Supplementary File of "Differential Evolution with Auto-enhanced Population Diversity"

CONTENTS

I. Experimental Setup

25 test instances (see Table I) proposed in the CEC 2005 special session on real-parameter optimization were used to study the performance of the proposed AEPD. In these functions, f_1–f_5 are unimodal functions, f_6–f_{12} are basic multimodal functions, f_{13}–f_{14} are expanded multimodal functions, and f_{15}–f_{25} are hybrid composition functions. Note that, functions f_7 and f_{25} have no boundary constraint. Therefore, for these two functions, for all algorithms we do not re-map individuals that are generated outside the initial search range during the search.

For each algorithm and each test function, 30 independent runs were conducted with $MaxFEs$=10000$\times D$ function evaluations as the termination criterion where D is the number of dimensions of the problems. In our experimental studies, the results are averaged over 30 independent runs for measuring the performance of each algorithm.

TABLE I
CEC05 benchmark functions. D denotes the dimensionality of the test problem, S denotes the ranges of the variables, and f_{min} is the function value of global optimum.

F	*Name*	S	f_{min}
f_1	Shifted Sphere Function(F_1)	$[-100, 100]^D$	-450
f_2	Shifted Schwefel's Problem 1.2(F_2)	$[-100, 100]^D$	-450
f_3	Shifted Rotated High Conditioned Elliptic Function(F_3)	$[-100, 100]^D$	-450
f_4	Shifted Schwefel's Problem 1.2 with Noise in Fitness(F_4)	$[-100, 100]^D$	-450
f_5	Schwefel's Problem 2.6 with Global Optimum on Bounds(F_5)	$[-100, 100]^D$	-310
f_6	Shifted Rosenbrock's Function(F_6)	$[-100, 100]^D$	390
f_7	Shifted Rotated Griewank's Function without Bounds(F_7)	$[0, 600]^D$	-180
f_8	Shifted Rotated Ackley's Function with Global Optimum on Bounds(F_8)	$[-32, 32]^D$	-140
f_9	Shifted Rastrigin's Function(F_9)	$[-5, 5]^D$	-330
f_{10}	Shifted Rotated Rastrigin's Function(F_{10})	$[-5, 5]^D$	-330
f_{11}	Shifted Rotated Weierstrass Function(F_{11})	$[-0.5, 0.5]^D$	90
f_{12}	Schwefel's Problem 2.13(F_{12})	$[-\pi, \pi]^D$	-460
f_{13}	Expanded Extended Griewank's plus Rosenbrocks Function(F_{13})	$[-5, 5]^D$	-130
f_{14}	Shifted Rotated Expanded Scaffer's F6(F_{14})	$[-100, 100]^D$	-300
f_{15}	Hybrid Composition Function(F_{15})	$[-5, 5]^D$	120
f_{16}	Rotated Hybrid Composition Function(F_{16})	$[-5, 5]^D$	120
f_{17}	Rotated Hybrid Composition Function with Noise in Fitness(F_{17})	$[-5, 5]^D$	120
f_{18}	Rotated Hybrid Composition Function(F_{18})	$[-5, 5]^D$	10
f_{19}	Rotated Hybrid Composition Function with a Narrow Basin for the Global Optimum(F_{19})	$[-5, 5]^D$	10
f_{20}	Rotated Hybrid Composition Function with the Global Optimum on the Bounds(F_{20})	$[-5, 5]^D$	10
f_{21}	Rotated Hybrid Composition Function(F_{21})	$[-5, 5]^D$	360
f_{22}	Rotated Hybrid Composition Function with High Condition Number Matrix(F_{22})	$[-5, 5]^D$	360
f_{23}	Non-Continuous Rotated Hybrid Composition Function(F_{23})	$[-5, 5]^D$	360
f_{24}	Rotated Hybrid Composition Function(F_{24})	$[-5, 5]^D$	260
f_{25}	Rotated Hybrid Composition Function without Bounds(F_{25})	$[2, 5]^D$	260

II. Comparison of AEPD-JADE with Other Algorithms

Table II and Table III summarize the results of average errors over 30 independent runs on each function with dimensions D=30 and D=50, respectively. The population size of AEPD-JADE is set to 20. For other algorithms, the population sizes are set to the recommended values in their original papers. For each function, the best result of all algorithms is shown in bold font. Note that, IPOP-CMA-ES cannot obtain any result on function f_{11} (the Shifted Rotated Weierstrass Function). The reason is that the original program of IPOP-CMA-ES was trapped in an infinite loop. From Table II and Table III, AEPD-JADE achieves the best results on 9 out of 25 30-dimensional functions and on 5 out of 25 50-dimensional functions.

We also compare all DE algorithms (except HdDE due to its population size cannot be changed) with the same population size NP=20 to ensure a fair testing condition. Table IV and Table V summarize the results of average

TABLE II

AVERAGE ERROR VALUES ± STANDARD DEVIATIONS ARCHIVED BY THE EIGHT ALGORITHMS ON THE 25 30-DIMENSIONAL CEC05 BENCHMARK FUNCTIONS OVER 30 INDEPENDENT RUNS.

