Supplementary Files for "A Competitive and Cooperative Multitasking Evolutionary Framework for Ensemble of Constraint Handling Techniques"

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S-I. Experimental Results

The results of the proposed CCMT with eight advanced constrained optimization evolutionary algorithms [1]–[8] on five constrained optimization problem (COP) benchmark suites [9]–[11] are presented in Table S-I to Table S-V. The results of CCMT component validation experiments on the 50-dimensional CEC2017 benchmark suite are presented in Table S-VI. The experimental results of parameter sensitivity analysis for CCMT on the 50-dimensional CEC2017 benchmark suite are shown in Table S-VII to Table S-XI. The results of CCMT on 33 real-world COPs are shown in Table S-XIII.

We describe the structure of these tables. For Table S-I to Table S-VI and Table S-XIII, the first line showed the name of each algorithm. The first column in the table showed the name of each problem in the benchmark suite. The data of each cell in the row with "Obj" in the second column showed the average objective value and standard deviation, and the data in the row with "CV" in the second column showed the average constraint violation and standard deviation. Note that when the results obtained by all algorithms for a problem are infeasible, the objective value were replaced with the constraint violation. If only partial algorithms on a problem failed to obtain a feasible solution, then its data was replaced with "NaN". In each data cell, the objective value or constraint violation and the standard deviation are followed by a symbol "+", "-", or "=", representing that the result of the algorithm for the column corresponding to this cell is significantly better, worse, or equal to the result of the "Base" algorithm in the Wilcoxon rank-sum test on the problem in this cell's corresponding row. The last row in the table showed the total number of significantly better, worse, and equal to the "Base" algorithm for each comparison algorithm on all problems. Different from the previous tables, Table S-VII to Table S-XI did not have the markers and summary statistics obtained by the Wilcoxon rank-sum test.

S-II. Real-world COPs

We used 33 real-world COPs [12] to test the performance of the proposed CCMT in real-world problems. The details of each problem are shown in Table S-XII. The first column of the table indicates the label of the problem. The second column shows the name of each problem. The last three columns indicate the dimensionality (D), the number of inequality constraints (g), and the number of equality constraints (h), respectively. These 33 problems are divided into three categories according to different types of real-world applications, which are industrial chemical processes [13] (RC01-RC07), process synthesis and design problems [14] (RC08-RC14), and mechanical engineering problems [15] (RC15-RC33).

TABLE S-I

Average objective values (Obj) or average constraint violations (CV) and standard deviations obtained by the selected advanced COEAs and the proposed CCMT on the CEC2006 benchmark suite.

		ECHT	VMCH	FROFI	C²oDE	CORCO	DeCODE	CAL-SHADE	LSHADE44	CCMT
g01	Obj	-1.5000e+01 (0.00e+00) =	-1.4400e+01 (1.50e+00) -	-6.0293e+00 (1.02e+00) -	-1.3061e+01 (4.77e-01) -	-6.3101e+00 (1.82e+00) -	-1.5000e+01 (0.00e+00) =	-9.1249e+00 (6.58e-01) -	-1.0620e+01 (1.29e+00) -	-1.5000e+01 (0.00e+00)
g02	Obj	-8.0140e-01 (4.49e-03) =	-7.9717e-01 (7.07e-03) -	-7.9468e-01 (7.41e-03) -	-8.0324e-01 (1.78e-03) =	-4.4118e-01 (2.89e-02) -	-8.0280e-01 (2.77e-03) =	-8.0360e-01 (2.27e-16) +	-7.9855e-01 (7.00e-03) =	-8.0045e-01 (6.39e-03)
g03	Obj	-1.0005e+00 (2.27e-16) =	-1.0002e+00 (1.62e-03) -	-9.1530e-01 (3.12e-02) -	-6.9047e-01 (1.06e-01) -	0.0000e+00 (0.00e+00) -	-1.0005e+00 (2.27e-16) =	-4.3922e-01 (3.06e-01) -	-1.9719e+00 (1.07e-01) -	-1.0005e+00 (2.27e-16)
g04	Obj	-3.0666e+04 (0.00e+00) =	-3.0666e+04 (0.00e+00) =	-3.0631e+04 (1.84e+01) -	-3.0666e+04 (2.54e+02) =	-2.9929e+04 (2.54e+02) -	-3.0666e+04 (0.00e+00) =	-3.0666e+04 (0.00e+00) =	-3.0666e+04 (0.00e+00) =	-3.0666e+04 (0.00e+00)
g05	Obj	5.1749e+03 (8.51e+01) =	5.1265e+03 (0.00e+00) =	NaN -	5.1265e+03 (0.00e+00) =	NaN -	5.1265e+03 (0.00e+00) =	5.2593e+03 (2.15e+02) -	5.3123e+03 (1.61e+02) -	5.1270e+03 (1.66e+00)
g06	Obj	-6.9618e+03 (9.28e-13) =	-5.2443e+03 (1.90e+03) -	-6.8926e+03 (1.07e+02) -	-6.9618e+03 (9.28e-13) -	-5.2993e+03 (1.55e+03) -	-6.9618e+03 (9.28e-13) =	-6.9429e+03 (3.21e+01) -	-6.8926e+03 (1.36e+02) -	-6.9618e+03 (9.28e-13)
g07	Obj	2.4306e+01 (3.63e-15) =	2.4306e+01 (3.63e-15) =	2.5272e+01 (2.45e-01) -	2.4337e+01 (7.24e-02) -	2.4306e+01 (3.63e-15) =	2.4306e+01 (3.63e-15) =	8.9809e+01 (1.93e+01) -	9.0928e+01 (3.40e+01) -	2.4306e+01 (3.63e-15)
g08	Obj	-9.5800e-02 (5.67e-17) =	-9.5800e-02 (5.67e-17) =	-9.5796e-02 (2.00e-05) =	-9.5800e-02 (5.67e-17) =	-8.8384e-02 (1.16e-02) -	-9.5800e-02 (5.67e-17) =	-9.3712e-02 (2.15e-03) -	-9.5728e-02 (1.46e-04) -	-9.5800e-02 (5.67e-17)
g09	Obj	6.8063e+02 (3.48e-13) =	6.8063e+02 (3.48e-13) =	6.8334e+02 (1.05e+00) -	6.8063e+02 (3.48e-13) =	6.8063e+02 (3.48e-13) =	6.8063e+02 (3.48e-13) =	8.1478e+02 (7.16e+01) -	7.3366e+02 (5.39e+01) -	6.8063e+02 (3.48e-13)
g10	Obj	7.0492e+03 (9.28e-13) =	7.0492e+03 (2.00e-02) =	1.2865e+04 (3.87e+03) -	8.5919e+03 (2.71e+02) -	7.5363e+03 (0.00e+00) -	7.0492e+03 (9.28e-13) =	1.0427e+04 (8.30e+02) -	9.9794e+03 (1.20e+03) -	7.0492e+03 (9.28e-13)
g11	Obj	7.4990e-01 (1.13e-16) =	8.4991e-01 (1.25e-01) -	7.5015e-01 (3.42e-04) -	7.4990e-01 (1.13e-16) =	1.0000e+00 (0.00e+00) -	7.4990e-01 (1.13e-16) =	7.6013e-01 (1.71e-02) -	7.7749e-01 (3.74e-02) -	7.4990e-01 (1.13e-16)
g12	Obj	-1.0000e+00 (0.00e+00) =	-1.0000e+00 (0.00e+00) =	-1.0000e+00 (0.00e+00) =	-1.0000e+00 (0.00e+00) =	-1.0000e+00 (0.00e+00) =	-1.0000e+00 (0.00e+00) =	-1.0000e+00 (0.00e+00) =	-1.0000e+00 (0.00e+00) =	-1.0000e+00 (0.00e+00)
g13	Obj	3.0728e-01 (4.17e-01) =	1.7708e-01 (1.83e-01) =	NaN -	5.3970e-02 (9.49e-05) +	2.6137e-01 (1.91e-01) =	5.3900e-02 (2.83e-17) +	8.8004e-01 (1.20e-01) -	9.6317e-01 (8.99e-02) -	4.1304e-01 (4.05e-01)
g14	Obj	-4.7765e+01 (7.25e-15) =	-4.7765e+01 (7.25e-15) =	NaN -	-4.7443e+01 (1.18e-01) -	NaN -	-4.7765e+01 (7.25e-15) =	-4.3168e+01 (2.38e+00) -	-4.5082e+01 (8.65e-01) -	-4.7765e+01 (7.25e-15)
g15	Obj	9.6184e+02 (4.39e-01) =	9.6172e+02 (1.16e-13) =	NaN -	9.6172e+02 (1.16e-13) =	NaN -	9.6172e+02 (1.16e-13) =	9.6477e+02 (2.91e+00) -	9.6272e+02 (1.34e+00) -	9.6172e+02 (1.16e-13)
g16	Obj	-1.9052e+00 (4.53e-16) =	-1.9052e+00 (4.53e-16) =	-1.8879e+00 (7.22e-03) -	-1.8803e+00 (1.50e-02) -	-1.9052e+00 (4.53e-16) =	-1.9052e+00 (4.53e-16) =	-1.6103e+00 (1.45e-01) -	-1.6365e+00 (7.57e-02) -	-1.9052e+00 (4.53e-16)
g17	Obj	8.9318e+03 (3.07e+01) -	8.9465e+03 (1.29e+02) -	NaN -	8.8716e+03 (3.51e+01) -	9.2815e+03 (0.00e+00) -	8.8814e+03 (3.65e+01) -	8.9386e+03 (5.18e+01) -	8.9438e+03 (2.60e+01) -	8.9032e+03 (3.79e+01)
g18	Obj	-8.6600e-01 (2.27e-16) =	-8.6600e-01 (2.27e-16) =	-1.8052e-01 (1.15e-01) -	-7.0067e-01 (2.11e-02) -	-8.6600e-01 (1.14e-01) +	-8.6600e-01 (2.27e-16) =	-5.1477e-01 (6.20e-02) -	-6.1002e-01 (6.39e-02) -	-8.6600e-01 (2.27e-16)
g19	Obj	3.2656e+01 (2.18e-14) =	3.2656e+01 (2.18e-14) =	3.5577e+01 (8.86e-01) -	3.2656e+01 (2.18e-14) =	3.2656e+01 (2.18e-14) =	3.2656e+01 (2.18e-14) =	3.2681e+01 (6.35e-02) -	3.7779e+01 (8.41e+00) -	3.2656e+01 (2.18e-14)
g20	CV	1.4379e-01 (7.97e-05) =	1.4371e-01 (2.67e-11) +	6.9846e-01 (1.28e-02) -	2.0403e-01 (1.07e-02) -	1.1702e+00 (1.15e-01) -	1.4465e-01 (2.02e-03) +	3.1156e-01 (1.98e-01) -	1.4371e-01 (8.45e-13) +	1.4664e-01 (1.77e-03)
g21	Obj	2.5610e+02 (6.70e+01) -	NaN -	NaN -	1.9439e+02 (3.87e-01) +	NaN -	2.0944e+02 (4.34e+01) =	2.8389e+02 (8.18e+01) -	3.0511e+02 (1.42e+02) -	2.0944e+02 (4.34e+01)
g22	CV	3.0801e+06 (2.61e+06) -	1.8832e+06 (3.05e+06) -	1.2030e+05 (6.00e+05) +	4.2423e+05 (6.13e+05) +	2.4196e+05 (8.30e+05) +	6.4904e+01 (4.31e+01) +	7.5967e+03 (6.95e+03) -	1.0810e+06 (1.91e+06) -	1.1600e+06 (1.89e+06)
g23	Obj	-2.1947e+02 (2.08e+02) -	-3.5505e+02 (1.30e+02) -	0.0000e+00 (0.00e+00) -	-3.3657e+02 (1.30e+01) -	-3.1605e+02 (1.46e+02) -	-3.5605e+02 (1.23e+02) -	6.0301e+01 (1.46e+02) -	-3.7006e+01 (1.18e+02) -	-4.0006e+02 (3.32e-03)
g24	Obj	-5.5080e+00 (9.06e-16) =	-5.5080e+00 (9.06e-16) =	-5.5055e+00 (1.42e-03) -	-5.5080e+00 (9.06e-16) =	-5.2971e+00 (8.84e-02) -	-5.5080e+00 (9.06e-16) =	-5.5080e+00 (9.06e-16) =	-5.5080e+00 (9.06e-16) =	-5.5080e+00 (9.06e-16)
+/-/=		1/5/18	1/7/16	0/21/3	3/9/12	2/16/6	2/0/22	1/19/4	1/18/5	Base

TABLE S-II

AVERAGE OBJECTIVE VALUES (OBJ) AND AVERAGE STANDARD DEVIATIONS OBTAINED BY THE SELECTED ADVANCED COEAs AND THE PROPOSED CCMT ON THE 10-DIMENSIONAL CEC2010 BENCHMARK SUITE.

