Multimodal Multi-objective Optimization: Comparative Study of the State-of-the-Art *Supplementary Material*

I. Overview

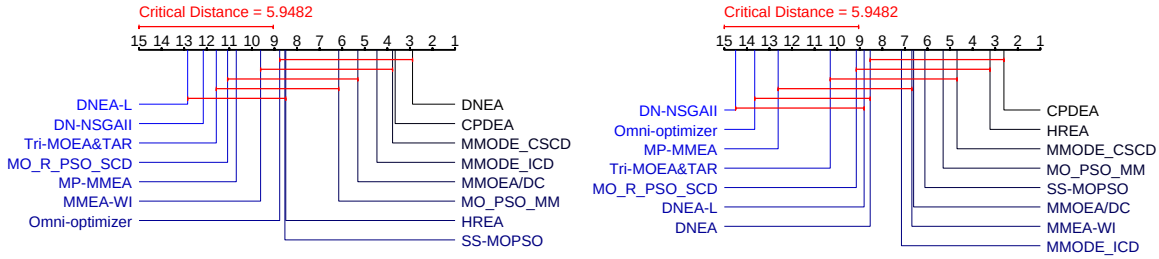
This is the supplementary material for Multimodal Multi-objective Optimization: Comparative Study of the State-of-the-Art. In this document, the detailed results (average values and variance of $IGDX$, IGD and $RPSP$) of the compared MMEAs on various MMOP test suites are given. In addition, some of the obtained PSs of all MMEAs are presented.

II. Results

To comprehensively compared the performances of MMEAs, four groups of MMOP test problems are adopted. It's worth mentioning that, all experiments are independently executed 30 times and the average results are used to present and analyze.

III. Performance comparison on CEC 2020 test problems

Fig. 1 shows the Friedman ranking critical differences of all compared MMEAs on part of the CEC 2020 test suite. In particular, if the distance of ranks of two MMEAs is less than the critical distance, it means that there is no significant difference of these two algorithms in terms of the Friedman ranks. Fig. 2 and Fig. 3 present the solutions distribution on MMF1 and MMF3 respectively.



(a) IGD (b) IGDX

Fig. 1. The critical difference of all compared MMEAs on part of the CEC 2020 test suite, where the red lines indicate that there is no significant difference in the Friedman ranks of the two MMEAs.

IV. Performance comparison on IDMP problems

TABLE I

AVERAGE AND VARIANCE OF IGD RESULTS OF THE COMPARED ALGORITHMS ON PART OF THE CEC 2020 MULTIMODAL TEST SUITE, WHERE THE BEST MEAN FOR EACH TEST INSTANCE IS HIGHLIGHTED.

