Table 1: Results of the eight algorithms for the CEC 2020 benchmark test suite when $D = 10$ with the Wilcoxon rank sum test. "+" or "−" denotes that the current result is significantly better or statistical worse than the result of SMSDE in terms of the Wilcoxon rank sum test at a 0.05 significance level, respectively. Meanwhile, "≈" represents that there is no significant difference

Function	Average (standard deviation)							
	IMODE	AGSK	NL-SHADE-RSP	EA4eig	NL-SHADE-LBC	APGSK-IMODE-FL	AMCDE	SMSDE
F1	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00e+00	0.00E+00
	(0.00E+00)≈	(0.00E+00)≈	(0.00E+00)≈	(0.00E+00)≈	(0.00E+00)≈	(0.00E+00)≈	(0.00E+00)≈	(0.00E+00)
F2	3.93E+00	3.42E+01	7.03E-01	4.42E+00	2.47E-01	6.04E+00	5.52E+00	3.28E+00
	(3.41E+00)≈	(3.86E+01)−	(2.06E+00)+	(5.10E+00)≈	(5.94E-01)+	(4.80E+00)−	(3.11E+00)−	(2.35E+00)
F3	1.24E+01	9.20E+00	7.97E+00	1.07E+01	1.04E+01	1.20E+01	9.91E+00	1.19E+01
	(7.58E-01)≈	(4.20E+00)≈	(1.85E+01)+	(1.22E+00)+	(2.35E-02)+	(7.73E-01)≈	(3.05E+00)+	(1.05E+00)
F4	2.96E-03	6.01E-01	0.00E+00	3.08E-01	1.66E-01	1.14E-01	0.00E+00	6.92E-03
	(4.60E-03)≈	(1.40E-01)−	(0.00E+00)+	(7.35E-02)−	(2.97E-02)−	(7.40E-02)−	(0.00E+00)+	(1.08E-02)
F5	4.23E-01	2.91E-01	2.47E-01	5.55E-02	5.69E+00	5.51E-01	1.87E-01	1.23E-01
	(3.88E-01)−	(2.16E-01)−	(7.64E-02)≈	(9.36E-02)+	(2.13E+01)−	(4.05E-01)−	(1.38E-01)≈	(2.28E-01)
F6	1.20E-01	3.76E-01	6.90E-02	4.78E-02	1.13E-01	7.30E-02	3.97E-02	8.82E-02
	(7.22E-02)≈	(0.00E+00)−	(5.83E-03)+	(9.67E-02)+	(1.53E-01)−	(9.29E-02)+	(2.77E-02)+	(5.73E-02)
F7	6.76E-04	1.24E-03	1.10E-03	2.09E-02	1.36E-01	8.52E-04	1.28E-04	2.65E-04
	(7.30E-04)−	(1.82E-03)−	(1.37E-06)−	(7.96E-02)−	(2.01E-01)−	(1.53E-03)−	(1.61E-04)≈	(4.62E-04)
F8	2.72E+00	2.39E+01	3.29E+00	1.00E+02	1.00E+02	3.20E+01	2.45E+00	4.31E+00
	(7.46E+00)≈	(3.03E+01)−	(5.70E+01)≈	(0.00E+00)−	(0.00E+00)−	(3.62E+01)−	(7.27E+00)≈	(7.86E+00)
F9	4.15E+01	7.00E+01	6.44E+01	2.56E+02	2.57E+02	8.85E+01	6.43E+01	5.98E+01
	(4.38E+01)≈	(4.66E+01)≈	(2.28E+03)≈	(9.65E+01)−	(1.03E+02)−	(3.11E+01)−	(4.80E+01)≈	(4.48E+01)
F10	3.98E+02	3.18E+02	3.68E+02	4.09E+02	4.08E+02	3.58E+02	3.68E+02	1.36E+02
	(3.42E12)−	(1.34E+02)−	(8.25E+03)−	(1.96E+01)−	(1.93E+01)−	(1.03E+02)−	(9.08E+01)−	(9,21E+01)
+/−/≈	0/3/7	0/7/3	4/2/4	3/5/2	2/7/1	1/7/2	3/2/5	

