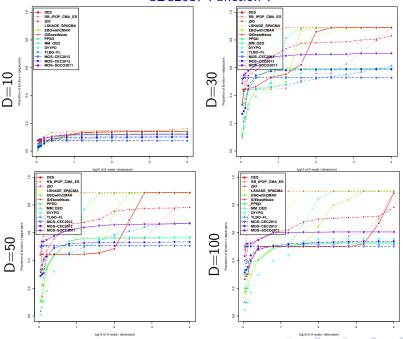
log10 of (F-evals / dimension)

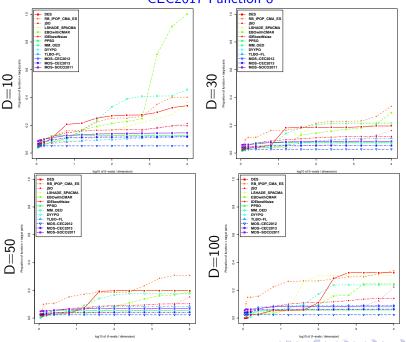


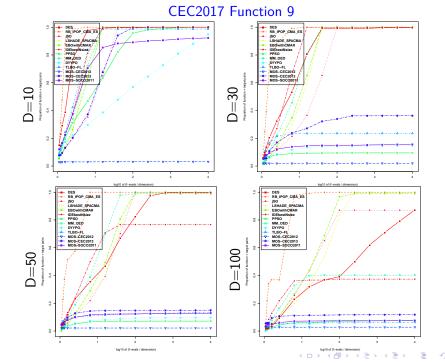
CEC2017 Function 6 - RB IPOP CMA ES RB IPOP CMA ES -- JSO jso LSHADE SPACMA LSHADE SPACMA - EBOwithCMAR EBOwithCMAR IDEbestNsize IDEbestNsize PPSO PPSO MM OF MM OF DYYPO DYYPO TLBO-FL TLBO-FL MOS-CEC2012 MOS-CEC2012 MOS-SQC02011 MOS-CEC2013, MOS-SOCO2011 =309 -- RB IPOP CMA ES - RB IPOP CMA ES JSO LSHADE SPACMA JSO LSHADE SPACMA EBOwithOMAR EBOwith CMAR IDEbestNsize - IDEbestNsize PPSO PPSO MM_OED MM_OED DYYPO DYYPO TLBO-FL TLBO-FL MOS-CEC2012 MOS-CEC2012 MOS-SOCO2011 MOS-CEC2013 MOS-SOC02011 D = 100=50

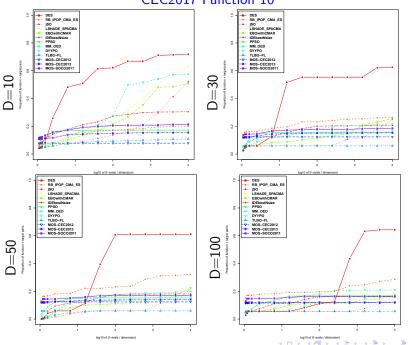
log10 of (f-evals / dimension)

log10 of (F-evals / dimension)