		ECHT	VMCH	FROFI	C^2oDE	CORCO	DeCODE	CAL-SHADE	LSHADE44	CCMT
C01	Obj	-7.4596e-01 (2.74e-03) =	-7.4472e-01 (4.81e-03) =	-7.2559e-01 (4.81e-03) -	-7.4730e-01 (3.40e-16) +	-5.1910e-01 (8.22e-02) -	-7.4730e-01 (3.40e-16) +	-7.4730e-01 (3.40e-16) +	-7.4492e-01 (4.19e-03) =	-7.4596e-01 (2.74e-03)
C02	Obj	-1.6514e-01 (1.63e+00) -	7.8019e-01 (8.44e-01) -	-1.4380e+00 (4.78e-01) -	8.6009e-01 (1.75e+00) -	-1.7239e+00 (1.55e-01) -	-1.9637e+00 (2.21e-01) -	5.8893e-01 (6.00e-01) -	1.4977e+00 (5.95e-01) -	-2.0177e+00 (3.97e-01)
C03	Obj	0.0000e+00 (0.00e+00) =	4.6153e+00 (4.53e+00) -	8.5237e+00 (1.78e+00) -	NaN -	1.8440e-03 (3.04e-04) -	0.0000e+00 (0.00e+00) =	0.0000e+00 (0.00e+00) =	3.3071e+06 (1.39e+07) -	3.0463e+13 (7.75e+13) -	0.0000e+00 (0.00e+00)
C04	Obj	0.0000e+00 (0.00e+00) =	0.0000e+00 (0.00e+00) =	NaN -	NaN -	1.8440e-03 (3.04e-04) -	0.0000e+00 (0.00e+00) =	0.0000e+00 (0.00e+00) =	1.3031e+01 (4.74e+00) -	1.3625e-01 (3.19e-01) -	0.0000e+00 (0.00e+00)
C05	Obj	NaN -	3.8514e+02 (1.78e+02) -	-4.8357e+02 (2.45e-02) +	NaN -	-3.9630e+02 (5.30e+01) -	-4.8361e+02 (1.16e-13) +	2.1625e+02 (1.38e+02) -	4.8845e+02 (1.10e+02) -	-4.8354e+02 (0.00e+00)
C06	Obj	-5.7767e+02 (6.68e-01) -	2.3587e+02 (2.21e+02) -	NaN -	NaN -	-5.7302e+02 (2.16e+00) -	-5.7866e+02 (0.00e+00) +	1.7703e+02 (3.19e+02) -	5.3281e+02 (8.08e+01) -	-5.7809e+02 (4.14e-01)
C07	Obj	2.5732e+00 (1.28e+00) -	0.0000e+00 (0.00e+00) =	5.7672e+02 (4.29e+02) -	0.0000e+00 (0.00e+00) =	0.0000e+00 (0.00e+00) =	0.0000e+00 (0.00e+00) =	0.0000e+00 (0.00e+00) =	0.0000e+00 (0.00e+00) =	0.0000e+00 (0.00e+00)
C08	Obj	7.4521e+00 (4.93e+00) -	1.5490e+01 (2.93e+01) -	1.0916e+01 (1.35e-01) -	7.5971e+00 (4.75e+00) -	8.4574e+00 (4.20e+00) -	8.7062e+00 (4.10e+00) -	5.9595e+00 (1.05e+01) -	3.8389e+00 (6.65e+00) -	0.0000e+00 (0.00e+00)
C09	Obj	2.0407e+08 (8.90e+08) -	3.7850e+12 (4.05e+12) -	7.0531e+01 (1.65e+00) -	2.5085e+12 (0.00e+00) -	0.0000e+00 (0.00e+00) =	0.0000e+00 (0.00e+00) =	3.7728e+11 (9.43e+11) -	1.6000e+13 (8.87e+12) -	0.0000e+00 (0.00e+00)
C10	Obj	9.1711e+08 (4.20e+09) -	5.8951e+12 (7.76e+12) -	4.2007e+01 (1.07e-01) -	NaN -	0.0000e+00 (0.00e+00) =	4.0057e+01 (8.35e+00) -	1.3793e+12 (3.12e+12) -	1.0864e+13 (8.73e+12) -	0.0000e+00 (0.00e+00)
C11	Obj	-1.5000e-03 (2.29e-19) =	-1.5000e-03 (4.43e-19) =	NaN -	-9.5556e-04 (4.36e-04) -	-1.5000e-03 (4.43e-19) =	-1.5000e-03 (4.43e-19) =	-5.1905e-04 (5.40e-04) -	-1.0640e-03 (1.82e-04) -	-1.5000e-03 (4.43e-19)
C12	Obj	-4.4848e+00 (2.33e+01) =	-2.3332e+01 (6.63e+01) =	-1.9670e-01 (4.36e-04) -	-1.9920e-01 (1.10e+00) -	-6.3015e-01 (2.15e+00) =	-1.7152e-01 (1.31e+02) +	-8.8385e+00 (5.47e+01) +	-1.1289e+00 (3.23e+00) -	-1.1289e+00 (3.23e+00)
C13	Obj	-6.3737e+01 (4.87e+00) -	-6.8429e+01 (2.90e-14) =	-6.4084e+01 (3.61e+00) -	-5.1043e+01 (4.72e+00) -	-6.8315e+01 (4.69e-01) -	-6.8429e+01 (2.90e-14) =	-4.3331e+01 (3.03e+00) -	-4.7945e+01 (2.57e+00) -	-6.8429e+01 (2.90e-14)
C14	Obj	2.7166e+00 (1.04e+00) -	6.8777e+05 (3.44e+06) -	7.8268e+00 (1.84e+00) -	7.1112e+10 (8.28e+10) -	3.1893e+01 (1.10e+00) -	0.0000e+00 (0.00e+00) =	7.9420e+06 (3.91e+07) -	4.3955e+12 (3.46e+12) -	0.0000e+00 (0.00e+00)
C15	Obj	1.7730e+08 (8.87e+08) -	1.4608e+12 (2.35e+12) -	3.9010e+00 (2.54e-01) -	3.9265e+12 (3.31e+12) -	5.2600e+01 (2.63e+00) -	3.3793e+00 (1.02e+00) -	1.0448e+10 (3.84e+10) -	3.6017e+13 (3.09e+13) -	0.0000e+00 (0.00e+00)
C16	Obj	1.0096e+00 (4.59e-02) -	8.4090e-01 (2.81e-01) -	2.1800e-03 (8.41e-03) -	8.0695e-01 (2.80e-01) -	0.0000e+00 (0.00e+00) +	1.5860e-02 (2.13e-02) -	4.2181e-01 (4.07e-01) -	9.5644e-01 (7.78e-02) -	3.2520e-03 (7.95e-03)
C17	Obj	4.5512e+01 (1.49e+02) -	8.3391e+01 (5.94e+01) -	0.0000e+00 (0.00e+00) =	2.1193e+02 (1.58e+02) -	0.0000e+00 (0.00e+00) =	0.0000e+00 (0.00e+00) =	2.4636e+01 (2.28e+01) -	2.2577e+02 (8.87e+01) -	0.0000e+00 (0.00e+00)
C18	Obj	9.5070e+03 (5.38e+03) -	2.0105e+03 (1.33e+03) -	0.0000e+00 (0.00e+00) =	5.7870e+03 (3.29e+03) -	0.0000e+00 (0.00e+00) =	0.0000e+00 (0.00e+00) =	7.4215e+02 (7.63e+02) -	5.4208e+03 (1.85e+03) -	0.0000e+00 (0.00e+00)
+/-/=		0/13/5	0/12/6	1/14/3	1/16/1	1/6/11	3/5/10	2/15/1	1/15/2	Base

TABLE S-III

AVERAGE OBJECTIVE VALUES (OBJ) AND AVERAGE STANDARD DEVIATIONS OBTAINED BY THE SELECTED ADVANCED COEAs AND THE PROPOSED CCMT ON THE 30-DIMENSIONAL CEC2010 BENCHMARK SUITE.

		ECHT	VMCH	FROFI	C^2oDE	CORCO	DeCODE	CAL-SHADE	LSHADE44	CCMT
C01	Obj	-8.1082e-01 (1.21e-02) =	-7.9745e-01 (1.55e-02) -	-8.0747e-01 (6.72e-03) -	-8.2096e-01 (2.04e-03) +	-4.0324e-01 (3.09e-02) -	-8.1960e-01 (2.92e-03) +	-8.2168e-01 (7.98e-04) +	-7.9640e-01 (1.61e-02) -	-8.1320e-01 (1.05e-02)
C02	Obj	8.4569e-01 (1.40e+00) -	2.1677e+00 (7.26e-01) -	-2.1458e+00 (4.91e-02) -	3.7899e-01 (6.57e-01) -	-1.9040e+00 (8.53e-01) -	-2.1774e+00 (4.09e-02) =	1.9708e+00 (7.84e-01) -	3.0176e+00 (4.90e-01) -	-2.1693e+00 (3.13e-02)
C03	Obj	9.1377e+12 (4.29e+13) -	2.3193e+05 (5.99e+05) -	2.8707e+01 (1.34e-02) -	2.8681e+01 (2.92e-03) -	0.0000e+00 (0.00e+00) =	2.4086e+01 (1.07e+01) -	2.2540e+05 (1.09e+06) -	1.8035e+13 (1.42e+13) -	0.0000e+00 (0.00e+00)
C04	Obj	9.8333e-03 (6.61e-03) +	9.1812e-02 (2.60e-01) =	NaN -	9.7760e-03 (1.40e-02) +	0.0000e+00 (0.00e+00) +	1.9380e+01 (0.00e+00) -	2.4419e-01 (3.13e-01) -	2.5964e-02 (1.30e-01) -	2.5964e-02 (1.30e-01)
C05	Obj	NaN -	4.7182e+02 (7.90e+01) -	-4.8341e+02 (7.55e-02) +	1.2146e+02 (2.06e+02) -	-4.5922e+02 (3.12e+01) +	-4.8347e+02 (1.25e-01) +	3.9435e+02 (9.66e+01) -	5.2035e+02 (6.31e+01) -	-4.7990e+02 (3.76e+00)
C06	Obj	NaN -	5.3430e+02 (9.02e+01) -	-5.3052e+02 (1.08e-01) +	-3.7199e+01 (5.24e+01) -	-5.1659e+02 (5.17e+00) -	-5.2815e+02 (9.18e+01) -	3.0300e+02 (1.86e+02) -	5.5773e+02 (6.03e+01) -	-5.2991e+02 (3.28e-01)
C07	Obj	9.4895e-01 (1.26e+00) -	0.0000e+00 (0.00e+00) =	1.3859e+04 (1.12e+04) -	0.0000e+00 (0.00e+00) =	1.5946e-01 (7.97e-01) =	0.0000e+00 (0.00e+00) =	6.3786e-01 (1.49e+00) -	1.5946e-01 (7.97e-01) =	1.5946e-01 (7.97e-01)
C08	Obj	1.7024e+01 (6.34e+01) -	2.5625e+02 (6.34e+02) -	3.7660e+01 (2.37e+01) -	3.9600e-04 (1.59e-03) -	0.0000e+00 (0.00e+00) =	0.0000e+00 (0.00e+00) =	2.0290e+02 (3.82e+02) -	6.5738e+00 (1.66e+01) -	0.0000e+00 (0.00e+00)
C09	Obj	4.3107e+13 (1.53e+13) -	2.4375e+13 (1.53e+13) -	1.7602e-01 (8.80e-01) -	1.9914e+12 (1.33e+12) -	0.0000e+00 (0.00e+00) =	2.7284e+01 (3.22e+01) -	1.5337e+12 (2.80e+12) -	3.6548e+13 (1.45e+13) -	0.0000e+00 (0.00e+00)
C10	Obj	4.7679e+12 (0.00e+00) -	2.1139e+13 (1.11e+13) -	3.1347e+01 (1.24e+02) -	2.3982e+12 (1.02e+12) -	0.0000e+00 (0.00e+00) +	3.1309e+01 (3.63e-15) -	1.1510e+11 (3.00e+11) -	4.2069e+13 (1.96e+13) -	7.6579e+00 (9.30e+00)
C11	Obj	NaN -	-4.0000e-04 (0.00e+00) =	NaN -	NaN -	-4.0000e-04 (5.53e-20) =	-4.0000e-04 (5.53e-20) =	5.2632e-05 (2.20e-04) -	-8.5714e-05 (7.93e-05) -	-4.0000e-04 (5.53e-20)
C12	Obj	-1.9929e-01 (3.59e-05) -	-1.9930e-01 (0.00e+00) =	NaN -	-1.9554e-01 (9.90e-04) -	-1.9930e-01 (0.00e+00) =	-1.9930e-01 (0.00e+00) =	1.4015e+00 (1.87e+00) =	-2.2509e+00 (1.30e+01) +	-1.9930e-01 (0.00e+00)
C13	Obj	-5.7857e+01 (5.65e+00) -	-6.6899e+01 (1.36e+00) -	-6.4088e+01 (1.94e+00) -	-3.3491e+01 (2.09e+00) -	-6.8429e+01 (0.00e+00) +	-6.8088e+01 (8.40e+01) -	-2.8147e+01 (1.51e+00) -	-3.2190e+01 (1.53e+00) -	-6.8240e+01 (3.47e+01)
C14	Obj	1.4281e+01 (6.99e+00) -	2.2407e+03 (1.12e+04) -	6.8518e+02 (9.90e+02) -	6.5987e+09 (1.80e+10) -	0.0000e+00 (0.00e+00) =	0.0000e+00 (0.00e+00) =	1.0522e+06 (5.26e+06) -	8.0346e+13 (7.21e+13) -	0.0000e+00 (0.00e+00)
C15	Obj	1.2144e+13 (1.80e+13) -	1.9423e+13 (1.40e+13) -	2.7827e+01 (8.97e-01) -	3.5253e+13 (2.34e+13) -	1.7234e+01 (8.62e-01) =	2.1603e+01 (0.00e+00) =	8.8007e+08 (4.40e+09) -	2.5839e+14 (8.05e+13) -	0.0000e+00 (0.00e+00)
C16	Obj	0.0000e+00 (0.00e+00) =	8.0042e-01 (3.46e-01) -	5.1200e-04 (2.56e-03) -	8.1507e-01 (1.40e-01) -	0.0000e+00 (0.00e+00) =	0.0000e+00 (0.00e+00) =	0.0000e+00 (0.00e+00) =	1.1009e+00 (2.25e-02) -	0.0000e+00 (0.00e+00)
C17	Obj	3.9097e+02 (8.42e+02) -	6.3242e+02 (2.55e+02) -	1.3468e-01 (1.75e-01) -	3.7835e+02 (3.08e+02) -	4.1912e-01 (4.37e-01) +	1.6492e-02 (7.79e-02) +	1.0751e+02 (9.72e+01) -	1.1367e+03 (1.50e+02) -	1.2266e+00 (2.28e+00)
C18	Obj	2.4259e+04 (1.07e+04) -	9.7742e+03 (6.91e+03) -	1.6000e-05 (6.24e-05) =	8.6039e+03 (4.98e+03) -	3.7221e+02 (7.20e+02) -	0.0000e+00 (0.00e+00) =	4.2591e+02 (6.79e+02) -	2.3313e+04 (3.58e+03) -	0.0000e+00 (0.00e+00)
+/-/=		1/14/3	0/14/4	2/12/4	2/14/2	4/5/9	4/5/9	1/15/2	1/16/1	Base

TABLE S-IV

AVERAGE OBJECTIVE VALUES (OBJ) OR CONSTRAINT VIOLATIONS (CV) AND STANDARD DEVIATIONS OBTAINED BY THE SELECTED ADVANCED COEAs AND THE PROPOSED CCMT ON THE 50-DIMENSIONAL CEC2017 BENCHMARK SUITE.

