

A simple and effective cooperative competitive hybrid algorithm for continuous optimization:

Supplementary material

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1. Table I shows the average errors obtained by IPOP-CMA-ES, ILS, iCMAES-ILS-portfolio, iCMAES-ILS-relay-001, iCMAES-ILS-relay-0025, iCMAES-ILS-relay-005, iCMAES-ILS-relay-01, iCMAES-ILS-relay-025, iCMAES-ILS-relay-05, iCMAES-LTH-ILS-001, iCMAES-LTH-ILS-0025, iCMAES-LTH-ILS-005, iCMAES-LTH-ILS-01, iCMAES-LTH-ILS-025 and iCMAES-LTH-ILS-05 for each CEC'05 function.
2. Tables II and III show the parameters of ILSt and IPOP-CMA-ESt, respectively.

TABLE I

THE AVERAGE ERRORS OBTAINED BY IPOP-CMA-ES, ILS, ICMAES-ILS-PORTFOLIO, ICMAES-ILS-RELAY-001, ICMAES-ILS-RELAY-0025, ICMAES-ILS-RELAY-005, ICMAES-ILS-RELAY-01, ICMAES-ILS-RELAY-025, ICMAES-ILS-RELAY-05, ICMAES-LTH-ILS-001, ICMAES-LTH-ILS-0025, ICMAES-LTH-ILS-005, ICMAES-LTH-ILS-01, ICMAES-LTH-ILS-025 AND ICMAES-LTH-ILS-05 FOR EACH CEC'05 FUNCTION. IN THIS TABLE, PORTFOLIO, RELAY AND LTH ARE THE ABBREVIATIONS OF ICMAES-ILS-PORTFOLIO, ICMAES-ILS-RELAY AND ICMAES-LTH-ILS. ERROR VALUES LOWER THAN 10^{-8} ARE APPROXIMATED TO 10^{-8} .