	f_1	f_2	f_3	f_4	f_5
AEPD-JADE	**0.00e+000±0.00e+000**	1.17e-013±4.30e-013	**0.00e+000±0.00e+000**	1.09e-001±1.57e-001	1.14e-002±2.84e-002
DE/rand/1/bin	**0.00e+000±0.00e+000**	1.90e-004±1.96e-004↑	**0.00e+000±0.00e+000**	4.10e-002±3.14e-002↓	3.84e-001±4.28e-001↑
JADE	**0.00e+000±0.00e+000**	**0.00e+000±0.00e+000**↓	**0.00e+000±0.00e+000**	**3.90e-010±1.08e-009**↓	2.85e-006±5.78e-006↓
jDE	1.89e-015±1.04e-014	6.74e+000±4.08e+000↑	1.89e-015±1.04e-014	1.13e+002±7.62e+001↑	6.68e+001±2.19e+001↑
SaDE	5.68e-014±0.00e+000↑	9.76e-002±5.14e-001↑	5.68e-014±0.00e+000↑	9.84e+002±7.84e+002↑	2.26e-004±6.34e-004↓
CoDE	5.68e-014±0.00e+000↑	2.21e-003±5.50e-003↑	5.49e-014±1.04e-014↑	5.90e+002±1.43e+003↑	3.01e+002±1.11e+002↑
Pro DE/rand/1/bin	**0.00e+000±0.00e+000**	1.33e-004±1.20e-004↑	**0.00e+000±0.00e+000**	5.10e-002±5.02e-002	3.42e-001±1.90e-001↑
HdDE	**0.00e+000±0.00e+000**	1.86e+000±1.11e+000↑	**0.00e+000±0.00e+000**	3.55e+001±1.97e+001↑	1.26e+002±5.00e+001↑
EPSDE	1.57e-007±8.21e-008↑	1.24e+003±4.06e+002↑	8.99e-004±5.47e-004↑	5.34e-003±1.46e-002↓	9.38e+003±2.36e+003↑
CLPSO	5.68e-014±0.00e+000↑	6.22e+002±2.23e+002↑	7.77e-014±3.16e-014↑	5.37e+003±1.35e+003↑	9.20e+003±1.86e+003↑
IPOP-CMA-ES	**0.00e+000±0.00e+000**	**0.00e+000±0.00e+000**↓	**0.00e+000±0.00e+000**	4.94e+004±5.75e+004↑	**2.35e-010±1.66e-011**↓
	f_6	f_7	f_8	f_9	f_{10}
AEPD-JADE	5.32e-001±1.38e+000	1.28e-002±1.15e-002	2.09e+001±6.32e-002	**0.00e+000±0.00e+000**	**3.73e+001±7.85e+000**
DE/rand/1/bin	3.25e+000±1.36e+000↑	**0.00e+000±0.00e+000**↓	2.09e+001±5.85e-002	1.27e+002±2.04e+001↑	1.83e+002±1.00e+001↑
JADE	3.13e+000±8.12e+000↑	5.50e-003±7.48e-003↓	2.09e+001±2.20e-001	**0.00e+000±0.00e+000**	5.39e+001±7.26e+000↑
jDE	1.16e+001±1.01e+000↑	2.47e-004±1.35e-003↓	2.10e+001±3.53e-002	1.16e-004±3.81e-004↑	1.38e+002±8.76e+000↑
SaDE	2.00e+000±2.72e+000↑	1.40e-002±1.05e-002	2.09e+001±4.32e-002↓	6.33e+000±8.62e+000↑	7.47e+001±1.94e+001↑
CoDE	7.47e+000±1.58e+000↑	3.74e-003±1.65e-002↓	2.09e+001±4.12e-002	2.31e-013±2.50e-013↑	2.07e+002±1.22e+001↑
Pro DE/rand/1/bin	3.25e+000±1.44e+000↑	1.89e-015±7.21e-015↓	2.09e+001±5.43e-002	1.21e+002±2.26e+001↑	1.82e+002±1.38e+001↑
HdDE	1.21e+001±5.31e-001↑	1.15e-003±3.02e-003↓	2.09e+001±1.31e-001	3.32e-002±1.82e-001	5.41e+001±1.25e+001↑
EPSDE	2.63e+001±2.07e+000↑	1.57e-001±7.91e-002↑	2.10e+001±6.13e-002↑	1.71e+000±7.41e-001↑	1.81e+002±1.71e+001↑
CLPSO	2.35e+001±1.16e+000↑	6.48e+003±1.36e+001↑	2.10e+001±4.19e-002↑	1.49e+000±1.50e+000↑	1.25e+002±1.52e+001↑
IPOP-CMA-ES	**1.33e-001±7.28e-001**↓	1.31e-003±3.02e-003↓	**2.01e+001±2.92e-001**↓	2.37e+002±7.25e+001↑	9.88e+001±1.17e+002↑
	f_{11}	f_{12}	f_{13}	f_{14}	f_{15}
AEPD-JADE	**9.24e+000±2.43e+000**	**1.14e+003±2.35e+003**	1.29e+000±6.34e-001	**1.05e+001±5.99e-001**	**1.00e+002±2.89e-014**
DE/rand/1/bin	3.91e+001±1.30e+000↑	4.96e+003±4.75e+003↑	1.26e+000±2.94e-001	1.35e+001±1.36e-001↑	1.20e+002±1.09e+002↑
JADE	2.66e+001±1.47e+000↑	1.75e+004±5.49e+003↑	1.69e+000±1.93e-001↑	1.27e+001±1.77e-001↑	1.00e+002±3.47e-013
jDE	3.35e+001±1.47e+000↑	3.90e+004±9.72e+003↑	2.08e+000±5.28e-001↑	1.32e+001±2.07e-001↑	1.00e+002±3.92e-013↑
SaDE	2.30e+001±2.50e+000↑	3.63e+003±4.30e+003↑	7.37e+000±3.41e+000↑	1.24e+001±3.82e-001↑	7.27e+002±1.24e+002↑
CoDE	3.29e+001±1.58e+000↑	8.38e+004±1.97e+004↑	3.90e+000±4.12e-001↑	1.33e+001±2.21e-001↑	1.00e+002±3.36e-007↑
Pro DE/rand/1/bin	3.97e+001±8.97e-001↑	8.07e+003±5.50e+003↑	**1.25e+000±4.99e-001**	1.34e+001±2.13e-001↑	1.19e+002±1.03e+002↑
HdDE	1.62e+001±5.08e+000↑	5.05e+003±4.62e+003↑	1.31e+000±2.53e-001	1.27e+001±4.99e-001↑	1.95e+002±2.16e+002↑
EPSDE	3.16e+001±1.67e+000↑	5.85e+004±1.18e+004↑	2.76e+000±2.80e-001↑	1.33e+001±1.64e-001↑	1.20e+002±1.36e+001↑
CLPSO	2.81e+001±2.17e+000↑	3.64e+004±9.46e+003↑	2.69e+000±4.99e-001↑	1.32e+001±1.83e-001↑	4.56e+002±2.76e+002↑
IPOP-CMA-ES	—	1.77e+004±1.29e+004↑	3.17e+000±1.32e+000↑	1.48e+001±5.63e-003↑	7.63e+002±1.95e+001↑
	f_{16}	f_{17}	f_{18}	f_{19}	f_{20}
AEPD-JADE	1.19e+002±1.05e+002	**1.02e+002±2.96e-001**	4.43e+002±2.91e+002	4.35e+002±2.74e+002	9.62e+002±1.27e+002
DE/rand/1/bin	1.00e+002±4.38e-013↓	1.12e+002±6.30e+000↑	3.00e+002±2.46e-012	3.00e+002±1.51e-012	**3.00e+002±2.79e-011**↓
JADE	**1.00e+002±2.89e-014**	3.74e+002±3.06e+002↑	3.77e+002±2.35e+002	3.78e+002±2.38e+002	1.02e+003±1.98e+002↑
jDE	1.00e+002±4.47e-013↓	4.55e+002±2.51e+002↑	3.00e+002±1.18e-012	3.00e+002±1.06e-012	3.00e+002±4.28e-009↓
SaDE	5.47e+002±2.75e+002↑	6.22e+002±2.31e+002↑	1.05e+003±1.46e+002↑	1.01e+003±1.40e+002↑	1.05e+003±2.84e+001↑
CoDE	7.47e+002±2.58e+001↑	8.64e+002±1.74e+001↑	1.12e+003±2.88e+001↑	1.11e+003±3.13e+001↑	1.16e+003±1.78e+001↑
Pro DE/rand/1/bin	1.00e+002±4.38e-013↓	1.13e+002±8.25e+000↑	3.00e+002±2.25e-012	3.00e+002±1.47e-012	3.00e+002±7.46e-011↓
HdDE	**1.00e+002±2.89e-014**	3.84e+002±2.91e+002↑	**3.00e+002±5.57e-013**↓	**3.00e+002±6.55e-013**↓	4.71e+002±2.88e+002↓
EPSDE	7.55e+002±1.87e+001↑	5.71e+002±2.87e+002↑	1.28e+003±3.44e+001↑	1.26e+003±2.56e+001↑	1.21e+003±1.99e+001↑
CLPSO	6.79e+002±8.41e+001↑	8.09e+002±1.22e+001↑	1.11e+003±2.80e+001↑	1.08e+003±4.41e+001↑	1.12e+003±1.95e+001↑
IPOP-CMA-ES	2.18e+002±2.40e+002↑	1.00e+003±1.07e+002↑	1.21e+003±5.95e+001↑	1.20e+003±1.43e+001↑	1.16e+003±1.63e+001↑
	f_{21}	f_{22}	f_{23}	f_{24}	f_{25}
AEPD-JADE	1.17e+003±1.78e+001	8.92e+002±4.11e+002	1.23e+003±2.27e+001	1.07e+003±1.55e+001	1.08e+003±1.67e+002
DE/rand/1/bin	1.14e+003±6.35e+000↓	9.18e+002±3.49e+002	**1.19e+003±6.21e+000**↓	1.12e+003±2.77e+000↑	1.03e+003±4.25e+002
JADE	1.16e+003±2.19e+001	1.17e+003±1.10e+001↑	1.20e+003±1.03e+001↓	1.09e+003±5.36e+000↑	1.20e+003±1.03e+001↑
jDE	1.15e+003±1.18e+001↓	1.18e+003±1.45e+001↑	1.19e+003±8.39e+000↓	1.11e+003±4.24e+000↑	1.25e+003±1.32e+001↑
SaDE	1.20e+003±2.25e+001↑	1.12e+003±4.26e+001	1.24e+003±1.59e+001	1.08e+003±7.31e+000↑	1.16e+003±2.98e+001↑
CoDE	1.30e+003±1.43e+001↑	1.23e+003±1.21e+001↑	1.30e+003±1.61e+001↑	1.13e+003±3.75e+000↑	1.29e+003±1.08e+001↑
Pro DE/rand/1/bin	**1.14e+003±6.12e+000**↓	**8.83e+002±3.74e+002**	1.19e+003±7.39e+000↓	1.12e+003±3.36e+000↑	**9.58e+002±4.72e+002**
HdDE	1.15e+003±1.39e+001↓	1.12e+003±1.57e+002↑	1.20e+003±9.52e+000↓	1.08e+003±1.43e+001↑	1.16e+003±3.06e+001↑
EPSDE	1.30e+003±1.63e+001↑	1.25e+003±1.26e+001↑	1.31e+003±1.40e+001↑	1.11e+003±5.60e+000↑	1.24e+003±8.46e+000↑
CLPSO	1.25e+003±1.24e+001↑	1.21e+003±1.15e+001↑	1.26e+003±1.18e+001↑	1.12e+003±4.14e+000↑	1.25e+003±1.17e+001↑
IPOP-CMA-ES	1.23e+003±4.40e+001↑	1.06e+003±3.20e+001	1.29e+003±4.48e+001↑	**1.06e+003±7.75e+000**↓	1.16e+003±1.91e+001↑