Problems	Omni-optimizer	DN-NSGAII	MO_Ring_PSO_SCD	MO_PSO_MM	DNEA	Tri-MO EA&TAR	DNEA-L	CPDEA	SS-MOPSO	MMODE_CSCD	MP-MMEA	MMOEA/DC	MMODE_ICD	MMEA-WI	HREA
MMF1	3.88E-03	4.65E-03	3.73E-03	2.68E-03	2.61E-03	4.61E-03	3.97E-03	2.60E-03	3.25E-03	2.53E-03	3.75E-03	3.48E-03	3.07E-03	3.85E-03	3.70E-03
	5.30E-04	8.90E-04	2.05E-04	9.78E-05	1.42E-04	6.12E-04	3.42E-04	1.03E-04	2.58E-04	1.02E-04	2.50E-04	1.38E-04	1.79E-04	2.23E-04	1.99E-04
MMF2	2.90E-02	2.94E-02	2.06E-02	1.54E-02	2.03E-02	3.39E-02	1.81E-02	1.23E-02	1.48E-02	7.39E-03	2.80E-02	9.73E-03	1.33E-02	1.59E-02	1.81E-02
	2.30E-02	2.28E-02	4.27E-03	2.74E-03	8.31E-03	5.88E-02	3.68E-03	2.52E-03	2.21E-03	1.02E-03	1.35E-02	1.67E-03	1.81E-03	1.37E-02	7.64E-03
MMF3	1.74E-02	2.23E-02	1.69E-02	1.35E-02	1.73E-02	2.25E-02	1.83E-02	1.22E-02	1.28E-02	6.02E-03	2.36E-02	9.67E-03	1.19E-02	1.12E-02	1.69E-02
	1.38E-02	1.32E-02	3.54E-03	2.34E-03	5.44E-03	1.24E-02	3.83E-03	1.70E-03	1.67E-03	6.66E-04	8.29E-03	2.34E-03	1.55E-03	1.79E-03	4.16E-03
MMF4	2.86E-03	3.14E-03	3.59E-03	2.66E-03	2.32E-03	3.31E-02	4.55E-03	2.56E-03	3.46E-03	2.41E-03	5.55E-03	2.97E-03	2.41E-03	3.75E-03	3.31E-03
	2.71E-04	1.90E-04	2.89E-04	1.62E-04	1.54E-04	6.82E-02	3.29E-04	1.72E-04	3.87E-04	1.60E-04	9.39E-04	5.95E-04	1.70E-04	2.81E-04	2.45E-04
MMF5	3.38E-03	3.92E-03	3.68E-03	2.73E-03	2.57E-03	4.68E-03	4.66E-03	2.62E-03	3.09E-03	2.54E-03	3.72E-03	3.61E-03	3.27E-03	3.62E-03	3.58E-03
	5.48E-04	7.25E-04	1.43E-04	8.60E-05	1.14E-04	1.49E-03	3.16E-04	7.46E-05	1.91E-04	8.11E-05	1.85E-04	1.60E-04	2.10E-04	2.00E-04	2.67E-04
MMF6	3.11E-03	3.80E-03	3.57E-03	2.58E-03	2.40E-03	3.79E-03	4.60E-03	2.57E-03	3.24E-03	2.44E-03	3.44E-03	3.51E-03	2.82E-03	3.75E-03	3.59E-03
	1.81E-04	5.49E-04	1.90E-04	7.84E-05	6.50E-05	6.46E-04	2.80E-04	8.82E-05	3.37E-04	6.27E-05	1.39E-04	1.08E-04	1.32E-04	2.81E-04	1.91E-04
MMF7	3.17E-03	3.89E-03	3.81E-03	2.62E-03	2.38E-03	4.30E-03	4.11E-03	2.55E-03	4.85E-03	2.43E-03	3.65E-03	3.57E-03	2.47E-03	3.96E-03	3.72E-03
	3.37E-04	2.95E-04	2.38E-04	7.17E-05	1.14E-04	1.29E-03	2.49E-04	6.68E-05	3.68E-03	5.81E-05	2.06E-04	4.95E-04	1.18E-04	2.01E-04	1.99E-04
MMF8	3.26E-03	4.06E-03	4.77E-03	3.66E-03	2.63E-03	3.45E-03	5.26E-03	3.13E-03	3.28E-03	3.75E-03	5.63E-03	2.82E-03	2.74E-03	3.82E-03	3.93E-03
	2.44E-04	5.50E-04	3.04E-04	2.37E-04	7.58E-05	7.55E-05	5.03E-04	1.31E-04	1.79E-04	2.96E-04	1.48E-03	3.56E-04	2.18E-04	2.92E-04	2.05E-04
MMF9	1.30E-02	1.41E-02	1.56E-02	1.25E-02	6.29E-03	6.84E-02	1.52E-02	6.72E-03	2.51E-02	1.03E-02	1.05E-02	7.02E-03	1.26E-02	1.05E-02	1.95E-02
	1.41E-03	1.46E-03	1.24E-03	7.79E-04	5.02E-04	4.85E-03	1.29E-03	3.50E-04	5.52E-03	6.99E-04	7.20E-04	4.27E-04	1.14E-03	1.06E-03	4.98E-03
MMF14	9.76E-02	1.11E-01	8.08E-02	7.86E-02	6.02E-02	8.66E-02	9.19E-02	5.75E-02	8.85E-02	7.29E-02	8.70E-02	6.64E-02	6.99E-02	6.94E-02	6.59E-02
	4.42E-03	9.91E-03	2.62E-03	2.15E-03	1.64E-03	1.11E-03	3.56E-03	9.41E-04	4.07E-03	1.59E-03	6.64E-03	1.26E-03	1.63E-03	1.13E-03	1.11E-03
MMF1_e	2.40E-02	2.45E-02	1.18E-02	8.99E-03	4.43E-03	1.92E-02	8.84E-03	1.06E-02	9.55E-03	1.35E-02	7.03E-03	5.82E-03	8.59E-03	2.26E-02	9.19E-03
	3.08E-02	1.62E-02	1.17E-03	1.05E-03	1.06E-03	3.53E-02	2.22E-03	1.31E-03	1.32E-03	2.02E-03	1.23E-03	9.21E-04	2.87E-03	9.12E-03	1.97E-03
MMF1_z	3.07E-03	3.46E-03	3.61E-03	2.61E-03	2.46E-03	4.39E-03	3.93E-03	2.61E-03	3.10E-03	2.46E-03	3.51E-03	3.30E-03	2.55E-03	3.76E-03	3.30E-03
	3.34E-04	3.03E-04	1.74E-04	8.43E-05	1.23E-04	7.10E-04	3.01E-04	9.03E-05	1.93E-04	7.44E-05	1.58E-04	3.46E-04	1.28E-04	2.73E-04	1.28E-04
MMF14_a	1.05E-01	1.21E-01	7.88E-02	7.45E-02	5.92E-02	7.92E-02	1.06E-01	5.92E-02	7.76E-02	7.23E-02	1.01E-01	6.74E-02	7.26E-02	7.43E-02	6.87E-02
	5.18E-03	5.44E-03	2.12E-03	1.74E-03	1.46E-03	1.58E-03	4.01E-03	9.18E-04	2.21E-03	1.53E-03	9.99E-03	2.06E-03	1.80E-03	1.62E-03	1.20E-03