Dim	f_{ccc}	IPOP-CMA-ES	ILS	portfolio	relay-001	relay-0025	relay-005	relay-01	relay-025	relay-05	LTH-001	LTH-0025	LTH-005	LTH-01	LTH-025	LTH-05	
30	f_{ccc1}	1.00E-08	1.00E-08	1.00E-08	1.00E-08	1.00E-08	1.00E-08	1.00E-08	1.00E-08	1.00E-08	1.00E-08	1.00E-08	1.00E-08	1.00E-08	1.00E-08	1.00E-08	
	f_{ccc2}	1.00E-08	1.00E-08	1.00E-08	1.00E-08	1.55E-07	1.00E-08	1.00E-08	1.00E-08	1.00E-08	1.00E-08	1.00E-08	1.00E-08	1.00E-08	1.00E-08	1.00E-08	
	f_{ccc3}	1.00E-08	1.71E+05	1.00E-08	4.15E+05	1.77E+05	2.90E+04	2.80E+02	1.00E-08	1.00E-08	1.00E-08	1.00E-08	1.00E-08	1.00E-08	1.00E-08	1.00E-08	
	f_{ccc4}	3.90E+02	2.47E+04	4.02E+02	1.42E+03	8.23E+01	1.00E-08	3.28E-03	1.16E+02	4.02E+02	3.90E+02	3.90E+02	3.90E+02	3.90E+02	3.90E+02	3.90E+02	3.90E+02
	f_{ccc5}	1.00E-08	6.68E+03	1.00E-08	1.30E+03	5.17E+02	4.81E+01	3.23E-01	1.00E-08	1.00E-08	1.00E-08	1.00E-08	1.00E-08	1.00E-08	1.00E-08	1.00E-08	1.00E-08
	f_{ccc6}	1.00E-08	4.25E+01	1.00E-08	4.70E+00	3.07E+00	5.80E-01	3.08E-02	1.00E-08	1.00E-08	1.00E-08	1.00E-08	1.00E-08	1.00E-08	1.00E-08	2.69E-03	1.00E-08
	f_{ccc7}	1.00E-08	1.08E-02	1.00E-08	1.31E-02	1.00E-08	1.00E-08	1.00E-08	1.00E-08	1.00E-08	1.00E-08	1.00E-08	1.00E-08	1.00E-08	1.00E-08	1.00E-08	1.00E-08
	f_{ccc8}	2.04E+01	2.00E+01	2.00E+01	2.00E+01	2.00E+01	2.00E+01	2.00E+01	2.00E+01	2.00E+01	2.00E+01	2.04E+01	2.05E+01	2.04E+01	2.04E+01	2.05E+01	2.04E+01
	f_{ccc9}	1.95E+00	1.23E+00	9.95E-01	1.00E-08	3.18E-01	5.17E-01	6.37E-01	4.38E-01	7.96E-01	1.22E+00	1.16E+00	1.23E+00	5.97E-01	2.39E-01	7.16E-01	1.00E-08
	f_{ccc10}	1.18E+00	1.51E+02	3.74E+00	3.66E+01	3.60E+01	2.15E+01	1.91E+01	6.96E+00	3.66E+00	1.65E+00	2.68E+00	3.22E+00	3.26E+00	8.82E+00	2.75E+01	1.00E-08
	f_{ccc11}	7.17E-02	2.41E+01	1.75E-01	6.35E+00	3.91E+00	5.26E+00	1.61E+00	3.82E-01	1.75E-01	1.00E-08	1.00E-08	2.06E-04	3.03E-01	1.34E+00	3.82E+00	1.00E-08
	f_{ccc12}	1.19E+04	1.39E+03	1.58E+03	5.97E+03	2.54E+03	1.18E+03	1.12E+03	1.41E+03	1.53E+03	1.18E+04	1.17E+04	1.18E+04	1.18E+04	1.18E+04	1.20E+04	1.00E-08
	f_{ccc13}	2.62E+00	1.20E+00	1.43E+00	1.31E+00	1.35E+00	1.35E+00	1.38E+00	1.39E+00	1.45E+00	2.13E+00	2.06E+00	2.02E+00	1.81E+00	1.60E+00	1.35E+00	1.00E-08
	f_{ccc14}	1.26E+01	1.39E+01	1.30E+01	1.26E+01	1.24E+01	1.26E+01	1.27E+01	1.28E+01	1.27E+01	1.26E+01	1.25E+01	1.27E+01	1.27E+01	1.28E+01	1.29E+01	1.00E-08
	f_{ccc15}	2.00E+02	1.92E+02	1.61E+02	2.36E+02	2.40E+02	2.00E+02	1.92E+02	1.62E+02	1.92E+02	2.88E+02	2.88E+02	2.74E+02	2.50E+02	2.24E+02	2.13E+02	1.00E-08
	f_{ccc16}	1.48E+01	2.85E+02	2.64E+01	1.38E+02	1.26E+02	8.92E+01	3.97E+01	2.77E+01	2.50E+01	1.08E+02	1.09E+02	7.91E+01	9.42E+01	1.08E+02	1.18E+02	1.00E-08
	f_{ccc17}	2.01E+02	5.59E+02	2.39E+02	9.57E+01	1.46E+02	1.40E+02	1.97E+02	2.39E+02	2.59E+02	1.98E+02	1.98E+02	2.03E+02	1.97E+02	2.05E+02	2.03E+02	1.00E-08
	f_{ccc18}	9.04E+02	1.02E+03	9.04E+02	9.06E+02	8.98E+02	9.06E+02	8.84E+02	8.96E+02	9.00E+02	9.04E+02	9.04E+02	9.04E+02	8.84E+02	8.72E+02	8.69E+02	1.00E-08
	f_{ccc19}	9.04E+02	1.05E+03	9.04E+02	9.06E+02	9.02E+02	9.06E+02	8.96E+02	9.00E+02	9.04E+02	9.04E+02	9.04E+02	9.04E+02	8.96E+02	8.96E+02	8.76E+02	8.77E+02
	f_{ccc20}	9.04E+02	1.05E+03	9.04E+02	9.06E+02	9.02E+02	9.06E+02	9.01E+02	9.05E+02	9.04E+02	9.04E+02	9.04E+02	9.04E+02	8.88E+02	8.79E+02	8.80E+02	8.68E+02
	f_{ccc21}	5.00E+02	5.08E+02	4.96E+02	5.00E+02	5.00E+02	5.00E+02	5.00E+02	5.00E+02	5.00E+02	5.00E+02	5.00E+02	5.00E+02	5.00E+02	5.00E+02	5.00E+02	5.00E+02
	f_{ccc22}	8.11E+02	1.23E+03	8.25E+02	8.87E+02	8.58E+02	8.42E+02	8.38E+02	8.29E+02	8.25E+02	8.17E+02	8.12E+02	8.11E+02	8.24E+02	8.26E+02	8.37E+02	1.00E-08
	f_{ccc23}	5.34E+02	5.34E+02	5.34E+02	5.34E+02	5.34E+02	5.34E+02	5.34E+02	5.34E+02	5.34E+02	5.34E+02	5.34E+02	5.34E+02	5.34E+02	5.34E+02	5.34E+02	5.34E+02
	f_{ccc24}	2.00E+02	2.00E+02	2.00E+02	2.00E+02	2.00E+02	2.00E+02	2.00E+02	2.00E+02	2.00E+02	2.00E+02	2.00E+02	2.00E+02	2.00E+02	2.00E+02	2.00E+02	2.00E+02
	f_{ccc25}	2.10E+02	2.06E+02	2.05E+02	2.09E+02	2.09E+02	2.09E+02	2.10E+02	2.10E+02	2.10E+02	2.10E+02	2.10E+02	2.10E+02	2.10E+02	2.10E+02	2.10E+02	2.10E+02