↑ AEPD-JADE performs significantly better than this algorithm at a 0.05 level of significance by the paired samples Wilcoxon signed rank test.
↓ AEPD-JADE performs significantly worse than this algorithm at a 0.05 level of significance by the paired samples Wilcoxon signed rank test.

errors on each function with D=30 and D=50, respectively. From Table IV and Table V, AEPD-JADE achieves the best results on 18 out of 30-dimensional functions and on 15 out of 50-dimensional functions.

TABLE III

AVERAGE ERROR VALUES ± STANDARD DEVIATIONS ARCHIVED BY THE EIGHT ALGORITHMS ON THE 25 50-DIMENSIONAL CEC05 BENCHMARK FUNCTIONS OVER 30 INDEPENDENT RUNS.

	f_1	f_2	f_3	f_4	f_5
AEPD-JADE	5.31e-014±1.44e-014	3.16e-010±1.03e-009	5.49e-014±1.04e-014	3.03e+001±1.93e+001	8.44e-001±3.01e-001
DE/rand/1/bin	8.59e-008±4.46e-008↑	1.03e+004±2.48e+003↑	3.78e-005±1.97e-005↑	3.40e+004±6.90e+003↑	6.13e+003±1.14e+003↑
JADE	**1.33e-014±2.45e-014**↓	3.43e-009±4.27e-009↑	**3.60e-014±2.79e-014**↓	**9.40e-001±2.07e+000**↓	4.59e+002±8.68e+002↑
jDE	5.31e-014±1.44e-014	1.18e+004±2.63e+003↑	7.81e-013±3.63e-013↑	3.46e+004±7.89e+003↑	4.03e+003±5.28e+002↑
SaDE	6.44e-014±1.97e-014	1.91e+000±2.84e+000↑	6.82e-014±2.31e-014↑	8.59e+003±4.13e+003↑	4.20e-002±6.58e-002↓
CoDE	1.93e-013±4.38e-014↑	3.36e+004±2.97e+004↑	1.86e-011±1.12e-011↑	8.73e+004±1.58e+004↑	2.01e+004±6.99e+003↑
Pro DE/rand/1/bin	9.72e-008±6.68e-008↑	1.06e+004±1.95e+003↑	3.62e-005±2.38e-005↑	3.17e+004±6.86e+003↑	5.99e+003±9.27e+002↑
HdDE	4.55e-014±2.31e-014	1.20e+002±6.23e+001↑	3.79e-014±2.73e-014↓	3.17e+003±1.59e+003↑	1.01e+003±3.78e+002↑
EPSDE	3.96e-008±1.89e-008↑	1.46e+004±2.68e+003↑	2.21e-004±8.59e-005↑	4.37e+002±4.18e+002↑	1.91e+004±3.40e+003↑
CLPSO	9.85e-014±2.56e-014↑	1.46e+004±2.24e+003↑	4.73e-012±2.72e-012↑	4.67e+004±8.21e+003↑	1.75e+004±5.16e+003↑
IPOP-CMA-ES	5.68e-014±0.00e+000	**5.68e-014±0.00e+000**↓	5.68e-014±0.00e+000	6.78e+004±8.15e+004↑	**7.53e-010±6.15e-011**↓
	f_6	f_7	f_8	f_9	f_{10}
AEPD-JADE	2.21e+000±2.31e+000	3.86e-003±8.33e-003	2.11e+001±3.28e-002	6.63e-002±2.52e-001	1.04e+002±2.79e+001
DE/rand/1/bin	4.10e+001±5.43e-001↑	2.42e+000±8.65e-001↑	2.11e+001±4.12e-002	3.76e+002±1.62e+001↑	3.92e+002±1.71e+001↑
JADE	6.97e+000±2.06e+000↑	1.40e-003±4.65e-003↓	2.11e+001±4.25e-002	**2.71e-005±1.67e-005**↓	1.55e+002±1.30e+001↑
jDE	4.00e+001±4.12e-001↑	4.90e+000±1.50e+000↑	2.11e+001±3.65e-002	8.04e+001±5.70e+000↑	3.30e+002±1.49e+001↑
SaDE	1.58e+001±7.47e+000↑	1.18e+000±5.00e-001↑	2.11e+001±4.57e-002↓	2.65e+000±3.50e+000↑	1.43e+002±3.01e+001↑
CoDE	5.86e+001±2.86e+001↑	1.28e+000±2.90e-001↑	2.11e+001±4.04e-002	4.99e+000±4.05e+000↑	4.84e+002±2.37e+001↑
Pro DE/rand/1/bin	4.12e+001±7.54e-001↑	2.69e+000±1.06e+000↑	2.11e+001±3.74e-002	3.75e+002±1.40e+001↑	3.91e+002±1.58e+001↑
HdDE	3.26e+001±1.59e+001↑	**1.76e-006±1.04e-006**	2.11e+001±1.61e-001↑	1.33e+000±1.21e+000↑	**1.03e+002±2.02e+001**
EPSDE	4.87e+001±1.47e+001↑	1.15e+001±6.68e+000↑	2.12e+001±3.17e-002↑	5.14e+000±1.17e+000↑	3.66e+002±2.96e+001↑
CLPSO	8.39e+001±3.23e+001↑	1.13e+004±4.93e+000↑	2.12e+001±4.19e-002↑	3.28e+000±1.76e+000↑	3.25e+002±2.89e+001↑
IPOP-CMA-ES	**2.66e-001±1.01e+000**↓	2.79e-003±5.16e-003	**2.01e+001±2.35e-001**↓	3.92e+002±3.39e+001↑	1.28e+002±2.96e+001↑
	f_{11}	f_{12}	f_{13}	f_{14}	f_{15}
AEPD-JADE	**2.37e+001±4.02e+000**	**6.11e+003±4.41e+003**	2.57e+000±1.39e+000	**1.96e+001±8.23e-001**	6.95e+002±2.72e+002
DE/rand/1/bin	7.28e+001±2.03e+000↑	1.95e+006±2.67e+005↑	4.90e+000±1.29e+000↑	2.32e+001±1.39e-001↑	4.10e+002±3.05e+001↓