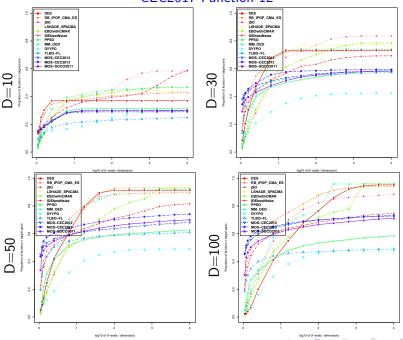




CEC2017 Function 11 RB IPOP CMA ES RB IPOP CMA ES -- JSO jso LSHADE SPACMA LSHADE SPACMA ◆ FRΩwithCMAR FBOwithCMAR IDEbestNsize IDEbestNsize PPSO PPSO MM OFD MM_OED DYYPO DYYPO TLBO-FL TLBO-FL MOS-CEC2012 MOS-CEC2012 * MOS-CEC2013 MOS-CEC2013 MOS-SOCO2011 MOS-SOCO2011 D = 30log10 of (F-evals / dimen log10 of (f-evals / dim RB IPOP CMA ES - RB IPOP CMA ES JSO LSHADE SPACMA JSO LSHADE SPACMA EBOwithCMAR EBOwith CMAR IDEbestNsize PPSO - IDEbestNsize PPSO MM_OED MM_OED DYYPO DYYPO TLBO-FL TLBO-FL MOS-CEG2012 MOS-CEC2012 MOS-CEC2013 MOS-SOCO2011 MOS-CEC2013 MOS-30C02011 0 = 100=50

log10 of (F-evals / dimension)

CEC2017 Function 12 jso



CEC2017 Function 13 RB IPOP CMA ES RB IPOP CMA ES -- JSO jso LSHADE SPACMA LSHADE SPACMA ◆ FRΩwithCMAR FBOwithCMAR IDEbestNsize IDEbestNsize PPSO PPSO MM OFD MM OFF DYYPO DYYPO TLBO-FL TLBO-FL MOS-CEC2012 MOS-CEC2012 * MOS-CEC2013 * MOS-CEC2013 MOS-SOCO2011 D = 30log10 of (F-evals / dimer RB IPOP CMA ES - RB IPOP CMA ES JSO LSHADE SPACMA JSO LSHADE SPACMA EBOwithCMAR ● EBOwithCMAR IDEbestNsize - IDEbestNsize PPSO PESO ----MM_OED DYYPO DYYPO TUBO-FL MOS-CEC2012 MOS-CEC2012 MOS-SECC2013 TLBO-FL MOS-CEC2012 MOS-CEC2013 0 = 100=50

log10 of (f-evals / dimension)

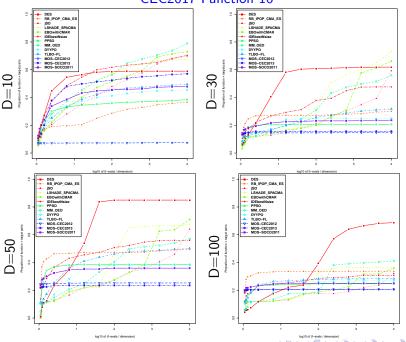
log10 of (F-evals / dimension)

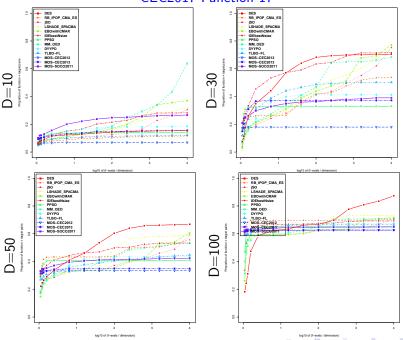
CEC2017 Function 14 - RB IPOP CMA ES RB IPOP CMA ES -- JSO jso LSHADE SPACMA LSHADE SPACMA ◆ FRΩwithCMAR FBOwithCMAR IDEbestNsize IDEbestNsize PPSO MM OFD DYYPO DYYPO TLBO-FL TLBO-FL MOS-CEC2012 M05-CE02012 * MOS-CEC2013 MOS-CEC2013 MOS-SOCO2011 MOS-SOCO2011 9'0 =309 -- RB IPOP CMA ES - RB IPOP CMA ES JSO LSHADE SPACMA LSHADE SPACMA EBOwithCMAR EBOwith CMAR IDEbastNeive - IDEbestNsize PPSO PPSO MM_OED MM_OED DYYPO DYYPO TLBO-FL TLBO-FL/ MOS-CEC2012 MOS-CEC2012 MOS-CEC2013 MOS-CEC2013 MOS-SOC02011 MQS/SQC02011 0 = 100=50log10 of (F-evals / dimension) log10 of (f-evals / dimension)