50	f_{ccc1}	1.00E-08	1.00E-08	1.00E-08	1.00E-08	1.00E-08	1.00E-08	1.00E-08	1.00E-08	1.00E-08	1.00E-08	1.00E-08	1.00E-08	1.00E-08	1.00E-08	1.00E-08	
	f_{ccc2}	1.00E-08	1.00E-08	1.00E-08	2.35E-03	1.19E-05	1.00E-08	1.00E-08	1.00E-08	1.00E-08	1.00E-08	1.00E-08	1.00E-08	1.00E-08	1.00E-08	1.00E-08	1.00E-08
	f_{ccc3}	1.00E-08	2.56E+05	1.00E-08	4.58E+05	2.98E+05	9.98E+04	8.95E+03	1.00E-08	1.00E-08	1.00E-08	1.00E-08	1.00E-08	1.00E-08	1.00E-08	1.00E-08	1.00E-08
	f_{ccc4}	1.72E+04	9.28E+04	1.85E+04	1.42E+04	9.47E+03	8.42E+03	8.46E+03	8.96E+03	1.84E+04	1.70E+04	1.76E+04	1.70E+04	1.73E+04	1.76E+04	1.73E+04	1.00E-08
	f_{ccc5}	6.25E-02	1.48E+04	8.38E+01	3.43E+03	2.77E+03	2.24E+03	1.59E+03	5.88E+02	6.15E+01	6.19E-02	1.34E-03	1.92E-03	6.58E-02	6.64E-02	1.13E-02	1.00E-08
	f_{ccc6}	1.00E-08	8.19E+01	9.27E-03	2.42E+01	1.89E+01	1.35E+01	3.22E+00	1.97E-03	3.19E-01	1.00E-08	1.00E-08	1.00E-08	1.00E-08	1.00E-08	1.68E-01	1.00E-08
	f_{ccc7}	1.00E-08	4.63E-03	1.00E-08	2.56E-03	1.00E-08	2.96E-04	1.00E-08	1.00E-08	1.00E-08	1.00E-08	1.00E-08	1.00E-08	1.00E-08	1.00E-08	1.00E-08	1.00E-08
	f_{ccc8}	2.09E+01	2.00E+01	2.00E+01	2.00E+01	2.00E+01	2.00E+01	2.00E+01	2.00E+01	2.00E+01	2.08E+01	2.09E+01	2.09E+01	2.09E+01	2.09E+01	2.08E+01	1.00E-08
	f_{ccc9}	4.37E+00	1.99E-01	2.27E+00	1.00E-08	1.00E-08	2.39E-01	2.79E+00	5.97E-01	1.43E+00	3.55E+00	1.79E+00	2.33E+00	1.47E+00	7.17E-01	1.69E+00	1.00E-08
	f_{ccc10}	2.26E+00	4.58E+02	8.27E+00	6.93E+01	7.06E+01	3.83E+01	2.74E+01	1.40E+01	8.20E+00	2.72E+00	3.00E+00	6.95E+00	7.20E+00	1.55E+01	5.04E+01	1.00E-08
	f_{ccc11}	9.24E-03	4.86E+01	6.40E-01	1.46E+01	1.09E+01	1.13E+01	4.99E+00	2.48E+00	5.99E-01	2.66E-01	6.12E-02	2.11E-01	3.04E-01	3.46E+00	9.05E+00	1.00E-08
	f_{ccc12}	4.25E+04	1.43E+04	2.12E+04	2.78E+04	1.84E+04	1.32E+04	1.02E+04	1.16E+04	1.35E+04	4.25E+04	4.25E+04	4.25E+04	4.25E+04	4.25E+04	4.25E+04	4.25E+04
	f_{ccc13}	4.44E+00	2.28E+00	2.73E+00	2.16E+00	2.32E+00	2.47E+00	2.58E+00	2.35E+00	2.45E+00	4.08E+00	4.11E+00	3.69E+00	3.44E+00	3.12E+00	2.61E+00	1.00E-08
	f_{ccc14}	2.28E+01	2.36E+01	2.29E+01	2.22E+01	2.22E+01	2.22E+01	2.23E+01	2.25E+01	2.25E+01	2.27E+01	2.27E+01	2.27E+01	2.29E+01	2.28E+01	2.28E+01	1.00E-08
	f_{ccc15}	2.00E+02	2.26E+02	1.50E+02	2.24E+02	2.44E+02	2.00E+02	2.00E+02	1.97E+02	2.00E+02	2.56E+02	2.56E+02	2.44E+02	2.35E+02	2.38E+02	2.21E+02	1.00E-08
	f_{ccc16}	1.21E+01	3.80E+02	1.96E+01	9.51E+01	1.21E+02	8.63E+01	4.37E+01	2.87E+01	1.98E+01	7.82E+01	7.61E+01	7.61E+01	7.98E+01	9.40E+01	1.11E+02	1.00E-08
	f_{ccc17}	2.12E+02	9.87E+02	2.12E+02	1.09E+02	9.23E+01	1.47E+02	1.21E+02	2.04E+02	2.12E+02	2.12E+02	2.11E+02	2.12E+02	2.12E+02	2.01E+02	2.12E+02	1.00E-08
	f_{ccc18}	9.13E+02	1.05E+03	9.15E+02	9.19E+02	9.12E+02	9.18E+02	9.16E+02	9.17E+02	9.06E+02	9.15E+02	9.15E+02	9.14E+02	9.16E+02	9.10E+02	9.06E+02	1.00E-08
	f_{ccc19}	9.14E+02	1.01E+03	9.12E+02	9.13E+02	9.11E+02	9.18E+02	9.08E+02	9.09E+02	9.17E+02	9.15E+02	9.15E+02	9.13E+02	9.16E+02	9.01E+02	8.83E+02	1.00E-08
	f_{ccc20}	9.15E+02	1.03E+03	9.18E+02	9.14E+02	9.09E+02	9.17E+02	9.15E+02	9.15E+02	9.08E+02	9.14E+02	9.16E+02	9.15E+02	9.01E+02	9.05E+02	9.03E+02	1.00E-08
	f_{ccc21}	6.55E+02	5.48E+02	5.00E+02	5.00E+02	5.12E+02	5.00E+02	5.00E+02	5.00E+02	5.00E+02	6.75E+02	5.97E+02	5.32E+02	5.20E+02	5.12E+02	5.12E+02	1.00E-08
	f_{ccc22}	8.20E+02	1.31E+03	8.35E+02	9.27E+02	8.93E+02	8.58E+02	8.64E+02	8.47E+02	8.34E+02	8.17E+02	8.19E+02	8.17E+02	8.20E+02	8.25E+02	8.55E+02	1.00E-08
	f_{ccc23}	6.97E+02	6.09E+02	5.53E+02	5.39E+02	5.39E+02	5.39E+02	5.39E+02	5.39E+02	5.39E+02	7.35E+02	7.16E+02	6.76E+02	6.19E+02	6.18E+02	6.18E+02	1.00E-08
	f_{ccc24}	2.00E+02	2.00E+02	2.00E+02	2.00E+02	2.00E+02	2.00E+02	2.00E+02	2.00E+02	2.00E+02	2.00E+02	2.00E+02	2.00E+02	2.00E+02	2.00E+02	2.00E+02	2.00E+02
	f_{ccc25}	2.14E+02	2.19E+02	2.14E+02	2.13E+02	2.13E+02	2.13E+02	2.13E+02	2.14E+02	2.14E+02	2.14E+02	2.14E+02	2.14E+02	2.14E+02	2.14E+02	2.14E+02	2.14E+02