JADE	5.38e+001±2.20e+000↑	1.76e+005±2.36e+004↑	3.50e+000±5.15e-001↑	2.25e+001±1.99e-001↑	4.32e+002±1.23e+002↓
jDE	6.64e+001±1.69e+000↑	4.42e+005±5.63e+004↑	4.60e+000±1.04e+000↑	2.31e+001±1.93e-001↑	5.47e+002±2.21e+002↓
SaDE	4.78e+001±4.79e+000↑	7.96e+003±6.97e+003	1.54e+001±5.31e+000↑	2.21e+001±5.57e-001↑	8.61e+002±9.44e+001↑
CoDE	6.66e+001±2.55e+000↑	5.50e+005±5.40e+004↑	1.15e+001±1.07e+000↑	2.31e+001±1.87e-001↑	4.46e+002±4.93e+001↓
Pro DE/rand/1/bin	7.32e+001±1.01e+000↑	1.85e+006±2.46e+005↑	4.76e+000±1.05e+000↑	2.32e+001±1.24e-001↑	**4.00e+002±1.40e-001**↓
HdDE	3.59e+001±8.45e+000↑	1.42e+004±1.11e+004↑	**2.09e+000±5.02e-001**	2.26e+001±3.54e-001↑	6.42e+002±2.26e+002
EPSDE	5.83e+001±2.14e+000↑	1.90e+005±2.93e+004↑	4.31e+000±4.45e-001↑	2.29e+001±2.12e-001↑	7.93e+002±1.03e+002
CLPSO	5.89e+001±2.62e+000↑	1.70e+005±2.96e+004↑	5.10e+000±9.57e-001↑	2.31e+001±1.55e-001↑	8.43e+002±7.02e+001↑
IPOP-CMA-ES	—	4.80e+004±4.62e+004↑	4.69e+000±1.33e+000↑	2.40e+001±1.49e-002↑	7.05e+002±2.53e+002
	f_{16}	f_{17}	f_{18}	f_{19}	f_{20}
AEPD-JADE	8.44e+002±1.59e+002	**8.21e+002±1.96e+002**	1.05e+003±3.51e+001	1.04e+003±2.00e+001	1.07e+003±1.64e+001
DE/rand/1/bin	1.51e+002±1.14e+002↓	1.01e+003±1.78e+001↑	3.01e+002±5.90e-001↓	3.01e+002±9.89e-001↓	3.01e+002±8.54e-001↓
JADE	9.11e+002±2.42e+001↑	9.48e+002±1.96e+001↑	8.94e+002±3.37e+002	1.04e+003±1.52e+002	1.13e+003±9.87e+000↑
jDE	1.37e+002±1.48e+002↓	9.68e+002±1.96e+001↑	**3.00e+002±1.10e-002**↓	**3.00e+002±1.90e-002**↓	**3.00e+002±1.35e-002**↓
SaDE	8.43e+002±6.73e+001	9.10e+002±5.59e+001	1.11e+003±1.53e+001↑	1.08e+003±1.66e+001↑	1.10e+003±1.96e+001↑
CoDE	7.82e+002±5.17e+001↓	1.02e+003±1.56e+001↑	1.20e+003±1.43e+001↑	1.17e+003±1.50e+001↑	1.20e+003±1.73e+001↑
Pro DE/rand/1/bin	**1.11e+002±5.46e+001**↓	1.01e+003±1.37e+001↑	3.01e+002±8.56e-001↓	3.01e+002±5.64e-001↓	3.01e+002±5.28e-001↓
HdDE	8.61e+002±1.14e+002↑	9.44e+002±9.62e+000↑	4.61e+002±2.97e+002↓	4.99e+002±3.10e+002↓	5.66e+002±3.57e+002↓
EPSDE	8.83e+002±4.62e+001	9.02e+002±4.75e+001	1.22e+003±1.34e+001↑	1.19e+003±1.37e+001↑	1.23e+003±1.27e+001↑
CLPSO	9.37e+002±1.28e+001↑	9.82e+002±6.93e+000↑	1.16e+003±1.15e+001↑	1.14e+003±1.32e+001↑	1.18e+003±9.78e+000↑
IPOP-CMA-ES	8.24e+002±1.67e+002	1.08e+003±3.52e+001↑	1.15e+003±1.53e+001↑	1.12e+003±1.50e+001↑	1.15e+003±1.34e+001↑
	f_{21}	f_{22}	f_{23}	f_{24}	f_{25}
AEPD-JADE	1.23e+003±1.31e+001	1.15e+003±1.24e+001	1.26e+003±1.44e+001	1.13e+003±1.45e+001	**1.20e+003±1.24e+001**
DE/rand/1/bin	**1.13e+003±1.52e+001**↓	1.14e+003±6.03e+000↓	**1.16e+003±7.40e+000**↓	1.20e+003±3.24e+000↑	1.35e+003±6.04e+000↑
JADE	1.21e+003±2.48e+001↓	1.16e+003±6.13e+000↑	1.26e+003±1.46e+001	1.18e+003±5.19e+000↑	1.30e+003±1.04e+001↑
jDE	1.14e+003±1.28e+001↓	1.13e+003±6.84e+000↓	1.16e+003±8.91e+000↓	1.19e+003±3.91e+000↑	1.33e+003±5.22e+000↑
SaDE	1.16e+003±9.68e+000↓	1.11e+003±2.77e+001↓	1.18e+003±9.68e+000↓	1.15e+003±7.59e+000↑	1.23e+003±1.60e+001↑
CoDE	1.24e+003±6.70e+000↑	1.20e+003±8.41e+000↑	1.24e+003±6.57e+000↓	1.22e+003±4.31e+000↑	1.38e+003±1.06e+001↑
Pro DE/rand/1/bin	1.13e+003±1.38e+001↓	1.14e+003±7.36e+000↓	1.16e+003±6.48e+000↓	1.20e+003±3.12e+000↑	1.35e+003±6.63e+000↑
HdDE	1.19e+003±1.07e+001↓	1.15e+003±1.80e+001↑	1.23e+003±9.88e+000↓	1.16e+003±1.81e+001↑	1.25e+003±4.19e+001↑
EPSDE	1.23e+003±1.04e+001	1.20e+003±1.27e+001↑	1.23e+003±1.22e+001↓	1.18e+003±5.03e+000↑	1.31e+003±9.72e+000↑
CLPSO	1.29e+003±1.02e+001↑	1.22e+003±9.57e+000↑	1.30e+003±9.11e+000↑	1.22e+003±5.14e+000↑	1.37e+003±1.21e+001↑
IPOP-CMA-ES	1.24e+003±2.10e+001↑	**1.05e+003±1.60e+001**↓	1.28e+003±2.20e+001↑	**1.13e+003±1.20e+001**	1.23e+003±1.45e+001↑