		ECHT	VMCH	FROFI	C^2oDE	CORCO	DeCODE	CAL-SHADE	LSHADE44	CCMT
C01	Obj	2.9600e-04 (2.65e-04) -	0.0000e+00 (0.00e+00) =	1.7668e+02 (3.35e+02) -	0.0000e+00 (0.00e+00) =	0.0000e+00 (0.00e+00) =	0.0000e+00 (0.00e+00) =	0.0000e+00 (0.00e+00) =	0.0000e+00 (0.00e+00) =	0.0000e+00 (0.00e+00)
C02	Obj	1.1200e-04 (1.01e-04) -	0.0000e+00 (0.00e+00) =	8.5941e+03 (1.52e+03) -	0.0000e+00 (0.00e+00) =	0.0000e+00 (0.00e+00) =	0.0000e+00 (0.00e+00) =	2.2625e+01 (6.04e+01) -	4.0816e+04 (5.81e+03) -	0.0000e+00 (0.00e+00)
C03	Obj	5.5152e+06 (8.27e+06) -	1.0590e+06 (4.86e+05) -	6.6147e+03 (1.13e+04) -	1.2162e+05 (1.53e+05) -	0.0000e+00 (0.00e+00) =	1.5041e+03 (5.87e+02) -	9.1595e+05 (1.39e+06) -	2.5318e+06 (3.54e+06) -	0.0000e+00 (0.00e+00)
C04	Obj	4.8453e+02 (6.62e+01) -	1.3855e+01 (7.78e-01) +	8.1502e+01 (2.89e+01) -	7.7668e+01 (2.58e+01) -	1.5379e+01 (1.68e+00) +	1.5189e+01 (1.79e+00) +	1.3573e+01 (0.00e+00) +	1.3573e+01 (3.04e+00) +	4.0190e+01 (2.18e+01)
C05	Obj	1.0596e+00 (2.65e+00) -	7.9732e-01 (1.63e+00) -	3.7946e+02 (2.18e+02) -	1.5320e+03 (4.08e+03) -	0.0000e+00 (0.00e+00) =	3.1893e+01 (1.10e+00) -	2.5149e+01 (2.06e+01) -	1.1956e+05 (3.34e+04) -	0.0000e+00 (0.00e+00)
C06	Obj	NaN -	8.0056e+03 (1.04e+03) -	5.5767e+01 (0.00e+00) +	NaN -	0.0000e+00 (0.00e+00) +	9.6980e+02 (1.36e+03) =	2.3695e+03 (1.17e+03) =	8.4323e+03 (1.61e+03) -	1.3042e+02 (2.51e+02)
C07	Obj	NaN -	-4.0221e+02 (1.73e+02) -	-2.2515e+03 (1.87e+01) +	-4.6255e+02 (1.77e+02) =	-7.0528e+01 (2.02e+02) -	3.7809e+01 (1.98e+02) =	-2.0121e+02 (1.25e+02) =	-2.9675e+02 (1.11e+02) =	-1.9298e+03 (5.84e+02)
C08	Obj	1.9800e-03 (9.92e-04) -	-1.0000e-04 (1.38e-20) +	-3.6000e-05 (3.90e-04) -	3.9560e-03 (4.05e-04) -	-1.0000e-04 (1.38e-20) =	-1.0000e-04 (1.38e-20) =	7.6200e-03 (1.38e-03) -	5.6880e-03 (9.03e-04) -	1.6000e-05 (2.79e-04)
C09	Obj	1.1120e-03 (1.48e-02) -	-2.0000e-04 (1.33e-18) -	-2.0000e-04 (1.33e-18) -	3.2978e+00 (8.16e-01) -	NaN -	-1.8786e-03 (2.75e-04) -	1.8560e-01 (1.27e+00) -	1.2562e-01 (2.60e+00) -	-2.0000e-04 (1.33e-18)
C10	Obj	2.1600e-04 (9.43e-05) -	0.0000e+00 (0.00e+00) =	8.0000e-06 (4.00e-05) -	1.1520e-03 (9.18e-05) -	0.0000e+00 (0.00e+00) =	0.0000e+00 (0.00e+00) =	3.1760e-03 (3.13e-03) -	1.7760e-03 (5.30e-03) -	0.0000e+00 (0.00e+00)
C11	CV	1.7836e+02 (1.65e+01) -	9.8460e-16 (4.92e-15) +	3.3285e+03 (1.16e+03) -	1.6165e+04 (5.76e+01) -	1.7750e+04 (3.31e+03) -	9.2574e+03 (2.69e+03) -	9.2056e+01 (6.11e+01) -	5.0936e-16 (1.49e-15) +	4.2867e+00 (6.45e+00)
C12	Obj	1.4884e+01 (8.23e+00) -	2.5527e+01 (9.09e+00) -	7.7082e+00 (8.18e+00) +	1.8265e+02 (1.74e+01) -	9.0499e+00 (4.43e-01) -	1.1367e+01 (6.05e+00) -	6.2950e+00 (6.13e-01) +	2.3636e+02 (2.20e+01) -	7.8789e+00 (3.96e+00)
C13	Obj	6.4603e+02 (1.33e+03) -	3.1768e+01 (4.73e+01) -	4.5072e+01 (7.76e+00) -	2.4135e+03 (5.59e+02) -	0.0000e+00 (0.00e+00) =	0.0000e+00 (0.00e+00) =	9.3933e+02 (4.62e+02) -	3.4429e+03 (6.64e+02) -	0.0000e+00 (0.00e+00)
C14	Obj	1.5984e+00 (4.23e-02) -	1.1336e+00 (8.59e-02) -	1.1019e+00 (5.21e-03) +	1.6120e+00 (6.71e-02) -	1.6160e+00 (1.28e-01) -	1.0000e+00 (4.53e-16) +	1.7621e+00 (2.04e-02) -	1.5820e+00 (4.39e-02) -	1.1156e+00 (2.63e-02)
C15	Obj	1.1257e+01 (4.96e+00) -	1.5928e+01 (1.97e+00) -	5.7491e+00 (8.70e-01) -	1.3917e+01 (1.97e+00) -	4.8432e+00 (5.71e+00) -	6.1260e+00 (1.28e+00) -	7.7597e+00 (7.34e+00) -	1.7687e+01 (2.45e+00) -	2.3561e+00 (9.06e-16)
C16	Obj	2.2117e+01 (9.20e+00) -	2.5057e+02 (1.82e+01) -	6.2830e+00 (5.10e-05) -	1.7254e+02 (2.49e+01) -	0.0000e+00 (0.00e+00) =	6.2831e+00 (5.10e-05) -	0.0000e+00 (0.00e+00) =	2.6546e+02 (2.26e+01) -	0.0000e+00 (0.00e+00)
C17	CV	5.1000e+01 (2.91e-04) -	5.1000e+01 (0.00e+00) =	5.0920e+01 (4.00e-01) -	5.1000e+01 (1.17e-05) -	4.9503e+01 (5.95e-01) +	5.0920e+01 (4.07e-05) -	4.9015e+01 (1.93e-02) +	5.1000e+01 (0.00e+00) =	5.0520e+01 (8.72e-01)
C18	Obj	3.6495e+01 (1.73e-03) -	3.7308e+01 (1.96e+00) -	NaN -	3.7331e+01 (0.00e+00) -	NaN -	3.8040e+01 (3.25e+00) -	3.6515e+01 (1.47e+02) -	4.2116e+01 (6.96e+00) -	3.6491e+01 (3.23e-03)
C19	CV	7.2232e+04 (4.46e-11) -	7.2232e+04 (4.46e-11) =	7.2232e+04 (2.27e-04) -	7.2232e+04 (1.12e-08) -	7.2352e+04 (4.54e+00) -	7.2232e+04 (6.63e-09) -	7.2232e+04 (5.05e-11) -	7.2232e+04 (3.60e-11) -	7.2232e+04 (4.46e-11)
C20	Obj	1.4633e+01 (1.06e+00) -	2.1131e+01 (4.64e-01) +	5.3929e+01 (1.07e+00) =	4.4400e+00 (5.29e-01) +	6.6578e+00 (1.91e+00) -	5.1773e+00 (1.25e+00) +	2.6505e+00 (7.01e-01) +	2.3838e+00 (2.85e-01) +	4.9263e+00 (1.17e+00)
C21	Obj	5.9278e+01 (1.79e+01) -	1.1820e+01 (1.06e+01) +	6.7775e+00 (4.31e+00) +	1.9041e+02 (1.47e+01) -	NaN -	2.6964e+01 (1.28e+01) +	1.0855e+02 (1.80e+01) -	2.6017e+02 (2.58e+01) -	4.3179e+01 (1.93e+01)
C22	Obj	9.6765e+01 (5.52e+01) -	4.3264e+04 (1.34e+04) -	4.3955e+01 (3.66e-01) -	3.3429e+03 (1.60e+03) -	7.7154e+00 (2.18e+00) -	1.6850e+01 (2.07e+00) -	6.7550e+03 (8.69e+03) -	6.4290e+04 (1.01e+04) -	1.8378e+00 (1.42e+00)
C23	Obj	1.5199e+00 (4.76e-02) -	1.1125e+00 (4.33e-02) +	1.1028e+00 (1.04e-02) +	1.5121e+00 (5.14e-02) -	1.5479e+00 (2.20e-01) -	1.6205e+00 (9.79e-02) -	1.6320e+00 (2.69e-02) -	1.2509e+00 (7.97e-02) -	1.2509e+00 (7.97e-02)
C24	Obj	1.0147e+01 (2.74e+00) -	1.5676e+01 (1.37e+00) -	5.4977e+00 (3.74e-05) -	1.1907e+01 (1.10e+00) -	2.6180e+00 (8.87e-01) -	5.3720e+00 (1.43e+00) -	1.5048e+01 (2.12e+00) -	1.6053e+01 (1.54e+00) -	2.3561e+00 (9.06e-16)
C25	Obj	5.5041e+01 (1.96e+01) -	2.6496e+02 (1.89e+01) -	6.2831e+00 (4.36e-05) -	1.8516e+02 (2.19e+01) -	6.2831e+00 (5.10e-05) -	9.2928e+01 (3.14e+01) -	2.7891e+02 (1.57e+01) -	2.7891e+02 (1.57e+01) -	0.0000e+00 (0.00e+00)
C26	CV	5.1000e+01 (2.77e-04) -	5.1000e+01 (0.00e+00) =	5.1000e+01 (2.22e-05) -	5.1000e+01 (7.15e-06) -	5.1006e+01 (5.32e-03) -	5.1000e+01 (5.59e-05) -	5.1000e+01 (0.00e+00) =	5.1000e+01 (0.00e+00) =	5.1000e+01 (0.00e+00)
C27	CV	3.7695e+01 (4.23e+00) =	3.7329e+01 (3.07e+00) =	NaN -	5.1114e+01 (7.05e+00) -	NaN -	3.6487e+01 (4.87e-03) +	4.6295e+01 (6.82e+00) -	4.0312e+01 (6.52e+00) -	3.6767e+01 (1.34e+00)
C28	CV	7.2275e+04 (2.50e+01) +	7.2601e+04 (3.11e+01) -	7.2323e+04 (2.65e+01) =	7.2471e+04 (2.99e+01) -	7.2475e+04 (2.23e+01) -	7.2531e+04 (2.85e+01) -	7.2619e+04 (1.84e+01) -	7.2613e+04 (2.77e+01) -	7.2313e+04 (2.84e+01)
+/-/=		1/25/2	7/13/8	6/16/6	0/23/5	4/15/9	5/14/9	4/19/5	4/20/4	Base

TABLE S-V

AVERAGE OBJECTIVE VALUES (OBJ) OR AVERAGE CONSTRAINT VIOLATIONS (CV) AND STANDARD DEVIATIONS OBTAINED BY THE SELECTED ADVANCED COEAs AND THE PROPOSED CCMT ON THE 100-DIMENSIONAL CEC2017 BENCHMARK SUITE.