Table 2: Results of the eight algorithms for the CEC 2020 benchmark test suite when $D = 20$ with the Wilcoxon rank sum test. "+" or "−" denotes that the current result is significantly better or statistical worse than the result of SMSDE in terms of the Wilcoxon rank sum test at a 0.05 significance level, respectively. Meanwhile, "≈" represents that there is no significant difference

Function	Average (standard deviation)							
	IMODE	AGSK	NL-SHADE-RSP	EA4eig	NL-SHADE-LBC	APGSK-IMODE-FL	AMCDE	SMSDE
F1	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	(0.00E+00)≈	(0.00E+00)≈	(0.00E+00)≈	(0.00E+00)≈	(0.00E+00)≈	(0.00E+00)≈	(0.00E+00)≈	(0.00E+00)
F2	3.46E-01	1.41E+00	1.98E-02	3.53E+00	3.17E-03	2.63E-01	1.25E+00	1.93E-01
	(5.66E-01)−	(1.10E+00)−	(4.36E-04)+	(2.30E+00)−	(9.36E-03)+	(5.13E-01)≈	(1.01E+00)−	(4.23E-01)
F3	2.05E+01	2.04E+01	2.04E+01	2.22E+01	2.04E+01	2.04E+01	2.04E+01	2.04E+01
	(1.24E-01)−	(0.00E+00)+	(0.00E+00)≈	(8.19E-01)−	(0.00E+00)≈	(0.00E+00)+	(7.77E-02)≈	(0.00E-01)
F4	5.00E-01	7.89E-01	0.00E+00	7.24E-01	3.81E-01	5.50E-01	4.74E-01	3.44E-01
	(8.08E-02)−	(9.00E-02)−	(0.00E+00)+	(1.32E-01)−	(5.69E-02)≈	(5.73E-02)−	(8.27E-02)−	(9.26E-02)
F5	1.05E+01	3.67E+01	1.37E+01	1.26E+01	9.83E+01	6.57E+00	4.24E+00	2.86E+01
	(4.11E+00)−	(3.51E+01)−	(9.28E+02)−	(2.97E+01)≈	(7.09E+01)−	(3.41E+00)−	(2.77E+00)≈	(1.21E+01)
F6	2.87E-01	4.49E+02	1.38E-01	1.63E-01	5.94E-01	2.03E-01	1.77E-01	2.02E-01
	(7.40E-02)−	(2.89E-13)−	(1.83E-03)+	(9.35E-02)+	(1.07E-01)−	(6.80E-02)≈	(1.24E-01)≈	(6.10E-02)
F7	5.10E-01	4.29E-01	2.05E-01	5.72E-01	1.90E+01	1.43E+00	4.85E-01	1.62E+00
	(1.78E-01)−	(1.81E-01)−	(7.73E-03)≈	(1.56E+00)−	(4.28E+01)−	(2.88E+00)−	(1.33E-01)−	(8.55E-02)
F8	8.42E+01	1.00E+02	8.80E+01	1.00E+02	1.00E+02	9.82E+01	9.23E+01	7.50E+00
	(1.83E+01)−	(0.00E+00)−	(3.29E+02)−	(2.12E-13)−	(0.00E+00)−	(6.09E+00)−	(1.59E+01)−	(1.75E+00)
F9	9.67E+01	1.00E+02	1.00E+02	4.06E+02	3.75E+02	1.32E+02	9.80E+01	9.17E+01
	(1.83E+01)≈	(0.00E+00)≈	(3.43E-26)≈	(3.24E+00)−	(1.90E+01)−	(9.98E+01)−	(1.07E+01)≈	(2.64E+01)
F10	4.00E+02	3.99E+02	3.99E+02	4.06E+02	4.14E+02	4.05E+02	4.08E+02	3.99E+02
	(4.44E-01)−	(2.01E+00)+	(1.19E-01)+	(1.53E-02)−	(1.00E-02)−	(5.66E+00)−	(7.20E+00)−	(2.00E+00)
+/−/≈	0/8/2	2/6/2	4/2/4	1/7/2	1/6/3	1/6/3	0/5/5	