↑ and ↓ denote the same meanings as in Table II.

TABLE IV
AVERAGE ERROR VALUES ± STANDARD DEVIATIONS ARCHIVED BY THE EIGHT ALGORITHMS ON THE 25 30-DIMENSIONAL CEC05 BENCHMARK FUNCTIONS WITH NP=20 OVER 30 INDEPENDENT RUNS.

	f_1	f_2	f_3	f_4	f_5
AEPD-JADE	**0.00e+000±0.00e+000**	1.17e-013±4.30e-013	**0.00e+000±0.00e+000**	**1.09e-001±1.57e-001**	1.14e-002±2.84e-002
DE/rand/1/bin	6.40e+002±7.69e+002↑	1.01e+003±9.08e+002↑	8.92e+006±2.40e+007↑	3.40e+003±2.94e+003↑	3.94e+004±2.11e+004↑
JADE	**0.00e+000±0.00e+000**	**3.03e-014±2.88e-014**	**0.00e+000±0.00e+000**	1.54e+002±2.18e+002↑	**8.09e-004±1.96e-003**↓
jDE	5.68e-014±8.96e-014↑	6.86e-013±5.47e-013↑	3.60e-014±2.79e-014↑	8.99e+001±2.65e+002↑	6.42e-001±1.37e+000↑
SaDE	1.22e+001±3.24e+001↑	4.65e+003±3.94e+003↑	7.24e+004±2.78e+005↑	2.83e+004±1.05e+004↑	2.73e+004±2.05e+004↑
CoDE	5.12e-014±1.73e-014↑	1.27e-011±3.19e-011↑	4.55e-014±2.31e-014↑	1.01e+000±2.37e+000↑	3.51e-001±3.41e-001↑
Pro DE/rand/1/bin	8.47e+002±6.71e+002↑	1.47e+003±1.32e+003↑	7.17e+006±2.21e+007↑	2.28e+003±2.57e+003↑	3.95e+004±2.07e+004↑
EPSDE	3.22e-014±2.86e-014↑	7.14e+000±6.45e+000↑	3.41e-014±2.83e-014↑	6.54e+002±9.51e+002↑	2.88e+003±1.24e+003↑
	f_6	f_7	f_8	f_9	f_{10}
AEPD-JADE	5.32e-001±1.38e+000	1.28e-002±1.15e-002	2.09e+001±6.32e-002	**0.00e+000±0.00e+000**	**3.73e+001±7.85e+000**
DE/rand/1/bin	6.37e+008±7.95e+008↑	2.69e+002±2.68e+002↑	2.10e+001±5.62e-002	6.25e+001±1.23e+001↑	9.58e+001±2.32e+001↑
JADE	5.97e+000±8.16e+000↑	1.16e-002±1.07e-002	2.08e+001±2.70e-001	9.62e-001±2.13e+000↑	8.56e+001±1.41e+001↑
jDE	3.05e+000±3.71e+000↑	8.29e-003±7.63e-003	2.09e+001±5.16e-002	4.48e+000±3.19e+000↑	5.62e+001±1.09e+001↑
SaDE	2.31e+007±6.43e+007↑	2.87e+001±7.20e+001↑	**2.08e+001±6.29e-002**↓	9.53e+001±2.63e+001↑	1.91e+002±4.37e+001↑
CoDE	**2.13e-003±5.23e-003**↓	**2.47e-004±1.35e-003**↓	2.09e+001±1.40e-001	4.36e-014±2.45e-014↑	1.98e+002±1.96e+001↑
Pro DE/rand/1/bin	6.13e+008±7.04e+008↑	2.81e+002±2.28e+002↑	2.10e+001±4.02e-002	6.00e+001±1.39e+001↑	8.81e+001±2.51e+001↑
EPSDE	1.20e+001±7.29e+000↑	1.52e-002±1.40e-002	2.10e+001±4.99e-002↑	3.32e-002±1.82e-001↑	1.55e+002±2.48e+001↑
	f_{11}	f_{12}	f_{13}	f_{14}	f_{15}
AEPD-JADE	**9.24e+000±2.43e+000**	**1.14e+003±2.35e+003**	**1.29e+000±6.34e-001**	**1.05e+001±5.99e-001**	**1.00e+002±2.89e-014**
DE/rand/1/bin	2.98e+001±6.56e+000↑	2.61e+004±1.54e+004↑	9.22e+003±8.60e+003↑	1.30e+001±5.17e-001↑	8.29e+002±3.66e+001↑
JADE	2.72e+001±2.57e+000↑	5.94e+003±3.51e+003↑	2.81e+000±1.33e+000↑	1.26e+001±3.26e-001↑	4.62e+002±3.01e+002↑
jDE	2.02e+001±4.29e+000↑	3.82e+003±5.81e+003	3.55e+000±2.50e+000↑	1.30e+001±2.01e-001↑	7.08e+002±1.24e+002↑
SaDE	3.29e+001±4.57e+000↑	2.21e+004±2.54e+004↑	4.75e+002±1.30e+003↑	1.29e+001±3.44e-001↑	9.41e+002±3.78e+001↑
CoDE	3.21e+001±1.42e+000↑	6.61e+004±1.22e+004↑	3.11e+000±4.36e-001↑	1.32e+001±1.98e-001↑	1.00e+002±2.66e-013↑
Pro DE/rand/1/bin	3.33e+001±6.55e+000↑	2.80e+004±1.65e+004↑	9.64e+003±1.23e+004↑	1.30e+001±5.38e-001↑	8.19e+002±4.58e+001↑
EPSDE	3.06e+001±2.24e+000↑	3.25e+004±1.08e+004↑	1.73e+000±2.98e-001↑	1.32e+001±1.58e-001↑	1.94e+002±2.13e+002↑
	f_{16}	f_{17}	f_{18}	f_{19}	f_{20}
AEPD-JADE	**1.19e+002±1.05e+002**	**1.02e+002±2.96e-001**	**4.43e+002±2.91e+002**	**4.35e+002±2.74e+002**	**9.62e+002±1.27e+002**
DE/rand/1/bin	7.95e+002±3.75e+001↑	7.94e+002±4.43e+001↑	1.14e+003±4.11e+001↑	1.11e+003±4.31e+001↑	1.08e+003±2.58e+001↑
JADE	6.53e+002±1.90e+002↑	7.37e+002±1.24e+002↑	1.20e+003±4.98e+001↑	1.15e+003±5.23e+001↑	1.14e+003±2.56e+001↑
jDE	5.76e+002±2.43e+002↑	6.95e+002±1.16e+002↑	8.52e+002±3.12e+002↑	8.30e+002±3.01e+002↑	1.02e+003±2.38e+001↑
SaDE	9.20e+002±4.50e+001↑	9.56e+002±5.81e+001↑	1.25e+003±2.81e+001↑	1.23e+003±2.91e+001↑	1.18e+003±2.70e+001↑
CoDE	6.12e+002±2.61e+002↑	8.40e+002±1.71e+001↑	1.03e+003±2.08e+002↑	9.91e+002±2.35e+002↑	1.16e+003±2.30e+001↑
Pro DE/rand/1/bin	7.90e+002±3.06e+001↑	7.90e+002±3.37e+001↑	1.13e+003±3.62e+001↑	1.10e+003±3.94e+001↑	1.09e+003±1.91e+001↑
EPSDE	7.42e+002±2.21e+001↑	7.45e+002±1.79e+002↑	1.28e+003±3.30e+001↑	1.24e+003±3.70e+001↑	1.19e+003±2.67e+001↑
	f_{21}	f_{22}	f_{23}	f_{24}	f_{25}
AEPD-JADE	**1.17e+003±1.78e+001**	**8.92e+002±4.11e+002**	1.23e+003±2.27e001	1.07e+003±1.55e+001	**1.08e+003±1.67e+002**
DE/rand/1/bin	1.23e+003±2.03e+001↑	1.17e+003±3.20e+001↑	1.27e+003±2.23e+001↑	1.11e+003±1.39e+001↑	1.16e+003±3.81e+001↑
JADE	1.22e+003±2.39e+001↑	1.16e+003±2.34e+001↑	1.24e+003±2.07e+001↑	1.09e+003±6.46e+000↑	1.19e+003±1.44e+001↑
jDE	1.18e+003±1.57e+001↑	1.16e+003±2.52e+001↑	**1.22e+003±1.56e+001**	1.10e+003±1.06e+001↑	1.16e+003±3.24e+001↑
SaDE	1.32e+003±2.61e+001↑	1.17e+003±2.71e+001↑	1.33e+003±2.83e+001↑	1.12e+003±1.58e+001↑	1.23e+003±1.95e+001↑
CoDE	1.30e+003±1.38e+001↑	1.22e+003±1.50e+001↑	1.29e+003±2.26e+001↑	1.13e+003±6.32e+000↑	1.28e+003±1.65e+001↑
Pro DE/rand/1/bin	1.23e+003±2.52e+001↑	1.18e+003±1.48e+001↑	1.26e+003±1.76e+001↑	1.10e+003±1.53e+001↑	1.16e+003±3.49e+001↑
EPSDE	1.28e+003±2.90e+001↑	1.23e+003±1.68e+001↑	1.29e+003±2.34e+001↑	1.11e+003±8.24e+000↑	1.23e+003±1.31e+001↑

↑ and ↓ denote the same meanings as in Table II.

III. SENSITIVITY STUDIES OF THE PARAMETER c IN EQ.(14A) AND THE PARAMETER a IN EQ.(19)

We study the sensitivity of the parameter c in the following equation (Eq.(14a) in the paper):

$$z_G = \begin{cases} 1 & \text{if } \sum_{j=1}^{D} r_{j,G} = D \text{ or } randu < c \quad (1a) \\ 0 & \text{otherwise} \quad (1b) \end{cases}$$

Table VI summarizes the results of average errors over 30 independent runs for AEPD-JADE algorithm with different values of c=$\{10^{-1}, 10^{-2}, \ldots, 10^{-5}\}$. Table VII summarizes the statistical results of Table VI. From the results, it can be seen that AEPD-JADE with c=10^{-3} performs best. Therefore, we choose 10^{-3} as the default value of c.