		ECHT	VMCH	FROFI	C²oDE	CORCO	DeCODE	CAL-SHADE	LSHADE44	CCMT
C01	Obj	6.5210e+01 (3.42e+01) -	0.0000e+00 (0.00e+00) =	5.4907e+03 (3.61e+03) -	8.4000e-05 (8.98e-05) -	0.0000e+00 (0.00e+00) =	0.0000e+00 (0.00e+00) =	0.0000e+00 (0.00e+00) =	0.0000e+00 (0.00e+00) =	0.0000e+00 (0.00e+00)
C02	Obj	2.1056e+01 (7.91e+00) -	0.0000e+00 (0.00e+00) =	2.1430e+04 (8.01e+03) -	6.8000e-05 (6.90e-05) -	0.0000e+00 (0.00e+00) =	0.0000e+00 (0.00e+00) =	2.4416e+04 (4.57e+04) -	1.6848e+05 (3.89e+04) -	0.0000e+00 (0.00e+00)
C03	Obj	9.3506e+06 (2.59e+06) -	2.5217e+06 (1.72e+06) -	3.3028e+03 (3.82e+03) -	1.9746e+05 (8.72e+04) -	0.0000e+00 (0.00e+00) =	5.5250e+03 (1.82e+03) -	2.3229e+06 (2.57e+06) -	3.2003e+06 (2.17e+06) -	1.5470e+02 (9.32e+01)
C04	Obj	2.5423e+02 (7.41e+01) -	2.0825e+01 (1.45e+01) +	2.4213e+02 (4.73e+01) -	1.5048e+02 (2.65e+01) -	7.7401e+01 (1.91e+01) +	8.2387e+01 (2.00e+01) +	1.3573e+01 (0.00e+00) +	1.3573e+01 (0.00e+00) +	1.6192e+02 (5.05e+01)
C05	Obj	8.0179e+01 (2.23e+01) -	1.5946e-01 (7.97e-01) =	3.4016e+03 (1.38e+03) -	4.1871e+01 (1.33e+01) -	1.1804e+00 (2.69e+00) -	1.1151e+00 (1.89e+00) -	1.0106e+02 (2.63e+01) -	5.6065e+05 (1.01e+05) -	1.5946e-01 (7.97e-01)
C06	Obj	NaN -	1.6931e+04 (2.59e+03) -	NaN -	5.5772e+03 (1.16e+03) -	2.9485e+02 (1.15e+02) -	2.2711e+03 (3.00e+03) -	6.0188e+03 (2.27e+03) -	1.7994e+04 (2.35e+03) -	1.1220e+03 (3.96e+02)
C07	Obj	NaN -	-9.8889e+02 (2.54e+02) =	-4.5636e+03 (3.59e+01) +	-8.2383e+02 (1.44e+02) =	-1.0340e+02 (2.18e+02) -	-5.2659e+01 (2.51e+02) -	-2.9562e+02 (1.52e+02) -	-4.0168e+02 (9.74e+01) -	-7.6071e+02 (4.82e+02)
C08	Obj	NaN -	1.2480e-03 (2.86e-04) +	8.9600e-04 (1.06e-04) +	NaN -	3.2000e-03 (1.11e-03) +	1.7680e-03 (2.54e-04) +	8.1920e-03 (1.36e-03) =	7.0480e-03 (1.73e-03) =	3.7643e-03 (1.75e-03)
C09	Obj	6.4723e+00 (2.51e+00) -	0.0000e+00 (0.00e+00) +	0.0000e+00 (0.00e+00) +	1.1808e+00 (1.89e+00) -	NaN -	0.0000e+00 (0.00e+00) +	1.8924e+01 (8.85e-01) -	1.5579e+01 (1.94e+00) -	6.4000e-05 (1.58e-04)
C10	Obj	6.1600e-04 (1.03e-04) -	3.2000e-04 (5.77e-05) -	3.1600e-04 (4.73e-05) -	1.0960e-03 (8.41e-05) -	3.8800e-04 (6.00e-05) -	3.5200e-04 (8.72e-05) -	3.1760e-03 (1.15e-03) -	1.8320e-03 (4.14e-04) -	2.6400e-04 (5.69e-05)
C11	CV	2.0817e+02 (1.97e+02) =	2.3587e-02 (2.79e-02) +	4.4512e+02 (7.18e+02) -	4.5429e+02 (1.96e+02) -	2.1904e+04 (5.20e+03) -	3.0289e+04 (4.44e+03) -	4.7533e+02 (2.46e+02) -	2.5413e+02 (4.36e-02) +	1.2956e+02 (1.33e+01)
C12	Obj	2.7997e+01 (7.28e+00) -	1.2063e+01 (7.06e+00) +	6.4985e+00 (4.20e+00) +	2.5410e+02 (1.79e+01) -	NaN -	2.0294e+01 (9.63e+00) =	6.6052e+00 (3.94e-01) +	4.1459e+02 (3.12e+01) -	2.2137e+01 (7.85e+00)
C13	Obj	7.7077e+02 (8.40e+02) -	1.5405e+03 (6.25e+03) -	1.8068e+02 (1.24e+02) -	5.4161e+03 (1.22e+03) -	2.6994e+01 (2.10e+01) +	4.2224e+01 (1.82e+01) -	1.9201e+03 (3.47e+02) -	1.3510e+04 (1.95e+04) -	3.1672e+01 (1.94e+00)
C14	Obj	1.0691e+00 (3.10e-02) -	7.8960e-01 (1.36e-02) =	7.8831e-01 (9.39e-03) -	1.1227e+00 (2.57e-02) -	1.0844e+00 (9.76e-02) -	7.9734e-01 (6.57e-02) =	1.1678e+00 (3.38e-03) -	1.1128e+00 (1.38e-02) -	7.8569e-01 (4.84e-03)
C15	Obj	1.2409e+01 (2.87e+00) -	2.1834e+01 (2.40e+00) -	8.6393e+00 (9.07e-01) -	1.7436e+01 (1.28e+00) -	9.3933e+00 (1.64e+00) -	1.2284e+01 (1.18e+00) -	4.4924e+00 (3.10e+00) -	2.2462e+01 (2.03e+00) -	2.3561e+00 (9.06e-16)
C16	Obj	1.3697e+01 (1.64e+01) -	6.1871e+02 (2.57e+01) -	8.5449e+00 (3.08e+00) -	4.0244e+02 (3.72e+01) -	0.0000e+00 (0.00e+00) =	6.2831e+00 (5.10e-05) -	0.0000e+00 (0.00e+00) =	6.4114e+02 (2.65e+01) -	0.0000e+00 (0.00e+00)
C17	CV	1.0100e+02 (5.24e-04) -	1.0100e+02 (0.00e+00) =	1.0100e+02 (3.73e-05) -	1.0100e+02 (0.00e+00) =	1.0055e+02 (7.74e-01) -	1.0100e+02 (4.29e-05) -	9.9016e+01 (1.73e-02) +	1.0100e+02 (0.00e+00) =	1.0100e+02 (0.00e+00)
C18	Obj	4.5985e+01 (6.28e+00) -	3.7953e+01 (3.14e+00) -	NaN -	4.6996e+01 (5.92e+00) -	NaN -	3.8659e+01 (5.36e+00) -	3.6467e+01 (4.59e+02) +	4.5487e+01 (8.42e+00) -	3.6743e+01 (1.69e+00)
C19	CV	1.4594e+05 (8.91e-11) -	1.4594e+05 (8.91e-11) =	1.4594e+05 (1.09e-04) -	1.4594e+05 (1.37e-08) -	1.4622e+05 (7.45e+00) -	1.4594e+05 (1.04e-08) -	1.4594e+05 (2.80e-09) -	1.4594e+05 (1.32e-09) -	1.4594e+05 (8.91e-11)
C20	Obj	3.3499e+01 (1.44e+00) -	5.1292e+00 (9.41e-01) +	1.2342e+01 (2.16e+00) -	1.1695e+01 (3.03e+00) -	1.5432e+01 (4.71e+00) -	1.0702e+01 (2.43e+00) -	5.6084e+00 (6.93e-01) +	5.1225e+00 (7.57e-01) +	9.1587e+00 (2.02e+00)
C21	Obj	1.2517e+01 (7.10e+00) -	7.2185e+00 (3.97e+00) -	2.1489e+01 (1.34e+01) -	2.9521e+02 (2.30e+01) -	NaN -	6.0046e+00 (4.02e+00) +	2.5655e+02 (4.03e+01) -	4.6953e+02 (3.19e+01) -	9.1587e+00 (6.39e+00)
C22	Obj	2.7793e+03 (1.17e+03) -	NaN -	1.7567e+03 (7.41e+02) -	NaN -	8.4450e+01 (1.16e+01) -	2.5104e+02 (2.04e+02) -	1.1858e+04 (6.11e+03) -	NaN -	1.3371e+02 (2.09e+02)
C23	Obj	1.0411e+00 (1.43e-02) -	7.8420e-01 (1.13e-16) +	7.9930e-01 (1.32e-02) +	1.0618e+00 (1.71e-02) -	1.0154e+00 (9.34e-02) -	9.3212e-01 (1.50e-01) -	1.1191e+00 (2.13e-02) -	1.1327e+00 (1.02e-02) -	8.6092e-01 (6.15e-02)
C24	Obj	1.3540e+01 (2.58e+00) -	2.2337e+01 (1.54e+00) -	7.8853e+00 (1.37e+00) -	1.5299e+01 (1.04e+00) -	2.3561e+00 (9.06e-16) =	6.0004e+00 (1.18e+00) -	1.9195e+01 (2.00e+00) -	2.3091e+01 (2.72e+00) -	2.3561e+00 (9.06e-16)
C25	Obj	1.1228e+02 (2.29e+01) -	7.1195e+02 (2.18e+01) -	3.1667e+01 (1.69e+01) -	5.1937e+02 (2.99e+01) -	4.4485e+01 (2.15e+01) -	3.5437e+01 (1.80e+01) -	5.4915e+02 (8.26e+01) -	7.1396e+02 (2.19e+01) -	1.1184e+01 (6.65e+00)
C26	CV	1.0100e+02 (4.54e-04) -	1.0100e+02 (0.00e+00) =	1.0100e+02 (1.55e-05) -	1.0100e+02 (1.51e-07) -	1.0101e+02 (1.02e-02) -	1.0100e+02 (1.17e-05) -	1.0100e+02 (0.00e+00) =	1.0100e+02 (0.00e+00) =	1.0100e+02 (0.00e+00)
C27	Obj	3.9868e+01 (2.70e+01) =	3.9207e+01 (4.33e+00) =	NaN -	5.1299e+01 (3.05e+00) =	NaN -	4.7974e+01 (9.78e+00) =	4.7062e+01 (5.06e+00) =	3.9581e+01 (6.30e+00) =	4.4664e+01 (3.50e+00)
C28	CV	1.4626e+05 (1.30e+02) +	1.4679e+05 (3.04e+01) -	1.4641e+05 (3.13e+01) -	1.4658e+05 (5.52e+01) -	1.4668e+05 (3.88e+01) -	1.4667e+05 (4.04e+01) -	1.4680e+05 (2.31e+01) -	1.4679e+05 (2.77e+01) -	1.4635e+05 (3.60e+01)
+/-/=		1/24/3	7/10/11	5/21/2	0/22/6	6/17/5	4/16/8	5/18/5	3/20/5	Base

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TABLE S-VI

AVERAGE OBJECTIVE VALUES (OBJ) OR AVERAGE CONSTRAINT VIOLATIONS (CV) AND STANDARD DEVIATIONS OBTAINED BY THE PROPOSED CCMT AND ITS COMPONENT VARIANTS ON THE 50-DIMENSIONAL CEC2017 BENCHMARK SUITE.