Table 3: Results of the eight algorithms for the CEC 2022 benchmark test suite when $D = 10$ with the Wilcoxon rank sum test. "+" or "−" denotes that the current result is significantly better or statistical worse than the result of SMSDE in terms of the Wilcoxon rank sum test at a 0.05 significance level, respectively. Meanwhile, "≈" represents that there is no significant difference

Function	Average (standard deviation)							
	IMODE	AGSK	NL-SHADE-RSP	EA4eig	NL-SHADE-LBC	APGSK-IMODE-FL	AMCDE	SMSDE
F1	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	(0.00E+00)≈	(0.00E+00)≈	(0.00E+00)≈	(0.00E+00)≈	(0.00E+00)≈	(0.00E+00)≈	(0.00E+00)≈	(0.00E+00)
F2	0.00E+00	0.00E+00	0.00E+00	1.20E+00	1.33E-01	0.00E+00	0.00E+00	0.00E+00
	(0.00E+00)≈	(0.00E+00)≈	(0.00E+00)≈	(1.86E+00)−	(7.16E-01)≈	(0.00E+00)≈	(0.00E+00) ≈	(0.00E+00)
F3	0.00E+00	3.79E-14	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	(0.00E+00)≈	(5.45E-14)−	(0.00E+00)≈	(0.00E+00)≈	(0.00E+00)≈	(0.00E+00)≈	(0.00E+00)≈	(0.00E+00)
F4	6.70E+00	4.25E+00	9.06E+00	3.32E-01	5.97E-01	3.25E+00	2.26E+00	8.16E+00
	(1.54E+00)+	(1.38E+00)+	(5.05E+00)≈	(6.58E-01)+	(5.51E-01)+	(1.11E+00)+	(1.17E+00)+	(2.27E+00)
F5	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	(0.00E+00)≈	(0.00E+00)≈	(0.00E+00)≈	(0.00E+00)≈	(0.00E+00)≈	(0.00E+00)≈	(0.00E+00)≈	(0.00E+00)
F6	1.22E-01	4.26E-02	3.48E-02	8.10E-03	2.19E-01	4.60E-02	6.66E-02	1.48E-02
	(9.16E-02)−	(2.63E-02)−	(5.61E-04)−	(3.65E-02)+	(1.76E-01)−	(4.05E-02)−	(6.93E-02)−	(1.03E-02)
F7	0.00E+00	7.58E-15	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	(0.00E+00)≈	(4.15E-14)≈	(0.00E+00)≈	(0.00E+00)≈	(0.00E+00)≈	(0.00E+00)≈	(0.00E+00)≈	(0.00E+00)
F8	8.53E-03	4.76E-02	2.23E-02	2.57E-03	4.12E-03	1.76E-02	8.12E-03	9.95E-03
	(1.06E-02)≈	(5.74E-02)−	(5.84E-04)≈	(4.74E-03)+	(5.83E-03)+	(4.11E-02)≈	(7.59E-03)≈	(9.73E-03)
F9	2.22E+02	2.10E+02	2.22E+02	1.86E+02	2.29E+02	2.14E+02	2.14E+02	1.80E+02
	(4.19E+01)−	(6.17E+01)−	(1.75E+03)−	(0.00E+00)−	(4.67E-06)−	(5.82E+01)−	(5.82E+01)−	(8.56E+01)
F10	1.70E+01	9.83E+01	0.00E+00	1.00E+02	1.03E+02	8.04E+01	9.50E-01	4.53E-01
	(3.35E+01)−	(6.14E+00)−	(0.00E+00)+	(4.02E-02)−	(1.79E+01)−	(4.03E+01)−	(1.52E+00)−	(1.16E+00)
F11	0.00E+00	2.43E-13	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	(0.00E+00)≈	(2.31E-13)−	(0.00E+00)≈	(0.00E+00)≈	(0.00E+00)≈	(0.00E+00)≈	(0.00E+00)≈	(0.00E+00)
F12	1.59E+02	1.59E+02	1.60E+02	1.46E+02	1.65E+02	1.59E+02	1.60E+02	1.59E+02
	(7.05E-01)≈	(2.89E-14)+	(1.33E+00)−	(2.45E+00)+	(3.99E-01)−	(4.87E-01)≈	(1.13E+00)−	(9.36E-01)
+/−/≈	1/3/8	2/6/4	1/3/8	4/3/5	2/4/6	1/3/8	1/4/7	