TABLE V
AVERAGE ERROR VALUES ± STANDARD DEVIATIONS ARCHIVED BY THE EIGHT ALGORITHMS ON THE 25 50-DIMENSIONAL CEC05 BENCHMARK FUNCTIONS WITH NP=20 OVER 30 INDEPENDENT RUNS.

	f_1	f_2	f_3	f_4	f_5
AEPD-JADE	**5.31e-014±1.44e-014**	3.16e-010±1.03e-009	5.49e-014±1.04e-014	**3.03e+001±1.93e+001**	8.44e-001±3.01e-001
DE/rand/1/bin	2.98e+003±2.14e+003↑	1.87e+003±1.80e+003↑	1.34e+007±1.78e+007↑	1.48e+004±5.40e+003↑	1.03e+005±4.03e+004↑
JADE	5.49e-014±1.04e-014	**1.38e-013±1.08e-013**↓	**5.31e-014±1.44e-014**	6.66e+003±4.20e+003↑	**4.46e-001±1.59e-001**↓
jDE	9.09e-014±5.30e-014↑	1.85e-005±2.49e-005↑	8.34e-014±4.89e-014↑	5.85e+003±4.39e+003↑	3.07e+001±1.31e+001↑
SaDE	1.15e+003±1.96e+003↑	2.14e+004±9.42e+003↑	7.14e+005±1.24e+006↑	8.66e+004±1.96e+004↑	9.00e+004±7.85e+004↑
CoDE	5.68e-014±0.00e+000	1.12e+004±2.11e+004↑	5.68e-014±0.00e+000	6.22e+004±3.62e+004↑	9.54e+002±4.49e+002↑
Pro DE/rand/1/bin	2.34e+003±1.73e+003↑	2.55e+003±3.38e+003↑	9.40e+006±1.01e+007↑	1.40e+004±4.29e+003↑	9.91e+004±3.76e+004↑
EPSDE	5.87e-014±1.04e-014	4.59e+002±2.05e+002↑	6.06e-014±1.44e-014	8.22e+003±2.81e+003↑	7.12e+003±1.95e+003↑
	f_6	f_7	f_8	f_9	f_{10}
AEPD-JADE	**2.21e+000±2.31e+000**	**3.86e-003±8.33e-003**	2.11e+001±3.28e-002	**6.63e-002±2.52e-001**	**1.04e+002±2.79e+001**
DE/rand/1/bin	1.50e+009±1.31e+009↑	9.55e+001±1.14e+002↑	2.11e+001±4.65e-002	1.31e+002±2.59e+001↑	2.15e+002±3.22e+001↑
JADE	3.18e+001±3.37e+001↑	1.05e+000±2.52e-001↑	2.10e+001±3.32e-001	3.68e+000±3.75e+000↑	1.93e+002±3.08e+001↑
jDE	2.12e+001±2.32e+001↑	6.15e-003±1.19e-002	2.11e+001±3.73e-002	1.15e+001±6.78e+000↑	1.18e+002±2.13e+001
SaDE	1.82e+008±3.87e+008↑	3.59e+002±2.86e+002↑	**2.09e+001±4.52e-002**↓	2.08e+002±4.07e+001↑	4.77e+002±6.83e+001↑
CoDE	3.03e+001±1.03e+001↑	1.12e+000±2.84e-001↑	2.11e+001±4.25e-002	6.63e-002±2.52e-001↑	4.63e+002±3.21e+001↑
Pro DE/rand/1/bin	1.85e+009±2.28e+009↑	8.05e+001±6.96e+001↑	2.11e+001±3.74e-002	1.25e+002±2.39e+001↑	2.22e+002±3.87e+001↑
EPSDE	4.49e+001±2.96e+001↑	8.38e+000±5.53e+000↑	2.12e+001±3.25e-002↑	6.63e-002±2.52e-001↑	3.11e+002±3.79e+001↑
	f_{11}	f_{12}	f_{13}	f_{14}	f_{15}
AEPD-JADE	**2.37e+001±4.02e+000**	6.11e+003±4.41e+003	**2.57e+000±1.39e+000**	**1.96e+001±8.23e-001**	6.95e+002±2.72e+002
DE/rand/1/bin	7.18e+001±4.06e+000↑	5.37e+004±2.85e+004↑	7.68e+004±8.58e+004↑	2.31e+001±1.67e-001↑	9.39e+002±1.03e+001↑
JADE	5.43e+001±3.02e+000↑	2.33e+004±9.40e+003↑	1.09e+001±1.12e+001↑	2.21e+001±3.46e-001↑	8.73e+002±2.81e+001↑
jDE	5.36e+001±1.03e+001↑	**5.73e+003±4.63e+003**	1.55e+001±1.05e+001↑	2.28e+001±2.02e-001↑	8.69e+002±9.16e+001↑
SaDE	6.44e+001±7.76e+000↑	6.28e+004±1.05e+005↑	6.53e+003±2.04e+004↑	2.23e+001±3.77e-001↑	1.00e+003±2.23e+001↑
CoDE	6.56e+001±2.00e+000↑	4.62e+005±5.26e+004↑	8.92e+000±8.95e-001↑	2.31e+001±1.80e-001↑	**4.47e+002±1.02e+002**↓
Pro DE/rand/1/bin	7.20e+001±3.00e+000↑	5.62e+004±2.65e+004↑	8.69e+004±1.39e+005↑	2.31e+001±3.13e-001↑	9.35e+002±9.86e+000↑
EPSDE	5.77e+001±1.87e+000↑	1.04e+005±2.33e+004↑	2.81e+000±6.84e-001	2.28e+001±2.51e-001↑	7.98e+002±1.28e+002
	f_{16}	f_{17}	f_{18}	f_{19}	f_{20}
AEPD-JADE	8.44e+002±1.59e+002	**8.21e+002±1.96e+002**	**1.05e+003±3.51e+001**	**1.04e+003±2.00e+001**	**1.07e+003±1.64e+001**
DE/rand/1/bin	9.24e+002±2.42e+001↑	9.69e+002±2.37e+001↑	1.15e+003±1.41e+001↑	1.12e+003±1.29e+001↑	1.15e+003±1.09e+001↑
JADE	9.10e+002±2.07e+001	9.51e+002±3.40e+001↑	1.18e+003±1.91e+001↑	1.15e+003±1.36e+001↑	1.18e+003±1.48e+001↑
jDE	9.08e+002±1.61e+001	9.35e+002±1.28e+001↑	1.09e+003±2.39e+001↑	1.06e+003±1.91e+001↑	1.09e+003±2.27e+001↑
SaDE	9.85e+002±2.17e+001↑	1.04e+003±2.46e+001↑	1.22e+003±1.79e+001↑	1.20e+003±1.57e+001↑	1.22e+003±2.12e+001↑
CoDE	**7.65e+002±7.62e+001**↓	1.01e+003±1.64e+001↑	1.19e+003±1.90e+001↑	1.17e+003±1.71e+001↑	1.19e+003±2.34e+001↑
Pro DE/rand/1/bin	9.22e+002±2.51e+001↑	9.74e+002±1.46e+001↑	1.15e+003±1.53e+001↑	1.12e+003±1.49e+001↑	1.15e+003±1.41e+001↑
EPSDE	8.77e+002±7.26e+001	9.65e+002±3.54e+001↑	1.22e+003±1.34e+001↑	1.19e+003±1.59e+001↑	1.22e+003±1.30e+001↑
	f_{21}	f_{22}	f_{23}	f_{24}	f_{25}
AEPD-JADE	1.23e+003±1.31e+001	1.15e+003±1.24e+001	1.26e+003±1.44e+001	**1.13e+003±1.45e+001**	**1.20e+003±1.24e+001**
DE/rand/1/bin	1.21e+003±1.67e+001↓	1.17e+003±1.77e+001↑	1.22e+003±1.62e+001↓	1.19e+003±1.45e+001↑	1.24e+003±2.17e+001↑
JADE	**1.20e+003±1.31e+001**↓	**1.14e+003±1.38e+001**↓	**1.20e+003±1.06e+001**↓	1.18e+003±7.12e+000↑	1.28e+003±1.17e+001↑
jDE	1.23e+003±1.14e+001↑	1.18e+003±1.24e+001↑	1.27e+003±1.16e+001	1.18e+003±1.42e+001↑	1.26e+003±2.66e+001↑
SaDE	1.28e+003±2.28e+001↑	1.21e+003±3.54e+001↑	1.29e+003±1.91e+001↑	1.22e+003±1.45e+001↑	1.31e+003±1.75e+001↑
CoDE	1.23e+003±1.33e+001↑	1.20e+003±1.11e+001↑	1.24e+003±8.40e+000↓	1.22e+003±4.76e+000↑	1.37e+003±1.17e+001↑
Pro DE/rand/1/bin	1.21e+003±1.47e+001↓	1.17e+003±1.55e+001↑	1.22e+003±1.56e+001↓	1.19e+003±1.44e+001↑	1.24e+003±1.23e+001↑
EPSDE	1.22e+003±1.63e+001	1.19e+003±1.61e+001↑	1.22e+003±1.16e+001↓	1.19e+003±6.81e+000↑	1.31e+003±1.16e+001↑

↑ and ↓ denote the same meanings as in Table II.