		wo-RA	wo-KA	wo-KD	only-FP	only-EC	only-DeMO	only-COR	wo-Heu	wo-His	new-ECHT	new-VMCH	CCMT
C01	Obj	0.0000e+00 (0.00e+00) =	0.0000e+00 (0.00e+00) =	0.0000e+00 (0.00e+00) =	0.0000e+00 (0.00e+00) =	0.0000e+00 (0.00e+00) =	0.0000e+00 (0.00e+00) =	0.0000e+00 (0.00e+00) =	0.0000e+00 (0.00e+00) =	0.0000e+00 (0.00e+00) =	1.9261e-01 (1.56e-01) -	0.0000e+00 (0.00e+00) =	0.0000e+00 (0.00e+00)
C02	Obj	0.0000e+00 (0.00e+00) =	0.0000e+00 (0.00e+00) =	0.0000e+00 (0.00e+00) =	0.0000e+00 (0.00e+00) =	0.0000e+00 (0.00e+00) =	0.0000e+00 (0.00e+00) =	0.0000e+00 (0.00e+00) =	0.0000e+00 (0.00e+00) =	0.0000e+00 (0.00e+00) =	1.2751e-01 (9.47e-02) -	0.0000e+00 (0.00e+00) =	0.0000e+00 (0.00e+00)
C03	Obj	6.2830e+01 (3.80e+01) -	0.0000e+00 (0.00e+00) =	0.0000e+00 (0.00e+00) =	6.3878e+06 (5.59e+06) -	0.0000e+00 (0.00e+00) =	1.6402e+05 (1.22e+05) -	0.0000e+00 (0.00e+00) =	0.0000e+00 (0.00e+00) =	0.0000e+00 (0.00e+00) =	1.2142e+05 (2.70e+05) -	0.0000e+00 (0.00e+00) =	0.0000e+00 (0.00e+00)
C04	Obj	5.0935e+01 (2.03e+01) -	3.5644e+01 (1.45e+01) -	2.8142e+02 (3.60e+01) -	1.6268e+02 (1.41e+01) -	1.5880e+02 (1.56e+01) -	1.6149e+02 (1.36e+01) -	2.0089e+02 (1.66e+01) -	4.4292e+01 (1.72e+01) -	3.2141e+01 (1.30e+01) -	3.7374e+02 (2.15e+01) -	2.2177e+02 (9.38e+00) -	4.0190e+01 (2.18e+01)
C05	Obj	1.5946e+01 (7.97e-01) -	0.0000e+00 (0.00e+00) =	1.1624e+01 (1.30e+00) -	0.0000e+00 (0.00e+00) =	0.0000e+00 (0.00e+00) =	0.0000e+00 (0.00e+00) =	0.0000e+00 (0.00e+00) =	1.5946e-01 (7.97e-01) -	3.1893e-01 (1.10e+00) -	2.8793e+01 (6.43e-01) -	0.0000e+00 (0.00e+00) =	0.0000e+00 (0.00e+00)
C06	Obj	5.2365e+02 (2.83e+02) =	0.0000e+00 (0.00e+00) =	NaN -	8.7345e+03 (1.43e+03) -	NaN -	1.0016e+03 (0.00e+00) =	NaN -	2.4097e+02 (3.90e+02) =	5.3470e+02 (3.84e+02) =	NaN -	NaN -	1.3042e+02 (2.51e+02)
C07	Obj	-1.4029e+03 (9.33e+02) =	-2.0010e+03 (5.45e+02) =	NaN -	-4.3534e+01 (2.40e+02) -	-5.7845e+02 (0.00e+00) -	-1.5569e+02 (1.86e+02) -	1.1033e+01 (7.12e+01) -	-1.7486e+03 (6.83e+02) -	-2.1674e+03 (3.17e+01) -	-2.0379e+02 (0.00e+00) -	NaN -	-1.9296e+03 (5.84e+02)
C08	Obj	-9.6000e+05 (2.00e+05) +	-5.6000e+05 (8.21e+05) +	5.6057e+00 (3.83e+00) =	-1.0000e-04 (1.38e-20) +	2.1164e+03 (8.50e-04) -	-1.0000e-04 (1.38e-20) +	-1.0000e-04 (1.38e-20) +	-1.6263e-20 (3.29e-04) +	2.0000e-05 (3.62e-04) =	NaN -	-5.2000e-05 (7.70e-05) =	1.6000e-05 (2.79e-04)
C09	Obj	-2.0000e+03 (1.33e-18) =	-2.0000e+03 (1.33e-18) =	-2.0000e+03 (1.33e-18) =	-2.0000e-03 (1.33e-18) =	NaN -	NaN -	NaN -	-2.0000e+03 (1.33e-18) =	-2.0000e-03 (1.33e-18) =	NaN -	0.0000e+00 (0.00e+00) =	-2.0000e-03 (1.33e-18)
C10	Obj	0.0000e+00 (0.00e+00) =	0.0000e+00 (0.00e+00) =	8.9600e-04 (2.68e-04) -	0.0000e+00 (0.00e+00) =	2.2000e-04 (5.00e-05) -	0.0000e+00 (0.00e+00) =	0.0000e+00 (0.00e+00) =	0.0000e+00 (0.00e+00) =	0.0000e+00 (0.00e+00) =	1.0485e+04 (7.91e+02) -	5.6683e+00 (1.12e+00) +	0.0000e+00 (0.00e+00)
C11	CV	5.2915e+00 (7.92e+00) =	1.3444e+01 (1.68e+01) -	8.1895e+01 (5.24e+01) -	2.2153e-11 (7.77e-11) +	8.1280e-01 (1.56e+00) +	1.6815e+04 (2.61e+03) -	1.8051e+04 (3.98e+03) -	9.9812e+00 (6.84e+00) -	2.2981e+00 (2.44e+00) =	3.7947e+01 (1.13e+01) -	0.0000e+00 (0.00e+00) =	4.2867e+00 (6.45e+00)
C12	Obj	1.0416e+01 (5.61e+00) -	1.1037e+01 (6.04e+00) -	1.0665e+01 (1.56e+00) -	4.7846e+00 (1.46e+00) +	5.9579e+00 (1.22e+00) +	3.9816e+00 (2.00e-05) +	1.1591e+01 (4.53e+00) -	0.0000e+00 (0.00e+00) =	1.2848e+01 (5.99e+00) -	1.5665e+00 (3.52e-02) +	1.1000e+00 (1.80e+04) +	7.8789e+00 (3.96e+00)
C13	Obj	0.0000e+00 (0.00e+00) =	0.0000e+00 (0.00e+00) =	1.8750e+01 (8.83e-01) -	7.1483e+02 (1.54e+02) -	0.0000e+00 (0.00e+00) =	0.0000e+00 (0.00e+00) =	0.0000e+00 (0.00e+00) =	1.1192e+00 (2.16e-02) +	0.0000e+00 (0.00e+00) =	2.3561e+00 (2.77e-05) =	2.3562e+00 (4.64e-05) -	0.0000e+00 (0.00e+00)
C14	Obj	1.1325e+00 (3.37e+02) -	1.3279e+00 (1.71e-01) -	1.1823e+00 (7.76e-02) -	1.5990e+00 (3.69e-02) -	1.1000e+00 (4.53e-16) +	1.1000e+00 (4.53e-16) +	1.6074e+00 (2.90e-02) -	2.3561e+00 (9.06e-16) =	1.1066e+00 (1.04e-02) =	5.2000e-05 (5.10e-05) =	0.0000e+00 (0.00e+00) =	1.1156e+00 (2.63e-02)
C15	Obj	2.3561e+00 (9.06e-16) =	2.3561e+00 (4.36e-05) -	2.3561e+00 (4.08e-05) -	2.0775e+01 (2.38e+00) -	2.8588e+00 (1.18e+00) -	9.2677e+00 (1.28e+00) -	2.6075e+00 (8.70e-01) -	0.0000e+00 (0.00e+00) =	2.3561e+00 (9.06e-16) =	5.1000e+01 (5.07e-04) -	5.0204e+01 (9.71e-01) =	2.3561e+00 (9.06e-16)
C16	Obj	0.0000e+00 (0.00e+00) =	0.0000e+00 (0.00e+00) =	0.0000e+00 (0.00e+00) =	3.1906e+02 (1.98e-01) -	0.0000e+00 (0.00e+00) =	0.0000e+00 (0.00e+00) =	0.0000e+00 (0.00e+00) =	4.9880e+01 (1.01e+00) +	0.0000e+00 (0.00e+00) =	NaN -	NaN -	0.0000e+00 (0.00e+00)
C17	CV	5.0520e+01 (8.72e-01) =	5.0661e+01 (7.12e-01) =	5.1000e+01 (1.78e-04) -	5.1000e+01 (3.79e-05) -	5.0648e+01 (6.74e-01) -	5.0748e+01 (6.32e-01) -	5.1013e+01 (1.24e+00) -	3.6489e+01 (4.54e-03) -	5.0201e+01 (9.99e-01) =	7.2373e+04 (6.28e+00) -	7.2232e+04 (6.90e-06) =	5.0520e+01 (8.72e-01)
C18	CV	3.6474e+01 (3.80e-03) +	3.6500e+01 (3.61e-03) -	NaN -	3.6486e+01 (1.77e-03) +	3.6510e+01 (3.70e-03) -	3.6498e+01 (1.80e-03) -	NaN -	7.2232e+04 (4.46e-11) =	3.6493e+01 (3.14e-03) -	1.1329e+01 (3.83e-01) -	9.2563e+00 (4.04e-01) -	3.6491e+01 (3.23e-03)
C19	CV	7.2232e+04 (4.46e-11) =	7.2232e+04 (4.46e-11) =	7.2232e+04 (1.07e+04) -	7.2232e+04 (4.46e-11) =	7.2232e+04 (4.46e-11) =	7.2232e+04 (4.46e-11) =	7.2348e+04 (3.30e+00) -	4.5938e+00 (1.38e+00) -	4.9476e+00 (1.26e+00) -	NaN -	6.2654e+01 (1.42e+01) -	7.2232e+04 (4.46e-11)
C20	CV	4.8668e+00 (8.37e-01) =	5.3599e+00 (1.11e+00) =	1.0990e+01 (5.41e+01) -	8.6416e+00 (1.03e+00) -	5.0219e+01 (1.46e+01) -	8.9708e+00 (1.48e+00) -	8.8121e+00 (1.61e+00) -	4.6121e+01 (1.73e+01) -	4.1654e+01 (1.76e+01) -	4.3402e+01 (1.64e+00) -	3.5684e+01 (1.09e+02) -	4.9263e+00 (1.17e+00)
C21	Obj	4.1695e+01 (1.58e+01) =	5.3403e+01 (2.00e+01) -	7.5346e+01 (1.45e+00) -	5.5985e+01 (1.12e+00) -	5.1865e+01 (1.29e+01) -	5.1865e+01 (1.29e+01) -	NaN -	2.9099e+01 (1.02e+00) +	3.3671e+00 (1.00e+00) -	3.5684e+01 (1.09e+02) -	1.5832e+00 (3.11e-02) -	4.3179e+01 (1.93e+01)
C22	Obj	2.6852e+00 (1.52e+00) =	1.2518e+00 (7.39e-01) -	3.3377e+01 (9.60e+01) -	1.0542e+04 (1.41e+04) -	4.8699e+00 (2.83e+00) -	2.3446e+01 (1.61e+01) -	5.1886e+00 (2.49e+00) -	1.2625e+00 (5.85e-02) -	1.2229e+00 (8.39e-02) -	1.5104e+00 (5.02e-02) -	2.3561e+00 (4.90e-05) -	1.8578e+00 (1.42e+00)
C23	Obj	1.1799e+00 (4.32e+02) +	1.5142e+00 (2.06e-01) -	1.2296e+00 (3.66e-02) -	1.5655e+00 (4.54e-02) -	1.6424e+00 (3.07e-02) +	1.5851e+00 (5.28e-02) -	1.5851e+00 (5.28e-02) -	2.3561e+00 (9.06e-16) =	2.3561e+00 (9.06e-16) =	2.4818e+00 (6.28e-01) -	0.0000e+00 (0.00e+00) =	1.2509e+00 (7.97e-02)
C24	Obj	2.3561e+00 (9.06e-16) =	2.3561e+00 (2.00e-05) =	2.3561e+00 (4.76e-05) -	1.9321e+00 (2.22e+00) -	2.6075e+00 (8.70e-01) -	2.7332e+00 (1.38e+00) -	2.7332e+00 (1.38e+00) -	6.2828e-02 (3.14e-01) -	0.0000e+00 (0.00e+00) =	1.5707e+00 (0.00e+00) =	5.1000e+01 (1.73e-04) =	2.3561e+00 (9.06e-16)
C25	Obj	0.0000e+00 (0.00e+00) =	0.0000e+00 (0.00e+00) =	0.0000e+00 (0.00e+00) =	0.0000e+00 (0.00e+00) =	5.1000e+01 (2.19e-04) -	1.2189e+00 (1.30e+00) -	0.0000e+00 (0.00e+00) =	5.1000e+01 (0.00e+00) =	5.1000e+01 (0.00e+00) =	5.1000e+01 (2.99e-04) -	7.2269e+04 (1.23e+02) +	0.0000e+00 (0.00e+00)
C26	CV	5.1000e+01 (0.00e+00) =	5.1001e+01 (7.93e-04) =	5.1000e+01 (1.82e-04) -	5.1000e+01 (5.73e-05) -	4.1895e+01 (5.78e+00) -	5.1000e+01 (1.76e-05) -	5.1000e+01 (6.73e-03) -	3.7094e+01 (2.08e+00) -	3.6528e+01 (1.42e-01) =	7.2511e+04 (1.70e+01) -		5.1000e+01 (0.00e+00)
C27	Obj	3.6967e+01 (2.48e+00) -	3.7457e+01 (2.71e+00) -	NaN -	3.8387e+01 (6.00e+00) -	7.2503e+04 (2.94e+01) -	3.6560e+01 (2.94e-01) =	7.2427e+04 (1.96e+01) -	7.2335e+04 (2.89e+01) -	7.2307e+04 (2.68e+01) -			3.6767e+01 (1.34e+00)
C28	CV	7.2322e+04 (2.32e-01) =	7.2302e+04 (2.51e+01) =	7.2238e+04 (7.11e+00) +	7.2502e+04 (2.00e-01) -		7.2505e+04 (2.88e+01) -						7.2313e+04 (2.84e+01)
+/-/=		3/8/17	0/10/18	1/21/6	5/16/7	2/16/13	3/16/9	1/19/8	2/6/20	0/4/24	0/27/1	3/15/10	Base

TABLE S-VII
AVERAGE OBJECTIVE VALUES (OBJ) OR AVERAGE CONSTRAINT VIOLATIONS (CV) AND STANDARD DEVIATIONS OBTAINED BY THE PROPOSED CCMT WITH DIFFERENT kap SETTINGS ON THE 50-DIMENSIONAL CEC2017 BENCHMARK SUITE.