CEC2017 Function 15 RB IPOP CMA ES RB IPOP CMA ES -- JSO jso LSHADE SPACMA LSHADE SPACMA ◆ FRΩwithCMAR FBOwithCMAR IDEbestNsize IDEbestNsize PPSO PPSO MM_OED MM OFF DYYPO DYYPO TLBO-FL TLBO-FL MOS-CEC2012 MOS-CEC2012 * MOS-CEC2013 MOS-QEC2013 MOS-SOCO2011 MOS 30C02011 =30RB IPOP CMA ES - RB IPOP CMA ES JSO LSHADE SPACMA JSO LSHADE SPACMA EBOwithCMAR EBOwith CMAR IDEbestNsize PPSO MM_OED / MM_OED PYYPO TLBO-FL TLBO-FL MOS CEC2012 MOS CEC2013 MOS SOCO2011 MOS-GEC2012 MOS-CEC2013 MOS-SOCO2011 D = 100=50

log10 of (f-evals / dimension)

log10 of (F-evals / dimension)



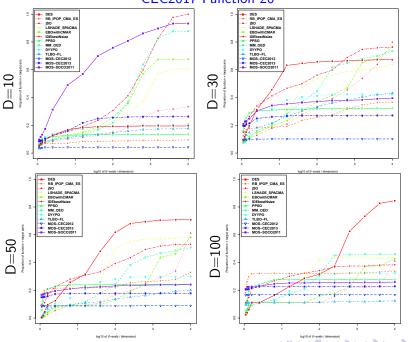


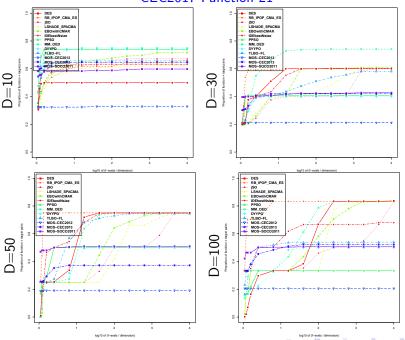
CEC2017 Function 18 - RB IPOP CMA ES RB IPOP CMA ES -- JSO jso LSHADE SPACMA LSHADE SPACMA ◆ FRΩwithCMAR FROwithCMAR IDEbestNsize IDEbestNsize PPSO PPSO MM OFD MM OFF DYYPO DYYPO TLBO-FL TLBO-FL MOS-CEC2012 MOS-@EC2012 * MOS-CEC2013 MOS-CEC2013 MOS-SOCO2011 MOS-SOCO2011 =30 \Box -- RB IPOP CMA ES - RB IPOP CMA ES JSO LSHADE_SPACMA LSHADE SPACMA EBOwithCMAR EBOwith CMAR DEbestNsize IDEbestNsize PPSO PPSO MM_OED MM_OED DYYPO DYYPO TLBO-FL TLBO-FL MOS-CEC2012 MOS-CEC2012 MOS-CEC2013 MOS-CEC2013 MOS-SOCO2011 MOS-SOC02011 =100=50

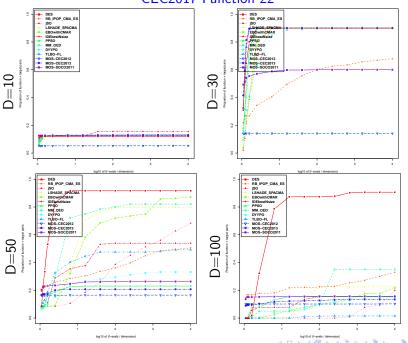
log10 of (f-evals / dimension)

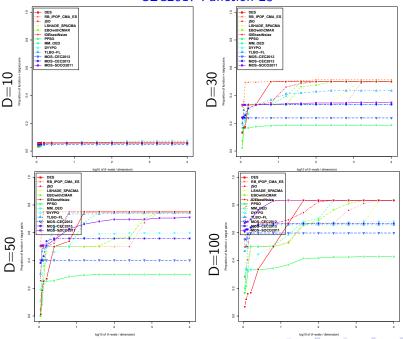
log10 of (F-evals / dimension)