We also study the sensitivity of the parameter a in the following equation (Eq.(19) in the paper):

$$\sigma_{j,G} = \exp\left(\frac{-a \cdot k}{D}\right) \cdot \bar{\sigma}_{j,G} \tag{2}$$

Table VIII summarizes the results of average errors over 30 independent runs for AEPD-JADE algorithm with different values of a=$\{0.0001, 0.0002, \ldots, 0.0006\}$. Table IX summarizes the statistical results of Table VIII. From the results, it can be seen that AEPD-JADE with a=0.0005 performs best. Therefore, we choose 0.0005 as the default value of a.

TABLE VI

AVERAGE ERROR VALUES ± STANDARD DEVIATIONS ARCHIVED BY AEPD-JADE WITH DIFFERENT VALUES OF c IN EQ. (1a) ON THE 25 30-DIMENSIONAL CEC05 BENCHMARK FUNCTIONS OVER 30 INDEPENDENT RUNS.

	f_1	f_2	f_3	f_4	f_5
$c = 10^{-1}$	3.79e-014±2.73e-014	1.42e-012±2.45e-012	3.22e-014±2.86e-014	1.52e+000±3.29e+000	2.56e-002±4.75e-002
$c = 10^{-2}$	2.84e-014±2.89e-014	2.22e-013±1.17e-013	4.17e-014±2.56e-014	**8.55e-002±9.32e-002**	1.50e-002±2.53e-002
$c = 10^{-3}$	**0.00e+000±0.00e+000**	1.17e-013±4.30e-013	**0.00e+000±0.00e+000**	1.09e-001±1.57e-001	1.14e-002±2.84e-002
$c = 10^{-4}$	3.41e-014±2.83e-014	**1.04e-013±3.68e-014**	3.03e-014±2.88e-014	9.24e-002±1.54e-001	**8.43e-003±1.99e-002**
$c = 10^{-5}$	3.22e-014±2.86e-014	1.10e-013±3.64e-014	2.84e-014±2.89e-014	8.92e-002±1.54e-001	1.02e-002±2.69e-002
	f_6	f_7	f_8	f_9	f_{10}
$c = 10^{-1}$	4.17e-007±1.44e-006	1.28e-002±1.15e-002	2.09e+001±5.33e-002	3.98e-014±2.65e-014	6.23e+001±1.55e+001
$c = 10^{-2}$	**2.58e-008±9.49e-008**	1.28e-002±1.15e-002	2.10e+001±4.58e-002	3.32e-002±1.82e-001	5.21e+001±1.15e+001
$c = 10^{-3}$	5.32e-001±1.38e+000	1.28e-002±1.15e-002	2.09e+001±6.32e-002	**0.00e+000±0.00e+000**	**3.73e+001±7.85e+000**
$c = 10^{-4}$	3.59e+000±5.25e+000	**1.09e-002±1.15e-002**	**2.09e+001±7.11e-002**	3.03e-014±2.88e-014	4.10e+001±9.82e+000
$c = 10^{-5}$	7.47e+000±7.32e+000	1.13e-002±1.13e-002	2.09e+001±7.22e-002	3.22e-014±2.86e-014	4.22e+001±1.06e+001
	f_{11}	f_{12}	f_{13}	f_{14}	f_{15}
$c = 10^{-1}$	1.34e+001±2.62e+000	2.34e+003±3.50e+003	1.60e+000±6.38e-001	1.25e+001±6.35e-001	1.00e+002±6.99e-012
$c = 10^{-2}$	1.17e+001±3.49e+000	2.76e+003±3.66e+003	**1.18e+000±5.76e-001**	1.13e+001±7.64e-001	1.00e+002±4.10e-013
$c = 10^{-3}$	**9.24e+000±2.43e+000**	**1.14e+003±2.35e+003**	1.29e+000±6.34e-001	**1.05e+001±5.99e-001**	**1.00e+002±2.89e-014**
$c = 10^{-4}$	1.01e+001±2.87e+000	1.75e+003±2.27e+003	1.91e+000±8.31e-001	1.07e+001±6.31e-001	1.00e+002±4.47e-013
$c = 10^{-5}$	9.97e+000±2.74e+000	1.68e+003±2.16e+003	2.21e+000±1.16e+000	1.08e+001±6.48e-001	1.00e+002±4.60e-013
	f_{16}	f_{17}	f_{18}	f_{19}	f_{20}
$c = 10^{-1}$	5.60e+002±2.59e+002	2.22e+002±2.42e+002	1.07e+003±1.54e+002	1.04e+003±4.04e+001	1.04e+003±2.58e+001
$c = 10^{-2}$	3.69e+002±2.93e+002	1.02e+002±3.78e-001	8.80e+002±2.98e+002	8.77e+002±2.65e+002	9.87e+002±1.32e+002
$c = 10^{-3}$	1.19e+002±1.05e+002	1.02e+002±2.96e-001	4.43e+002±2.91e+002	4.35e+002±2.74e+002	**9.62e+002±1.27e+002**
$c = 10^{-4}$	1.19e+002±1.07e+002	1.02e+002±4.01e-001	**4.19e+002±2.71e+002**	**3.22e+002±1.18e+002**	9.64e+002±1.28e+002
$c = 10^{-5}$	**1.19e+002±1.03e+002**	**1.02e+002±3.92e-001**	4.40e+002±2.87e+002	3.24e+002±1.30e+002	9.63e+002±1.28e+002
	f_{21}	f_{22}	f_{23}	f_{24}	f_{25}
$c = 10^{-1}$	1.20e+003±1.95e+001	**5.34e+002±4.13e+002**	1.23e+003±1.80e+001	1.07e+003±1.76e+001	1.11e+003±1.64e+001
$c = 10^{-2}$	1.19e+003±1.87e+001	7.14e+002±4.67e+002	1.22e+003±2.01e+001	**1.06e+003±1.39e+001**	1.10e+003±1.68e+001
$c = 10^{-3}$	1.17e+003±1.78e+001	8.92e+002±4.11e+002	1.23e+003±2.27e+001	1.07e+003±1.55e+001	**1.08e+003±1.67e+002**
$c = 10^{-4}$	1.17e+003±1.46e+001	9.42e+002±3.71e+002	1.20e+003±1.33e+001	1.07e+003±1.11e+001	1.11e+003±1.97e+001
$c = 10^{-5}$	**1.17e+003±1.29e+001**	9.96e+002±3.12e+002	**1.20e+003±1.31e+001**	1.07e+003±1.16e+001	1.11e+003±1.87e+001

TABLE VII

THE STATISTICAL RESULTS OF TABLE VI: $b/n/w$, WHERE b, n AND w DENOTE THE NUMBER OF FUNCTIONS ON WHICH AEPD-JADE WITH THE VALUE OF c IN THE FIRST COLUMN IS SIGNIFICANTLY BETTER THAN, STATISTICALLY EQUIVALENT TO, AND SIGNIFICANTLY WORSE THAN WITH THE VALUE OF c IN THE CURRENT ROW, RESPECTIVELY.