		$kap = 0$	$kap = 0.1$	$kap = 0.2$	$kap = 0.3$	$kap = 0.5$
C01	Obj	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)
C02	Obj	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)
C03	Obj	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	3.7443e+00 (1.67e+01)	8.0466e+01 (1.60e+01)	4.9921e+03 (1.35e+04)
C04	Obj	3.9971e+01 (2.42e+01)	4.3886e+01 (2.26e+01)	4.1114e+01 (1.56e+01)	6.9115e+01 (2.79e+01)	7.3452e+01 (1.80e+01)
C05	Obj	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	3.9866e-01 (1.23e+00)	1.9933e-01 (8.91e-01)
C06	Obj	3.3333e-05 (5.16e-05)	6.2464e+01 (9.14e+01)	1.5928e+02 (3.19e+02)	4.0916e+02 (3.71e+02)	NaN
C07	Obj	-2.1932e+03 (2.97e+01)	-2.0979e+03 (4.02e+02)	-1.7018e+03 (7.57e+02)	-1.5215e+03 (8.61e+02)	-1.1152e+03 (8.31e+02)
C08	Obj	-6.5000e-05 (8.13e-05)	-3.0000e-05 (8.65e-05)	1.2500e-04 (3.23e-04)	2.6500e-04 (4.17e-04)	5.2500e-04 (3.14e-04)
C09	Obj	-2.0000e-03 (8.90e-19)	-2.0000e-03 (8.90e-19)	-2.0000e-03 (8.90e-19)	-2.0000e-03 (8.90e-19)	-2.0000e-03 (8.90e-19)
C10	Obj	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)
C11	CV	1.5202e+01 (2.99e+01)	4.4576e+00 (6.95e+00)	9.2572e-01 (1.36e+00)	1.0538e+00 (1.59e+00)	7.0225e-01 (2.30e+00)
C12	Obj	9.9762e+00 (5.18e+00)	7.8468e+00 (3.58e+00)	1.0175e+01 (5.26e+00)	7.3032e+00 (2.68e+00)	1.2349e+01 (5.77e+00)
C13	Obj	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)
C14	Obj	1.2526e+00 (1.77e-01)	1.1147e+00 (2.90e-02)	1.1055e+00 (8.62e-03)	1.1064e+00 (8.27e-03)	1.1009e+00 (1.70e-03)
C15	Obj	2.3561e+00 (3.08e-05)	2.3561e+00 (4.56e-16)	2.3561e+00 (4.56e-16)	2.3561e+00 (4.56e-16)	2.3561e+00 (4.56e-16)
C16	Obj	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)
C17	CV	5.0560e+01 (8.20e-01)	5.0400e+01 (9.40e-01)	5.0400e+01 (9.40e-01)	5.0400e+01 (9.40e-01)	5.0000e+01 (1.03e+00)
C18	Obj	3.6502e+01 (5.76e-03)	3.6491e+01 (3.44e-03)	3.6480e+01 (7.49e-03)	3.6474e+01 (6.21e-03)	3.6472e+01 (6.04e-03)
C19	CV	7.2232e+04 (2.99e-11)	7.2232e+04 (2.99e-11)	7.2232e+04 (2.99e-11)	7.2232e+04 (2.99e-11)	7.2232e+04 (2.99e-11)
C20	Obj	5.3807e+00 (8.31e-01)	4.9062e+00 (1.05e+00)	4.3867e+00 (1.26e+00)	4.4830e+00 (1.41e+00)	4.5217e+00 (1.20e+00)
C21	Obj	5.4462e+01 (1.82e+01)	4.1931e+01 (1.93e+01)	4.6153e+01 (1.58e+01)	3.1923e+01 (1.67e+01)	3.9518e+01 (1.70e+01)
C22	Obj	1.4381e+00 (7.16e-01)	1.5504e+00 (9.02e-01)	2.1210e+00 (1.48e+00)	2.2410e+00 (1.48e+00)	3.3548e+00 (2.05e+00)
C23	Obj	1.3830e+00 (2.12e-01)	1.2549e+00 (8.21e-02)	1.2251e+00 (6.30e-02)	1.2330e+00 (4.54e-02)	1.2201e+00 (2.82e-02)
C24	Obj	2.3561e+00 (4.56e-16)	2.3561e+00 (4.56e-16)	2.3561e+00 (4.56e-16)	2.3561e+00 (4.56e-16)	2.3561e+00 (4.56e-16)
C25	Obj	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)
C26	CV	5.1001e+01 (6.41e-04)	5.1000e+01 (0.00e+00)	5.1000e+01 (0.00e+00)	5.1000e+01 (0.00e+00)	5.1000e+01 (0.00e+00)
C27	Obj	3.8820e+01 (5.50e+00)	3.6833e+01 (1.50e+00)	3.8264e+01 (5.53e+00)	3.6470e+01 (5.23e-04)	3.6470e+01 (1.57e-03)
C28	CV	7.2305e+04 (3.38e+01)	7.2309e+04 (2.32e+01)	7.2327e+04 (2.14e+01)	7.2360e+04 (2.51e+01)	7.2385e+04 (3.35e+01)

TABLE S-VIII
AVERAGE OBJECTIVE VALUES (OBJ) OR AVERAGE CONSTRAINT VIOLATIONS (CV) AND STANDARD DEVIATIONS OBTAINED BY THE PROPOSED CCMT WITH DIFFERENT α SETTINGS ON THE 50-DIMENSIONAL CEC2017 BENCHMARK SUITE.

		$\alpha = 0$	$\alpha = 0.25$	$\alpha = 0.5$	$\alpha = 0.75$	$\alpha = 1$
C01	Obj	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)
C02	Obj	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)
C03	Obj	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	7.1232e+01 (3.37e+01)
C04	Obj	4.1573e+01 (3.05e+01)	3.6564e+01 (2.21e+01)	4.3886e+01 (2.26e+01)	4.9338e+01 (2.64e+01)	5.7337e+01 (2.43e+01)
C05	Obj	1.9933e-01 (8.91e-01)	1.9933e-01 (8.91e-01)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)
C06	Obj	3.2358e+02 (3.63e+02)	4.0583e+02 (3.63e+02)	6.2464e+01 (9.14e+01)	4.3378e+02 (4.31e+02)	3.5164e+02 (4.97e+02)
C07	Obj	-1.8237e+03 (7.59e+02)	-1.7789e+03 (7.71e+02)	-2.0979e+03 (4.02e+02)	-2.0104e+03 (5.68e+02)	-1.4158e+03 (9.14e+02)
C08	Obj	7.2105e-04 (1.02e-03)	2.8947e-04 (6.07e-04)	-3.0000e-05 (8.65e-05)	-1.0000e-04 (1.39e-20)	-1.0000e-04 (1.39e-20)
C09	Obj	-2.0000e-03 (8.90e-19)	-2.0000e-03 (8.90e-19)	-2.0000e-03 (8.90e-19)	-2.0000e-03 (8.90e-19)	-2.0000e-03 (8.90e-19)
C10	Obj	0.0000e+00 (0.00e+00)	2.0000e-05 (6.16e-05)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)
C11	CV	7.6843e+01 (4.84e+01)	3.0411e+01 (2.63e+01)	4.4576e+00 (6.95e+00)	1.6500e-01 (5.00e-01)	6.6790e-09 (2.86e-08)
C12	Obj	8.9428e+00 (4.71e+00)	7.4576e+00 (2.56e+00)	7.8468e+00 (3.58e+00)	9.4986e+00 (7.58e+00)	7.8467e+00 (3.58e+00)
C13	Obj	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)
C14	Obj	1.1050e+00 (6.81e-03)	1.1098e+00 (1.22e-02)	1.1147e+00 (2.90e-02)	1.1132e+00 (2.96e-02)	1.1513e+00 (4.29e-02)
C15	Obj	2.3561e+00 (4.56e-16)	2.3561e+00 (4.56e-16)	2.3561e+00 (4.56e-16)	2.3561e+00 (4.56e-16)	2.3561e+00 (4.56e-16)
C16	Obj	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)
C17	CV	5.0500e+01 (8.89e-01)	5.0700e+01 (7.33e-01)	5.0400e+01 (9.40e-01)	5.0500e+01 (8.89e-01)	5.0800e+01 (6.16e-01)
C18	Obj	3.6498e+01 (3.08e-03)	3.6495e+01 (3.03e-03)	3.6491e+01 (3.44e-03)	3.6490e+01 (4.19e-03)	3.6471e+01 (2.54e-03)
C19	CV	7.2232e+04 (2.99e-11)	7.2232e+04 (2.99e-11)	7.2232e+04 (2.99e-11)	7.2232e+04 (2.99e-11)	7.2232e+04 (2.99e-11)
C20	Obj	4.7009e+00 (1.19e+00)	4.9198e+00 (1.11e+00)	4.9062e+00 (1.05e+00)	5.2838e+00 (6.90e-01)	4.8404e+00 (1.07e+00)
C21	Obj	4.2487e+01 (1.84e+01)	4.1189e+01 (1.79e+01)	4.1931e+01 (1.93e+01)	4.3941e+01 (1.65e+01)	3.9844e+01 (1.93e+01)
C22	Obj	1.5966e+00 (1.01e+00)	1.3740e+00 (8.12e-01)	1.5504e+00 (9.02e-01)	1.9019e+00 (9.71e-01)	7.2324e+00 (3.48e+00)
C23	Obj	1.3436e+00 (1.22e-01)	1.3176e+00 (1.09e-01)	1.2549e+00 (8.21e-02)	1.2080e+00 (8.81e-02)	1.1439e+00 (3.20e-02)
C24	Obj	2.3561e+00 (4.56e-16)	2.3561e+00 (4.56e-16)	2.3561e+00 (4.56e-16)	2.3561e+00 (4.56e-16)	2.3561e+00 (4.56e-16)
C25	Obj	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)
C26	CV	5.1000e+01 (0.00e+00)	5.1000e+01 (0.00e+00)	5.1000e+01 (0.00e+00)	5.1000e+01 (0.00e+00)	5.1000e+01 (0.00e+00)
C27	Obj	3.6504e+01 (4.05e-03)	3.6502e+01 (3.60e-03)	3.6833e+01 (1.50e+00)	3.7037e+01 (2.42e+00)	3.6507e+01 (1.67e-01)
C28	CV	7.2314e+04 (2.61e+01)	7.2318e+04 (2.52e+01)	7.2309e+04 (2.32e+01)	7.2317e+04 (2.03e+01)	7.2321e+04 (3.21e+01)

TABLE S-IX
AVERAGE OBJECTIVE VALUES (OBJ) OR AVERAGE CONSTRAINT VIOLATIONS (CV) AND STANDARD DEVIATIONS OBTAINED BY THE PROPOSED CCMT WITH DIFFERENT β SETTINGS ON THE 50-DIMENSIONAL CEC2017 BENCHMARK SUITE.

		$\beta = 0$	$\beta = 0.1$	$\beta = 0.2$	$\beta = 0.3$	$\beta = 0.5$
C01	Obj	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)
C02	Obj	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)
C03	Obj	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	3.7344e+00 (1.67e+01)
C04	Obj	3.6493e+01 (3.30e+01)	4.3886e+01 (2.26e+01)	5.6118e+01 (1.96e+01)	5.4788e+01 (1.55e+01)	4.7581e+01 (1.72e+01)
C05	Obj	1.9933e-01 (8.91e-01)	0.0000e+00 (0.00e+00)	1.9933e-01 (8.91e-01)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)
C06	Obj	2.0494e+02 (2.84e+02)	6.2464e+01 (9.14e+01)	3.1244e+02 (5.41e+02)	5.4183e+02 (3.57e+02)	2.3722e+02 (2.97e+02)
C07	Obj	-2.0101e+03 (4.46e+02)	-2.0979e+03 (4.02e+02)	-1.9399e+03 (6.74e+02)	-2.2032e+03 (4.11e+01)	-1.8581e+03 (7.37e+02)
C08	Obj	1.7000e-04 (5.05e-04)	-3.0000e-05 (8.65e-05)	-4.0000e-05 (1.67e-04)	-9.0000e-05 (3.08e-05)	-7.0000e-05 (4.70e-05)
C09	Obj	-2.0000e-03 (8.90e-19)	-2.0000e-03 (8.90e-19)	-2.0000e-03 (8.90e-19)	-2.0000e-03 (8.90e-19)	-2.0000e-03 (8.90e-19)
C10	Obj	5.0000e-06 (2.24e-05)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)
C11	CV	6.3759e+00 (8.21e+00)	4.4576e+00 (6.95e+00)	2.3243e+00 (3.40e+00)	1.5463e+00 (2.16e+00)	2.7415e+00 (5.11e+00)
C12	Obj	9.2425e+00 (4.46e+00)	7.8468e+00 (3.58e+00)	9.7573e+00 (5.21e+00)	1.0256e+00 (5.90e+00)	9.0593e+00 (4.99e+00)
C13	Obj	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)
C14	Obj	1.1081e+00 (9.35e-03)	1.1147e+00 (2.90e-02)	1.1149e+00 (2.08e-02)	1.1117e+00 (1.50e-02)	1.1201e+00 (2.92e-02)
C15	Obj	2.3561e+00 (4.56e-16)	2.3561e+00 (4.56e-16)	2.3561e+00 (4.56e-16)	2.3561e+00 (4.56e-16)	2.3561e+00 (4.56e-16)
C16	Obj	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)
C17	CV	5.0100e+01 (1.02e+00)	5.0400e+01 (9.40e-01)	5.0200e+01 (1.01e+00)	5.0300e+01 (9.79e-01)	5.0400e+01 (9.40e-01)
C18	Obj	3.6491e+01 (3.33e-03)	3.6491e+01 (3.44e-03)	3.6492e+01 (3.42e-03)	3.6491e+01 (3.00e-03)	3.6488e+01 (5.96e-03)
C19	CV	7.2232e+04 (2.99e-11)	7.2232e+04 (2.99e-11)	7.2232e+04 (2.99e-11)	7.2232e+04 (2.99e-11)	7.2232e+04 (2.99e-11)
C20	Obj	5.1849e+00 (7.59e-01)	4.9062e+00 (1.05e+00)	4.8611e+00 (1.09e+00)	5.0595e+00 (9.37e-01)	4.3822e+00 (9.37e-01)
C21	Obj	4.8729e+01 (1.61e+01)	4.1931e+01 (1.93e+01)	4.8365e+01 (1.47e+01)	4.4500e+01 (1.39e+01)	3.7143e+01 (1.78e+01)
C22	Obj	1.4870e+00 (6.89e-01)	1.5504e+00 (9.02e-01)	2.0295e+00 (8.62e-01)	3.4851e+00 (2.28e+00)	2.5362e+00 (1.25e+00)
C23	Obj	1.2415e+00 (1.07e-01)	1.2549e+00 (8.21e-02)	1.2272e+00 (9.05e-02)	1.2833e+00 (8.23e-02)	1.2659e+00 (1.09e-01)
C24	Obj	2.3561e+00 (4.56e-16)	2.3561e+00 (4.56e-16)	2.3561e+00 (4.56e-16)	2.3561e+00 (4.56e-16)	2.3561e+00 (4.56e-16)
C25	Obj	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)
C26	CV	5.1000e+01 (0.00e+00)	5.1000e+01 (0.00e+00)	5.1000e+01 (0.00e+00)	5.1000e+01 (0.00e+00)	5.1000e+01 (0.00e+00)
C27	Obj	3.6499e+01 (2.14e-03)	3.6833e+01 (1.50e+00)	3.6500e+01 (1.68e-03)	3.6498e+01 (2.83e-03)	3.6497e+01 (4.91e-03)
C28	CV	7.2284e+04 (1.71e+01)	7.2309e+04 (2.32e+01)	7.2322e+04 (2.99e+01)	7.2324e+04 (1.59e+01)	7.2318e+04 (2.10e+01)

TABLE S-X

Average objective values (Obj) or average constraint violations (CV) and standard deviations obtained by the proposed CCMT with different p_{min} settings on the 50-dimensional CEC2017 benchmark suite.