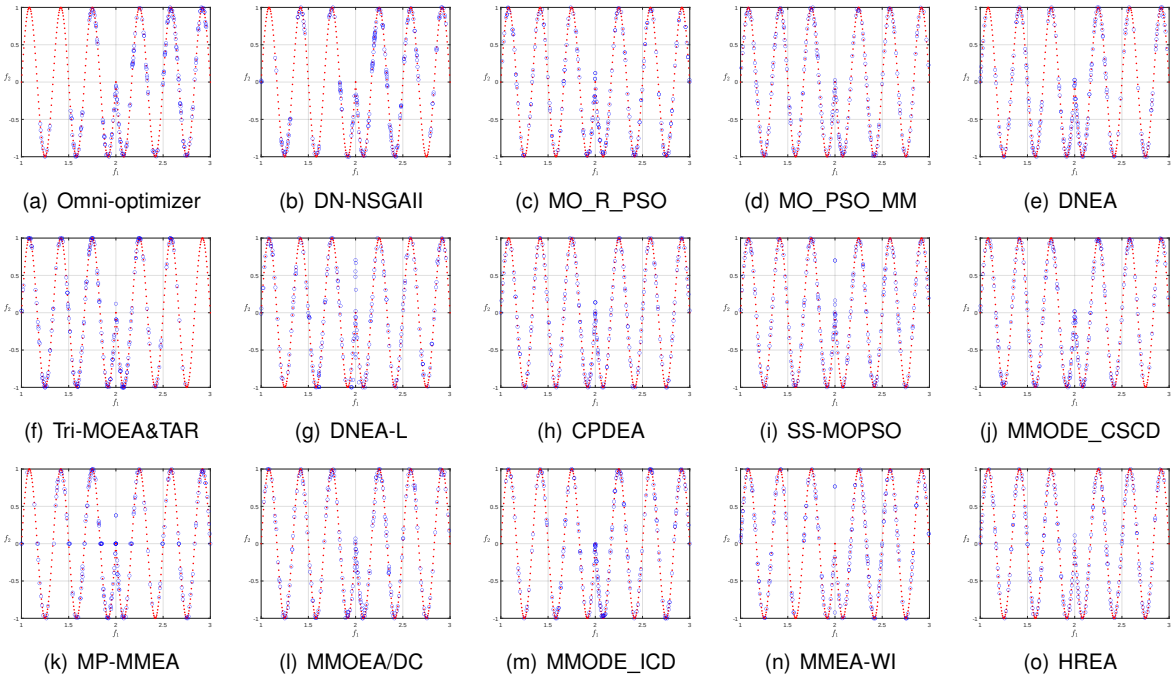
TABLE II

AVERAGE AND VARIANCE OF IGDX RESULTS OF THE COMPARED ALGORITHMS ON PART OF THE CEC 2020 MULTIMODAL TEST SUITE, WHERE THE BEST MEAN FOR EACH TEST INSTANCE IS HIGHLIGHTED.