	$c = 10^{-1}$	$c = 10^{-2}$	$c = 10^{-3}$	$c = 10^{-4}$	$c = 10^{-5}$
$c = 10^{-1}$	—	0/10/15	1/6/18	2/9/14	3/8/14
$c = 10^{-2}$	15/10/0	—	1/7/17	3/11/11	3/11/11
$c = 10^{-3}$	18/6/1	17/7/1	—	8/13/4	8/11/6
$c = 10^{-4}$	14/9/2	11/11/3	4/13/8	—	2/22/1
$c = 10^{-5}$	14/8/3	11/11/3	6/11/8	1/22/2	—

TABLE VIII

AVERAGE ERROR VALUES ± STANDARD DEVIATIONS ARCHIVED BY AEPD-JADE WITH DIFFERENT VALUES OF a IN EQ. (2) ON THE 25 30-DIMENSIONAL CEC05 BENCHMARK FUNCTIONS OVER 30 INDEPENDENT RUNS.

	f_1	f_2	f_3	f_4	f_5
$a = 0.0001$	3.41e-014±2.83e-014	1.25e-013±4.81e-014	3.60e-014±2.79e-014	1.15e-001±1.15e-001	1.35e-002±2.75e-002
$a = 0.0002$	3.03e-014±2.88e-014	3.45e-011±1.88e-010	3.60e-014±2.79e-014	2.17e-001±5.83e-001	1.38e-002±2.85e-002
$a = 0.0003$	3.22e-014±2.86e-014	1.27e-013±5.72e-014	3.60e-014±2.79e-014	8.59e-002±1.25e-001	1.20e-002±2.57e-002
$a = 0.0004$	3.79e-014±2.73e-014	1.21e-013±1.01e-013	3.41e-014±2.83e-014	**6.94e-002±1.01e-001**	1.03e-002±2.31e-002
$a = 0.0005$	**0.00e+000±0.00e+000**	1.17e-013±4.30e-013	**0.00e+000±0.00e+000**	1.09e-001±1.57e-001	1.14e-002±2.84e-002
$a = 0.0006$	1.89e-014±2.73e-014	**1.10e-013±4.46e-014**	3.22e-014±2.86e-014	7.86e-002±1.34e-001	**8.17e-003±2.04e-002**
	f_6	f_7	f_8	f_9	f_{10}
$a = 0.0001$	9.80e-001±2.20e+000	1.17e-002±1.10e-002	2.09e+001±4.89e-002	4.74e-014±2.15e-014	4.58e+001±1.09e+001
$a = 0.0002$	**4.02e-001±1.22e+000**	1.14e-002±1.08e-002	**2.09e+001±5.70e-002**	4.55e-014±2.31e-014	4.17e+001±8.99e+000
$a = 0.0003$	9.34e-001±2.51e+000	**1.09e-002±1.09e-002**	2.10e+001±4.39e-002	4.93e-014±1.97e-014	3.83e+001±8.23e+000
$a = 0.0004$	4.28e-001±1.22e+000	1.11e-002±1.06e-002	2.10e+001±5.22e-002	4.55e-014±2.31e-014	**3.68e+001±8.36e+000**
$a = 0.0005$	5.32e-001±1.38e+000	1.28e-002±1.15e-002	2.09e+001±6.32e-002	**0.00e+000±0.00e+000**	3.73e+001±7.85e+000
$a = 0.0006$	6.71e-001±1.53e+000	1.16e-002±1.09e-002	2.09e+001±5.71e-002	2.65e-014±2.88e-014	4.04e+001±8.49e+000
	f_{11}	f_{12}	f_{13}	f_{14}	f_{15}
$a = 0.0001$	2.61e+001±1.84e+000	1.46e+003±2.26e+003	1.03e+000±4.77e-001	1.31e+001±2.26e-001	1.00e+002±4.10e-013
$a = 0.0002$	1.97e+001±6.89e+000	1.53e+003±3.12e+003	1.25e+000±6.56e-001	1.27e+001±2.70e-001	1.00e+002±3.46e-013
$a = 0.0003$	9.49e+000±2.60e+000	**7.16e+002±2.01e+003**	**9.98e-001±5.89e-001**	1.16e+001±5.29e-001	1.00e+002±4.10e-013
$a = 0.0004$	9.93e+000±2.24e+000	1.67e+003±3.04e+003	1.11e+000±4.87e-001	1.11e+001±6.03e-001	1.00e+002±4.55e-013
$a = 0.0005$	**9.24e+000±2.43e+000**	1.14e+003±2.35e+003	1.29e+000±6.34e-001	**1.05e+001±5.99e-001**	**1.00e+002±2.89e-014**
$a = 0.0006$	1.07e+001±2.87e+000	8.43e+002±2.39e+003	1.29e+000±5.37e-001	1.08e+001±6.28e-001	1.00e+002±4.55e-013
	f_{16}	f_{17}	f_{18}	f_{19}	f_{20}
$a = 0.0001$	1.00e+002±3.71e-013	1.23e+002±1.18e+002	3.91e+002±2.37e+002	**3.21e+002±1.14e+002**	9.25e+002±2.15e+002
$a = 0.0002$	1.19e+002±1.04e+002	1.02e+002±3.84e-001	3.24e+002±1.29e+002	3.22e+002±1.18e+002	9.49e+002±1.79e+002
$a = 0.0003$	1.00e+002±4.58e-013	1.02e+002±4.49e-001	**3.00e+002±5.96e-013**	3.24e+002±1.31e+002	**8.43e+002±2.77e+002**
$a = 0.0004$	**1.00e+002±4.47e-013**	1.02e+002±2.74e-001	3.49e+002±1.86e+002	3.45e+002±1.71e+002	9.57e+002±1.26e+002
$a = 0.0005$	1.19e+002±1.05e+002	1.02e+002±2.96e-001	4.43e+002±2.91e+002	4.35e+002±2.74e+002	9.62e+002±1.27e+002
$a = 0.0006$	1.58e+002±1.77e+002	**1.02e+002±2.22e-001**	4.90e+002±3.22e+002	5.03e+002±3.17e+002	9.85e+002±2.31e+001
	f_{21}	f_{22}	f_{23}	f_{24}	f_{25}
$a = 0.0001$	**1.17e+003±1.54e+001**	1.08e+003±2.88e+002	1.20e+003±1.75e+001	1.09e+003±7.28e+000	1.12e+003±2.50e+002
$a = 0.0002$	1.18e+003±2.06e+001	9.58e+002±3.75e+002	**1.20e+003±1.20e+001**	1.09e+003±6.69e+000	1.18e+003±1.47e+001
$a = 0.0003$	1.17e+003±1.54e+001	**8.13e+002±4.45e+002**	1.20e+003±1.45e+001	1.09e+003±6.91e+000	**1.04e+003±2.86e+002**
$a = 0.0004$	1.17e+003±1.77e+001	8.14e+002±4.49e+002	1.21e+003±1.42e+001	1.08e+003±6.02e+000	1.08e+003±1.67e+002
$a = 0.0005$	1.17e+003±1.78e+001	8.92e+002±4.11e+002	1.23e+003±2.27e+001	1.07e+003±1.55e+001	1.08e+003±1.67e+002
$a = 0.0006$	1.17e+003±1.50e+001	8.84e+002±3.78e+002	1.21e+003±1.79e+001	**1.05e+003±1.13e+001**	1.10e+003±1.45e+001

TABLE IX

THE STATISTICAL RESULTS OF TABLE VIII: $b/n/w$, WHERE b, n AND w DENOTE THE NUMBER OF FUNCTIONS ON WHICH AEPD-JADE WITH THE VALUE OF a IN THE FIRST COLUMN IS SIGNIFICANTLY BETTER THAN, STATISTICALLY EQUIVALENT TO, AND SIGNIFICANTLY WORSE THAN WITH THE VALUE OF a IN THE CURRENT ROW, RESPECTIVELY.

	$a = 0.0001$	$a = 0.0002$	$a = 0.0003$	$a = 0.0004$	$a = 0.0005$	$a = 0.0006$
$a = 0.0001$	—	1/21/3	0/17/8	0/17/8	4/8/13	2/12/11
$a = 0.0002$	3/21/1	—	1/19/5	0/20/5	3/11/11	2/14/9
$a = 0.0003$	8/17/0	5/19/1	—	1/22/2	6/11/8	6/14/5
$a = 0.0004$	8/17/0	5/20/0	2/22/1	—	4/14/7	1/20/4
$a = 0.0005$	13/8/4	11/11/3	8/11/6	7/14/4	—	8/12/5
$a = 0.0006$	11/12/2	9/14/2	5/14/6	4/20/1	5/12/8	—