		$p_{min}=0$	$p_{min}=0.1$	$p_{min}=0.2$	$p_{min}=0.3$	$p_{min}=0.5$
C01	Obj	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)
C02	Obj	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)
C03	Obj	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	3.7770e+00 (1.69e+01)
C04	Obj	4.0320e+01 (2.52e+01)	4.3886e+01 (2.26e+01)	4.3613e+01 (2.42e+01)	3.9726e+01 (1.54e+01)	5.0765e+01 (2.22e+01)
C05	Obj	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	1.9933e-01 (8.91e-01)	1.9933e-01 (8.91e-01)
C06	Obj	1.7115e+02 (3.24e+02)	6.2464e+01 (9.14e+01)	2.4531e+02 (2.09e+02)	1.1795e+02 (2.31e+02)	2.5538e+02 (3.00e+02)
C07	Obj	-2.0699e+03 (4.79e+02)	-2.0979e+03 (4.02e+02)	-2.1315e+03 (2.83e+02)	-1.9545e+03 (5.25e+02)	-1.8554e+03 (7.50e+02)
C08	Obj	8.5000e-05 (2.94e-04)	-3.0000e-05 (8.65e-05)	-8.0000e-05 (5.23e-05)	-4.5000e-05 (1.32e-04)	-8.5000e-05 (3.66e-05)
C09	Obj	-2.0000e-03 (8.90e-19)	-2.0000e-03 (8.90e-19)	-2.0000e-03 (8.90e-19)	-2.0000e-03 (8.90e-19)	-2.0000e-03 (8.90e-19)
C10	Obj	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)
C11	CV	5.7501e+00 (7.22e+00)	4.4576e+00 (6.95e+00)	2.2280e+00 (5.02e+00)	1.4265e+00 (2.45e+00)	3.9658e+00 (5.71e+00)
C12	Obj	9.2425e+00 (4.46e+00)	7.8468e+00 (3.58e+00)	9.2640e+00 (5.00e+00)	8.7507e+00 (5.21e+00)	9.4773e+00 (5.10e+00)
C13	Obj	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)
C14	Obj	1.1153e+00 (2.81e-02)	1.1147e+00 (2.90e-02)	1.1160e+00 (1.88e-02)	1.1104e+00 (1.02e-02)	1.1141e+00 (2.26e-02)
C15	Obj	2.3561e+00 (4.56e-16)	2.3561e+00 (4.56e-16)	2.3561e+00 (4.56e-16)	2.3561e+00 (4.56e-16)	2.3561e+00 (4.56e-16)
C16	Obj	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)
C17	CV	5.0700e+01 (7.33e-01)	5.0400e+01 (9.40e-01)	5.0100e+01 (1.02e+00)	5.0400e+01 (9.40e-01)	5.0300e+01 (9.79e-01)
C18	Obj	3.6496e+01 (2.63e-03)	3.6491e+01 (3.44e-03)	3.6491e+01 (2.56e-03)	3.6486e+01 (3.74e-03)	3.6483e+01 (3.54e-03)
C19	CV	7.2232e+04 (2.56e-11)	7.2232e+04 (2.99e-11)	7.2232e+04 (2.99e-11)	7.2232e+04 (2.99e-11)	7.2232e+04 (2.99e-11)
C20	Obj	4.8600e+00 (9.09e-01)	4.9062e+00 (1.05e+00)	5.1478e+00 (1.12e+00)	4.3579e+00 (1.19e+00)	4.4094e+00 (1.15e+00)
C21	Obj	4.0442e+01 (1.63e+01)	4.1931e+01 (1.93e+01)	3.8230e+01 (1.62e+01)	4.5229e+01 (1.69e+01)	5.4439e+01 (1.21e+01)
C22	Obj	1.6542e+00 (9.09e-01)	1.5504e+00 (9.02e-01)	1.7719e+00 (9.77e-01)	2.1636e+00 (1.38e+00)	1.9169e+00 (7.84e-01)
C23	Obj	1.2384e+00 (1.00e-01)	1.2549e+00 (8.21e-02)	1.2464e+00 (8.44e-02)	1.2151e+00 (8.48e-02)	1.2133e+00 (5.23e-02)
C24	Obj	2.3561e+00 (4.56e-16)	2.3561e+00 (4.56e-16)	2.3561e+00 (4.56e-16)	2.3561e+00 (4.56e-16)	2.3561e+00 (4.56e-16)
C25	Obj	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)
C26	CV	5.1000e+01 (0.00e+00)	5.1000e+01 (0.00e+00)	5.1000e+01 (0.00e+00)	5.1000e+01 (0.00e+00)	5.1000e+01 (0.00e+00)
C27	Obj	3.6937e+01 (1.53e+00)	3.6833e+01 (1.50e+00)	3.6495e+01 (4.17e-03)	3.7116e+01 (2.79e+00)	3.6488e+01 (7.63e-03)
C28	CV	7.2300e+04 (1.86e+01)	7.2309e+04 (2.32e+01)	7.2312e+04 (2.83e+01)	7.2324e+04 (2.96e+01)	7.2318e+04 (2.73e+01)

TABLE S-XI

Average objective values (Obj) or average constraint violations (CV) and standard deviations obtained by the proposed CCMT with different RH settings on the 50-dimensional CEC2017 benchmark suite.

		$RH=1$	$RH=5$	$RH=10$	$RH=100$	$RH=1000$
C01	Obj	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)
C02	Obj	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)
C03	Obj	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)
C04	Obj	3.0894e+01 (2.13e+01)	3.0488e+01 (1.70e+01)	4.3886e+01 (2.26e+01)	4.9861e+01 (2.21e+01)	3.7808e+01 (2.27e+01)
C05	Obj	1.9933e-01 (8.91e-01)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	1.9933e-01 (8.91e-01)	0.0000e+00 (0.00e+00)
C06	Obj	2.0677e+02 (2.69e+02)	4.8283e+02 (3.93e+02)	6.2464e+01 (9.14e+01)	7.0961e+02 (2.48e+02)	2.6158e+02 (3.00e+02)
C07	Obj	-2.1306e+03 (3.67e+02)	-1.9993e+03 (7.27e+02)	-2.0979e+03 (4.02e+02)	-1.8282e+03 (7.63e+02)	-1.2388e+03 (8.60e+02)
C08	Obj	4.8333e-04 (3.67e-04)	7.5000e-05 (1.65e-04)	-3.0000e-05 (8.65e-05)	-5.5000e-05 (8.26e-05)	-2.5000e-05 (1.59e-04)
C09	Obj	-2.0000e-03 (8.90e-19)	-2.0000e-03 (8.90e-19)	-2.0000e-03 (8.90e-19)	-2.0000e-03 (8.90e-19)	-2.0000e-03 (8.90e-19)
C10	Obj	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)
C11	CV	4.6056e+01 (3.76e+01)	6.0103e+00 (6.51e+00)	4.4576e+00 (6.95e+00)	7.9600e-01 (1.18e+00)	4.9408e+00 (7.80e+00)
C12	Obj	8.9721e+00 (4.79e+00)	1.0738e+01 (5.91e+00)	7.8468e+00 (3.58e+00)	9.4773e+00 (5.10e+00)	9.3405e+00 (5.25e+00)
C13	Obj	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)
C14	Obj	1.1120e+00 (1.87e-02)	1.1188e+00 (3.38e-02)	1.1147e+00 (2.90e-02)	1.1094e+00 (1.03e-02)	1.1196e+00 (2.50e-02)
C15	Obj	2.3561e+00 (4.56e-16)	2.3561e+00 (4.56e-16)	2.3561e+00 (4.56e-16)	2.3561e+00 (4.56e-16)	2.3561e+00 (4.56e-16)
C16	Obj	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)
C17	CV	4.9900e+01 (1.02e+00)	5.0100e+01 (1.02e+00)	5.0400e+01 (9.40e-01)	5.0100e+01 (1.02e+00)	5.0700e+01 (7.33e-01)
C18	Obj	3.6498e+01 (4.15e-03)	3.6495e+01 (3.07e-03)	3.6491e+01 (3.44e-03)	3.6486e+01 (2.80e-03)	3.6479e+01 (4.54e-03)
C19	CV	7.2232e+04 (2.99e-11)	7.2232e+04 (2.99e-11)	7.2232e+04 (2.99e-11)	7.2232e+04 (2.99e-11)	7.2232e+04 (6.03e-03)
C20	Obj	4.9533e+00 (9.80e-01)	4.6367e+00 (1.17e+00)	4.9062e+00 (1.05e+00)	5.0273e+00 (1.33e+00)	5.2825e+00 (8.14e-01)
C21	Obj	4.0952e+01 (1.63e+01)	4.6520e+01 (1.72e+01)	4.1931e+01 (1.93e+01)	3.7508e+01 (1.93e+01)	4.1730e+01 (1.69e+01)
C22	Obj	1.6375e+00 (6.03e-01)	2.2927e+00 (1.97e+00)	1.5504e+00 (9.02e-01)	2.1075e+00 (6.95e-01)	1.9329e+00 (1.44e+00)
C23	Obj	1.3325e+00 (9.18e-02)	1.2510e+00 (8.55e-02)	1.2549e+00 (8.21e-02)	1.2513e+00 (8.03e-02)	1.1999e+00 (5.78e-02)
C24	Obj	2.3561e+00 (4.56e-16)	2.3561e+00 (4.56e-16)	2.3561e+00 (4.56e-16)	2.3561e+00 (4.56e-16)	2.3561e+00 (4.56e-16)
C25	Obj	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)
C26	CV	5.1000e+01 (0.00e+00)	5.1000e+01 (0.00e+00)	5.1000e+01 (0.00e+00)	5.1000e+01 (0.00e+00)	5.1000e+01 (0.00e+00)
C27	Obj	3.6504e+01 (3.93e-03)	3.6500e+01 (2.49e-03)	3.6833e+01 (1.50e+00)	3.6495e+01 (2.78e-03)	3.6680e+01 (8.94e-01)
C28	CV	7.2304e+04 (3.57e+01)	7.2314e+04 (2.99e+01)	7.2309e+04 (2.32e+01)	7.2316e+04 (2.43e+01)	7.2297e+04 (2.55e+01)

TABLE S-XII

DETAILS OF THE 33 REAL-WORLD COPs.

	Name	D	g	h
	Industrial chemical processes			
RC01	Heat exchanger network design (case 1)	9	0	8
RC02	Heat exchanger network design (case 2)	11	0	9
RC03	Optimal operation of Alkylation unit	7	14	0
RC04	Reactor network design (RND)	6	1	4
RC05	Haverly's pooling problem	9	2	4
RC06	Blending-pooling-separation problem	38	0	32
RC07	Propane, isobutane, n-Butane non-sharp separation	48	0	38
	Process synthesis and design problems			
RC08	Process synthesis problem	2	2	0
RC09	Process synthesis and design problem	3	1	1
RC10	Process flow sheeting problem	3	3	0
RC11	Two-reactor problem	7	4	4
RC12	Process synthesis problem	7	9	0
RC13	Process design problem	5	3	0
RC14	Multi-product batch plant	10	10	0
	Mechanical engineering problem			
RC15	Weight minimization of a speed reducer	7	11	0
RC16	Optimal design of industrial refrigeration system	14	15	0
RC17	Tension/compression spring design (case 1)	3	3	0
RC18	Pressure vessel design	4	4	0
RC19	Welded beam design	4	5	0
RC20	Three-bar truss design problem	2	3	0
RC21	Multiple disk clutch brake design problem	5	7	0
RC22	Planetary gear train design optimization problem	9	10	1
RC23	Step-cone pulley problem	5	8	3
RC24	Robot gripper problem	7	7	0
RC25	Hydro-static thrust bearing design problem	4	7	0
RC26	Four-stage gearbox problem	22	86	0
RC27	10-bar truss design	10	3	0
RC28	Rolling element bearing	10	9	0
RC29	Gas transmission compressor design (GTCD)	4	1	0
RC30	Tension/compression spring design (case 2)	3	8	0
RC31	Gear train design Problem	4	1	1
RC32	Himmelblau's function	5	6	0
RC33	Topology optimization	30	30	0

TABLE S-XIII

AVERAGE OBJECTIVE VALUES (OBJ) OR AVERAGE CONSTRAINT VIOLATIONS (CV) AND STANDARD DEVIATIONS OBTAINED BY THE SELECTED ADVANCED COEAs AND THE PROPOSED CCMT ON THREE TYPES OF REAL-WORLD COPs.