Table 4: Results of the eight algorithms for the CEC 2022 benchmark test suite when $D = 20$ with the Wilcoxon rank sum test. "+" or "−" denotes that the current result is significantly better or statistical worse than the result of SMSDE in terms of the Wilcoxon rank sum test at a 0.05 significance level, respectively. Meanwhile, "≈" represents that there is no significant difference

Function	Average (standard deviation)							
	IMODE	AGSK	NL-SHADE-RSP	EA4eig	NL-SHADE-LBC	APGSK-IMODE-FL	AMCDE	SMSDE
F1	0.00E+00 (0.00E+00)≈	1.89E-15 (1.04E-14)≈	0.00E+00 (0.00E+00)≈	0.00E+00 (0.00E+00)≈	0.00E+00 (0.00E+00)≈	0.00E+00 (0.00E+00)≈	0.00E+00 (0.00E+00)≈	0.00E+00 (0.00E+00)
F2	4.27E+01 (1.46E+01)−	1.63E+00 (8.20E+00)≈	3.62E+01 (3.39E+02)−	5.32E-01 (1.38E+00)−	4.91E+01 (9.54E-07)−	1.37E+01 (1.81E+01)−	3.46E+01 (1.94E+01)−	0.00E+00 (0.00E+00)
F3	0.00E+00 (0.00E+00)≈	1.10E-13 (2.08E-14)−	3.79E-15 (4.31E-28)≈	7.58E-15 (2.88E-14)≈	0.00E+00 (0.00E+00)≈	2.65E-14 (4.89E-14)−	0.00E+00 (0.00E+00)≈	0.00E+00 (0.00E+00)
F4	4.87E+01 (6.49E+00)≈	3.11E+01 (6.84E+00)+	5.19E+01 (7.50E+01)≈	8.59E+00 (3.32E+00)+	3.42E+00 (9.15E-01)+	2.05E+01 (3.85E+00)+	8.86E+00 (1.35E+01)+	4.88E+01 (7.57E+00)
F5	0.00E+00 (0.00E+00)≈	0.00E+00 (0.00E+00)≈	0.00E+00 (0.00E+00)≈	0.00E+00 (0.00E+00)≈	0.00E+00 (0.00E+00)≈	0.00E+00 (0.00E+00)≈	0.00E+00 (0.00E+00)≈	0.00E+00 (0.00E+00)
F6	2.88E-01 (7.98E-02)−	2.29E-01 (1.06E-01)−	4.44E-01 (1.56E-01)−	1.23E-01 (1.55E-01)+	5.18E-01 (4.21E-01)−	2.39E-01 (9.65E-02)−	3.19E-01 (8.74E-02)−	1.38E-01 (4.88E-02)
F7	1.96E+00 (7.58E-01)≈	1.19E+00 (1.27E+00)+	5.40E-02 (5.93E-02)+	2.40E+00 (3.56E+00)≈	8.34E-02 (1.60E-01)+	1.36E+00 (9.00E-01)≈	1.79E+00 (9.29E-01)≈	1.63E+00 (7.57E-01)
F8	1.62E+01 (4.19E+00)≈	1.76E+01 (5.42E+00)−	1.69E+01 (3.56E+01)−	1.63E+01 (7.56E+00)−	1.28E+01 (8.44E+00)≈	1.47E+01 (7.72E+00)≈	1.35E+01 (6.70E+00)≈	1.49E+01 (5.12E+00)
F9	1.81E+02 (8.67E-14)−	1.81E+02 (8.67E-14)−	1.81E+02 (7.52E-27)−	1.65E+02 (0.00E+00)−	1.81E+02 (6.33E-06)−	1.81E+02 (8.67E-14)−	1.81E+02 (8.67E-14)−	1.59E+02 (3.63E+01)
F10	0.00E+00 (0.00E+00)≈	1.00E+02 (1.87E-02)−	0.00E+00 (0.00E+00)≈	1.08E+02 (2.93E+01)−	1.00E+02 (1.99E-02)−	1.00E+02 (4.34E-02)−	0.00E+00 (0.00E+00)≈	0.00E+00 (0.00E+00)
F11	3.00E+02 (0.00E+00)−	2.00E+01 (7.61E+01)−	2.90E+02 (3.00E+03)−	3.23E+02 (4.30E+01)−	3.00E+02 (0.00E+00)−	1.20E+02 (1.49E+02)−	3.00E+02 (0.00E+00)−	2.00E+01 (7.61E+01)
F12	2.34E+02 (1.98E+00)≈	2.33E+02 (1.34E+00)+	2.38E+02 (1.22E+01)−	2.00E+02 (3.32E-04)+	2.37E+02 (3.69E+00)−	2.31E+02 (1.21E+00)+	2.32E+02 (1.68E+00)+	2.33E+02 (2.08E+00)
+/−/≈	0/4/8	3/6/3	1/6/5	3/5/4	2/6/4	2/6/4	2/4/6	