TABLE II

PARAMETERS THAT HAVE BEEN CONSIDERED FOR TUNING IPOP-CMA-ES. GIVEN ARE THE DEFAULT VALUES OF THE PARAMETERS AND THE RANGES WE CONSIDERED FOR TUNING. THE LAST COLUMN IS THE TUNED PARAMETER SETTINGS.

Algorithm	Parameter	Internal parameter	Default	Range	Tuned
IPOP-CMA-ES	a	Init pop size: $\lambda_0 = 4 + \lfloor a \ln(D) \rfloor$	3	r [1, 10]	9.600
	b	Parent size: $\mu = \lfloor \lambda/b \rfloor$	2	r [1, 5]	1.452
	c	Init step size: $\sigma_0 = c \cdot (B - A)$	0.5	r (0, 1]	0.6034
	d	IPOP factor: $ipop = d$	2	r [1, 4]	3.292
	e	$stopTolFun = 10^e$	-12	r [-20, -6]	-8.854
	f	$stopTolFunHist = 10^f$	-20	r [-20, -6]	-9.683
	g	$stopTolX = 10^g$	-12	r [-20, -6]	-12.55

TABLE III

PARAMETERS THAT HAVE BEEN CONSIDERED FOR TUNING ILS. GIVEN ARE THE DEFAULT VALUES OF THE PARAMETERS AND THE RANGES WE CONSIDERED FOR TUNING. THE LAST COLUMN IS THE TUNED PARAMETER SETTINGS.

Algorithm	Parameter	Internal parameter	Default	Range	Tuned
ILS	i_r	$LSIterations = i_r \times D$	1.5	o (1, 1.25, 1.5, 1.75, 2)	1
	ss_r	$ss = ss_r \times (B - A)$	0.5	r (0, 1]	0.8923
	$bias_e$	$BiasExtent = bias_e$	0	r [0, 1)	0.1732