		ECHT	VMCH	FROFI	C²oDE	CORCO	DeCODE	CAL-SHADE	LSHADE44	CCMT
RC01	Obj	NaN -	3.8663e+02 (1.03e+02) -	NaN -	NaN -	NaN -	4.3213e+02 (1.34e+02) -	2.3861e+02 (9.77e+00) +	4.1064e+02 (1.01e+02) -	2.7506e+02 (6.73e+01)
RC02	Obj	7.0490e+03 (0.00e+00) =	7.0490e+03 (0.00e+00) =	NaN -	7.0490e+03 (0.00e+00) =	7.0490e+03 (0.00e+00) =	NaN -	4.7059e+04 (6.53e+00) =	7.9190e+03 (1.67e+03) -	7.0490e+03 (0.00e+00)
RC03	Obj	-4.5291e+03 (1.86e-12) =	-4.5291e+03 (1.86e-12) =	NaN -	-4.3174e+03 (1.09e+02) -	NaN -	-4.5291e+03 (1.86e-12) =	3.7252e+02 (8.68e+02) -	-4.1715e+03 (2.56e+02) -	-4.5291e+03 (1.86e-12)
RC04	Obj	-2.8829e-01 (9.66e-02) =	-3.0352e-02 (1.05e-01) -	0.0000e+00 (0.00e+00) -	-1.7060e-01 (1.88e-01) -	NaN -	0.0000e+00 (0.00e+00) -	-2.6939e-01 (8.29e-02) -	-1.8080e-03 (4.52e-03) -	-3.1112e-01 (1.18e-01)
RC05	Obj	7.9973e+00 (2.77e+01) -	3.2000e+01 (4.76e+01) -	6.6667e+01 (5.77e+01) -	-4.8680e-03 (1.67e-03) -	NaN -	-2.7634e+02 (1.70e+02) +	8.6850e+01 (2.01e+02) -	1.5991e+01 (3.74e+01) -	-7.2001e+01 (1.49e+02)
RC06	CV	7.8136e+00 (4.42e+00) -	2.3729e+00 (8.45e-01) -	7.5551e+01 (6.27e+00) -	4.0410e+00 (3.79e+00) +	7.7233e+01 (5.50e-01) -	2.0046e+01 (1.80e+01) -	1.0162e+01 (4.48e+00) -	2.2276e+00 (7.05e-01) -	7.6541e+00 (1.56e+01)
RC07	CV	4.2019e+01 (2.31e+01) -	2.3361e+01 (6.04e-01) -	4.5376e+01 (1.87e+01) -	2.1683e+01 (1.87e+01) -	8.2825e+01 (3.49e+01) -	3.3137e+01 (3.34e+01) -	1.5201e+01 (4.29e+00) -	2.7959e+00 (3.17e+00) -	9.6381e+00 (1.47e+01)
RC08	Obj	2.0000e+00 (0.00e+00) =	2.0000e+00 (0.00e+00) =	2.0006e+00 (6.63e-04) -	2.0006e+00 (6.63e-04) -	2.0226e+00 (3.26e-02) -	2.0000e+00 (0.00e+00) =	2.0000e+00 (0.00e+00) =	2.0000e+00 (0.00e+00) =	2.0000e+00 (0.00e+00)
RC09	Obj	2.5577e+00 (1.36e-15) =	2.5577e+00 (1.36e-15) =	2.7990e+00 (1.32e-01) -	2.5579e+00 (1.17e-04) -	NaN -	2.5577e+00 (1.36e-15) =	2.5864e+00 (4.82e-02) -	2.5976e+00 (3.67e-02) -	2.5577e+00 (1.36e-15)
RC10	Obj	1.0765e+00 (4.53e-16) =	1.1009e+00 (5.90e-02) -	1.1036e+00 (1.44e-02) -	1.0768e+00 (2.75e-04) -	1.0765e+00 (4.53e-16) =	1.0765e+00 (4.53e-16) =	1.1765e+00 (6.01e-02) -	1.1185e+00 (6.33e-02) -	1.0765e+00 (4.53e-16)
RC11	Obj	1.1373e+02 (6.59e+00) -	1.0448e+02 (4.09e+00) =	NaN -	1.6702e+00 (2.77e-05) =	3.4740e+00 (6.48e-01) -	1.6702e+00 (6.80e-16) =	NaN -	1.1257e+02 (7.70e+00) -	1.1052e+02 (4.39e+00)
RC12	Obj	2.9248e+00 (4.53e-16) =	3.0414e+00 (3.22e-01) =	2.9791e+00 (3.44e-02) -	2.9248e+00 (2.77e-05) =	3.5289e+00 (7.46e-01) -	6.7634e+00 (1.92e+00) -	4.1742e+00 (5.07e-01) -	3.8020e+00 (4.64e-01) -	2.9248e+00 (4.53e-16)
RC13	Obj	2.6887e+04 (0.00e+00) =	2.6887e+04 (0.00e+00) =	2.6892e+04 (3.91e+00) -	2.6888e+04 (2.12e+00) -	2.8532e+04 (9.48e+02) -	2.6887e+04 (0.00e+00) =	2.6918e+04 (3.18e+01) -	2.6915e+04 (4.41e+01) -	2.6887e+04 (0.00e+00)
RC14	Obj	5.5369e+04 (0.00e+00) =	5.4498e+04 (2.01e+03) -	6.5640e+04 (4.72e+03) -	5.6884e+04 (1.19e+03) -	1.4935e+05 (2.88e+04) -	6.0126e+04 (4.56e+03) -	7.6855e+04 (5.79e+03) -	7.6347e+04 (1.36e+04) -	5.3639e+04 (0.00e+00)
RC15	Obj	2.9944e+03 (0.00e+00) =	2.9944e+03 (0.00e+00) =	3.0128e+03 (5.28e+00) -	2.9954e+03 (9.48e-01) -	3.5651e+03 (3.18e+02) -	2.9944e+03 (0.00e+00) =	3.0409e+03 (1.90e+01) -	3.0409e+03 (2.57e+01) -	2.9944e+03 (0.00e+00)
RC16	Obj	5.3260e-02 (4.91e-02) +	3.2200e-02 (0.00e+00) +	5.9724e-02 (6.22e-03) +	3.7113e-02 (2.15e-02) =	9.8503e+02 (1.65e+03) -	5.7067e-01 (2.69e+00) -	1.1552e+02 (1.62e+02) -	1.9498e+02 (5.94e+02) -	1.1650e-01 (3.77e-01)
RC17	Obj	1.2700e-02 (5.31e-18) =	1.2700e-02 (5.31e-18) =	1.2960e-02 (1.89e-04) -	1.2728e-02 (2.75e-04) -	1.2700e-02 (2.75e-02) -	1.2700e-02 (5.31e-18) =	1.3480e-02 (6.01e-04) -	1.2828e-02 (1.77e-04) -	1.2700e-02 (5.31e-18)
RC18	Obj	6.0597e+03 (0.00e+00) =	6.0634e+03 (1.02e+01) -	6.3011e+03 (1.66e+02) -	6.0597e+03 (0.00e+00) =	1.5659e+04 (3.91e+03) -	6.0597e+03 (0.00e+00) =	6.0882e+03 (6.09e+01) -	6.1771e+03 (1.86e+02) -	6.0597e+03 (0.00e+00)
RC19	Obj	1.6702e+00 (6.80e-16) =	1.6702e+00 (6.80e-16) =	1.7543e+00 (2.21e-02) -	1.6702e+00 (2.77e-05) =	3.4740e+00 (6.48e-01) -	1.6702e+00 (6.80e-16) =	1.6702e+00 (6.80e-16) =	1.6702e+00 (6.80e-16) =	1.6702e+00 (6.80e-16)
RC20	Obj	2.6390e+02 (1.16e-13) =	2.6390e+02 (1.16e-13) =	2.6407e+02 (1.49e-01) -	2.6390e+02 (1.16e-13) =	2.6863e+02 (4.21e+00) -	2.6390e+02 (1.16e-13) =	2.6391e+02 (3.34e-02) -	2.6390e+02 (1.16e-13) =	2.6390e+02 (1.16e-13)
RC21	Obj	2.3520e-01 (5.67e-17) =	2.3520e-01 (5.67e-17) =	2.3542e-01 (1.80e-04) -	2.3520e-01 (5.67e-17) =	2.4827e-01 (8.95e-03) -	2.3520e-01 (5.67e-17) =	2.3520e-01 (5.67e-17) =	2.3520e-01 (5.67e-17) =	2.3520e-01 (5.67e-17)
RC22	Obj	5.2648e-01 (1.21e-03) -	5.2833e-01 (3.73e-03) -	5.2602e-01 (3.23e-04) -	5.2882e-01 (3.00e-03) -	5.2790e-01 (3.98e-03) -	5.2630e-01 (5.77e-04) -	5.3519e-01 (6.27e-03) -	5.4740e-01 (1.88e-02) -	5.2645e-01 (1.10e-03)
RC23	Obj	1.6070e+01 (3.63e-15) =	1.6070e+01 (3.63e-15) =	1.6084e+01 (4.50e-03) -	1.6070e+01 (3.70e-15) =	1.6070e+01 (3.63e-15) =	1.6070e+01 (3.63e-15) =	1.6423e+01 (3.84e-01) -	1.6412e+01 (2.86e-01) -	1.6070e+01 (3.63e-15)
RC24	Obj	2.5447e+00 (6.87e-04) -	2.5438e+00 (9.06e-16) =	2.5486e+00 (2.04e-03) -	2.6423e+00 (1.26e-01) -	3.2954e+00 (1.16e+02) -	2.5438e+00 (9.06e-16) =	3.4616e+00 (4.79e-01) -	4.9222e+00 (6.20e-01) -	2.5438e+00 (9.06e-16)
RC25	Obj	1.6163e+03 (4.50e-01) -	1.6161e+03 (4.64e-13) =	4.8244e+03 (1.52e+03) -	2.4411e+03 (1.96e+02) -	4.3537e+03 (1.53e+03) -	1.9855e+03 (6.13e+02) -	2.8212e+03 (5.14e+02) -	4.0013e+03 (6.59e+02) -	1.6161e+03 (4.64e-13)
RC26	Obj	NaN -	4.9540e+01 (1.66e+01) -	NaN -	6.5327e+01 (4.45e-02) -	NaN -	3.8712e+01 (1.97e+00) -	4.3750e+01 (5.66e+00) -	5.1671e+01 (7.99e+00) -	3.6893e+01 (6.82e-01)
RC27	Obj	5.2478e+02 (7.51e-02) -	5.2445e+02 (2.32e-13) =	5.4606e+02 (4.42e+00) -	5.2749e+02 (1.42e+00) -	7.1846e+02 (5.38e+01) -	5.2445e+02 (2.32e-13) =	5.5424e+02 (1.08e+01) -	5.2615e+02 (2.54e+00) -	5.2445e+02 (2.32e-13)
RC28	Obj	1.6958e+04 (0.00e+00) =	1.6958e+04 (0.00e+00) =	1.7100e+04 (5.38e+01) -	1.6970e+04 (6.14e+00) -	2.6236e+04 (6.50e+03) -	1.6958e+04 (0.00e+00) =	1.7374e+04 (3.65e+02) -	1.7192e+04 (2.08e+02) -	1.6958e+04 (0.00e+00)
RC29	Obj	2.9649e+06 (0.00e+00) =	2.9649e+06 (0.00e+00) =	3.1097e+06 (6.53e+04) -	2.9649e+06 (0.00e+00) =	3.8812e+06 (4.54e+05) -	2.9649e+06 (0.00e+00) =	2.9649e+06 (0.00e+00) =	2.9649e+06 (0.00e+00) =	2.9649e+06 (0.00e+00)
RC30	Obj	2.6586e+00 (0.00e+00) =	2.6602e+00 (8.18e-03) -	3.1734e+00 (2.46e-01) -	2.6617e+00 (3.22e-03) -	7.7079e+00 (5.83e+00) -	2.6586e+00 (4.53e-16) =	2.9478e+00 (2.73e-01) -	2.6766e+00 (2.03e-02) -	2.6586e+00 (4.53e-16)
RC31	Obj	0.0000e+00 (0.00e+00) =	0.0000e+00 (0.00e+00) =	0.0000e+00 (0.00e+00) =	0.0000e+00 (0.00e+00) =	0.0000e+00 (0.00e+00) =	0.0000e+00 (0.00e+00) =	0.0000e+00 (0.00e+00) =	0.0000e+00 (0.00e+00) =	0.0000e+00 (0.00e+00)
RC32	Obj	-3.0666e+04 (0.00e+00) =	-3.0666e+04 (0.00e+00) =	-3.0628e+04 (1.49e+01) -	-3.0666e+04 (0.00e+00) =	-2.9916e+04 (2.74e+02) -	-3.0666e+04 (0.00e+00) =	-3.0666e+04 (0.00e+00) =	-3.0666e+04 (0.00e+00) =	-3.0666e+04 (0.00e+00)
RC33	Obj	2.6393e+00 (4.53e-16) =	2.6393e+00 (4.53e-16) =	2.6393e+00 (4.53e-16) =	2.6393e+00 (4.53e-16) =	2.6393e+00 (4.53e-16) =	2.6393e+00 (4.53e-16) =	2.6393e+00 (4.53e-16) =	2.6393e+00 (4.53e-16) =	2.6393e+00 (4.53e-16)
+/-/=		1/8/24	1/7/25	1/29/3	1/17/15	0/28/5	1/10/22	1/25/7	0/22/11	Base