Table 5: Ablation Experiment

Function	IMODE	IMODE+	SMSDE
F1	0.00E+00 (0.00E+00)	0.00E+00 (0.00E+00)	0.00E+00 (0.00E+00)
F2	4.13E+00 (3.12E+00)	2.10E+00 (2.94E+00)	9.25E-01 (1.33E+00)
F3	1.61E+01 (3.53E-01)	1.59E+01 (3.28E-01)	1.55E+01 (2.42E+00)
F4	3.72E-01 (9.17E-02)	2.26E-01 (8.62E-02)	2.66E-01 (9.23E-02)
F5	8.11E+00 (3.66E+00)	3.42E+00 (1.77E+00)	4.12E+00 (1.98E+00)
F6	5.79E+00 (3.18E+00)	2.79E+00 (3.09E+00)	2.45E+00 (2.68E+00)
F7	6.30E-01 (2.24E-01)	4.75E-01 (1.35E-01)	2.17E-01 (1.16E-01)
F8	7.51E-01 (4.11E+00)	1.54E+00 (4.90E+00)	3.66E+00 (7.27E+00)
F9	9.67E+01 (1.83E+01)	8.67E+01 (3.46E+01)	9.67E+01 (1.83E+01)
F10	4.00E+02 (0.00E+00)	4.00E+02 (0.00E+00)	2.40E+02 (1.28E+02)

Table 6: Outcome of Friedman Test for results of the pre-experiment to select secondary mutation strategies. 1 represents the original secondary mutation strategy in IMODE, while the other numbers denote the additional secondary mutation strategies in sequence

Combination	1&2	1&2&3	1&2&3&4	1&2&3&5	1&2&3&6	1&2&3&6&7
Friedman ranking	4.27	3.05	3.73	3.91	2.64	3.41

Table 7: Outcome of Friedman Test for results of the pre-experiment to determine sequence of the selected secondary mutation strategies

Sequence	1&2&3&6	1&2&6&3	1&3&6&2	1&6&2&3	1&3&6&2	1&6&3&2	1&3&2&6
Friedman ranking	3.14	4.18	5.05	4.05	5.05	3.55	3.00