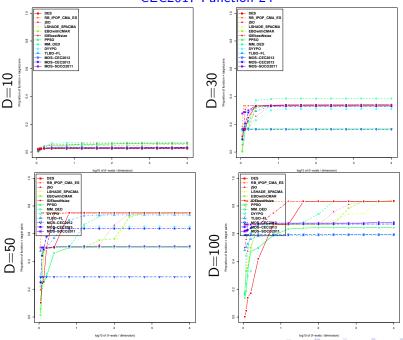
CEC2017 Function 19 RB IPOP CMA ES RB IPOP CMA ES - JSO jso LSHADE SPACMA LSHADE SPACMA ◆ FRΩwithCMAR FROwithCMAR IDEbestNsize IDEbestNsize PPSO PPSO MM_OED MM_OEO DYYPO DYYPO TLBO-FL TLBD-FL MOS-CEC2012 MOS-CEC2012 * MOS-CEC2013 MOS-SOCO2011 =30-- RB IPOP CMA ES - RB IPOP CMA ES jso LSHADE SPACMA LSHADE SPACMA EBOwithCMAR EBOwith CMAR IDEbestNsize* IDEbestNsize PRSD MM_OED PPSO MM_OED DYYPO DYYPO TLBO-FL TLBO-FL MOS-CEC2012 MOS-CEC2013 MOS-SOCO201 0 = 100=50log10 of (F-evals / dimension) log10 of (f-evals / dimension)

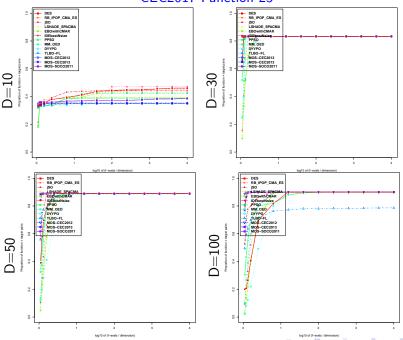


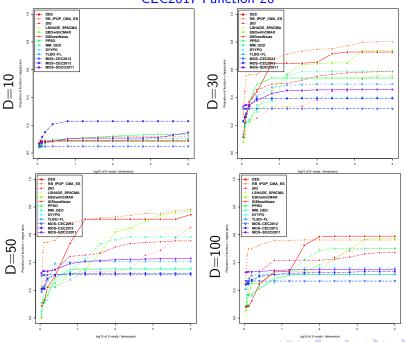


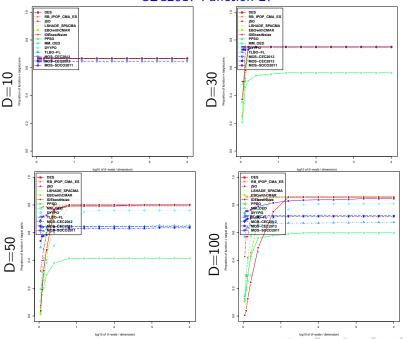


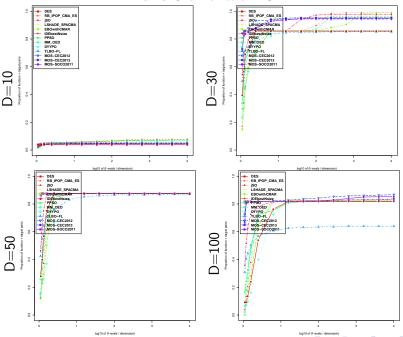




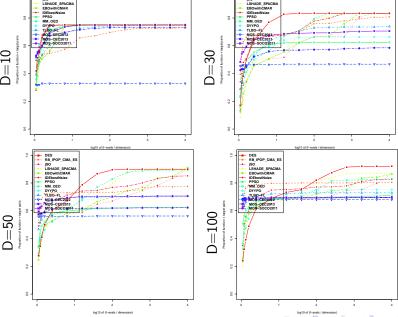








CEC2017 Function 29 RB IPOP CMA ES jso LSHADE SPACMA FBOwithCMAR IDEbestNsize PPSO MM OFD DYYPO TLBO-FM MOS-QEC2012 MOS-CEC2013 MOS-SOCO2011 9'0 =30



- RB IPOP CMA ES

-- JSO