Problems	Omni-optimizer	DN-NSGAII	MO_Ring_PSO_SCD	MO_PSO_MM	DNEA	Tri-MO EA&TAR	DNEA-L	CPDEA	SS-MOPSO	MMODE_CSCD	MP-MMEA	MMOEA/DC	MMODE_ICD	MMEA-WI	HREA
MMF1	9.56E-02	9.68E-02	4.81E-02	4.01E-02	4.97E-02	7.27E-02	4.56E-02	3.72E-02	4.10E-02	4.24E-02	6.62E-02	4.48E-02	5.51E-02	4.45E-02	3.88E-02
	1.70E-02	1.48E-02	2.06E-03	1.34E-03	7.26E-03	1.03E-02	2.43E-03	1.05E-03	1.53E-03	1.58E-03	1.16E-02	1.37E-03	4.05E-03	2.09E-03	1.90E-03
MMF2	1.27E-01	1.33E-01	3.98E-02	2.86E-02	7.03E-02	7.21E-02	3.44E-02	2.82E-02	2.97E-02	2.00E-02	6.21E-02	1.70E-02	1.94E-02	3.90E-02	4.04E-02
	7.72E-02	7.03E-02	1.38E-02	6.95E-03	3.56E-02	4.53E-02	7.94E-03	4.61E-03	1.03E-02	1.02E-02	2.35E-02	4.40E-03	3.19E-03	1.61E-02	1.22E-02
MMF3	9.60E-02	1.04E-01	4.79E-02	4.23E-02	8.83E-02	8.17E-02	4.18E-02	4.51E-02	4.13E-02	4.02E-02	7.21E-02	3.68E-02	3.93E-02	5.07E-02	5.46E-02
	3.17E-02	3.64E-02	1.10E-02	6.04E-03	2.94E-02	3.29E-02	6.41E-03	4.05E-03	6.31E-03	7.25E-03	2.12E-02	7.40E-03	3.51E-03	9.45E-03	9.59E-03
MMF4	7.84E-02	8.58E-02	2.77E-02	2.35E-02	2.23E-02	9.74E-02	3.10E-02	1.95E-02	2.47E-02	2.21E-02	8.15E-02	2.65E-02	2.40E-02	2.52E-02	1.91E-02
	1.60E-02	1.87E-02	1.71E-03	1.25E-03	3.62E-03	1.45E-01	2.16E-03	5.12E-04	2.00E-03	8.59E-04	2.30E-02	3.07E-03	1.88E-03	1.76E-03	7.48E-04
MMF5	1.69E-01	1.77E-01	8.44E-02	7.34E-02	8.55E-02	1.17E-01	8.30E-02	6.48E-02	7.40E-02	7.29E-02	1.18E-01	7.84E-02	9.98E-02	7.47E-02	6.38E-02
	2.02E-02	2.55E-02	4.59E-03	3.60E-03	7.12E-03	1.50E-02	4.75E-03	1.83E-03	3.05E-03	3.04E-03	1.12E-02	3.08E-03	8.10E-03	3.86E-03	2.75E-03
MMF6	1.42E-01	1.43E-01	7.27E-02	6.34E-02	7.08E-02	9.24E-02	7.31E-02	5.74E-02	6.56E-02	6.40E-02	1.08E-01	6.75E-02	7.75E-02	6.78E-02	5.45E-02
	1.78E-02	1.44E-02	3.50E-03	2.79E-03	8.37E-03	9.09E-03	3.61E-03	1.53E-03	2.77E-03	3.02E-03	1.40E-02	2.19E-03	4.06E-03	3.65E-03	1.42E-03
MMF7	4.93E-02	5.14E-02	2.65E-02	2.12E-02	2.40E-02	4.71E-02	2.69E-02	1.95E-02	2.44E-02	2.29E-02	4.21E-02	2.80E-02	2.28E-02	2.49E-02	1.96E-02
	9.40E-03	1.07E-02	1.82E-03	8.65E-04	3.78E-03	2.06E-02	2.29E-03	9.21E-04	1.92E-03	2.15E-03	8.90E-03	2.36E-03	3.15E-03	2.27E-03	9.46E-04
MMF8	3.24E-01	2.92E-01	6.62E-02	5.39E-02	1.54E-01	3.56E-01	9.30E-02	5.23E-02	5.59E-02	5.43E-02	3.90E-01	6.52E-02	1.28E-01	8.09E-02	4.97E-02
	1.37E-01	9.83E-02	5.22E-03	3.63E-03	4.77E-02	9.75E-02	1.94E-02	4.54E-03	5.53E-03	6.52E-03	1.83E-01	1.16E-02	3.56E-02	1.62E-02	6.73E-03
MMF9	2.10E-02	2.31E-02	8.02E-03	5.93E-03	4.92E-03	3.02E-03	9.24E-03	4.73E-03	7.06E-03	5.87E-03	8.25E-03	4.93E-03	4.83E-03	4.55E-03	6.09E-03
	5.20E-03	9.68E-03	5.53E-04	2.99E-04	4.09E-04	8.66E-05	8.51E-04	1.90E-04	4.95E-04	3.59E-04	3.36E-03	1.88E-04	3.41E-04	1.38E-04	9.44E-04
MMF14	8.94E-02	9.68E-02	5.37E-02	5.37E-02	4.53E-02	3.65E-02	6.23E-02	3.96E-02	5.74E-02	5.10E-02	6.42E-02	5.14E-02	4.22E-02	4.17E-02	3.77E-02
	5.34E-03	7.16E-03	1.46E-03	1.27E-03	1.22E-03	4.77E-04	2.51E-03	5.61E-04	2.64E-03	1.47E-03	7.33E-03	1.10E-03	7.89E-04	6.92E-04	4.34E-04
MMF1_e	1.44E+00	1.37E+00	5.22E-01	4.65E-01	1.83E+00	1.55E+00	3.32E-01	3.28E-01	3.93E-01	5.57E-01	2.23E+00	5.08E-01	1.20E+00	7.15E-01	3.08E-01
	7.13E-01	6.59E-01	2.38E-01	1.39E-01	6.83E-01	5.24E-01	6.66E-02	3.47E-02	9.93E-02	4.37E-01	6.70E-01	1.98E-01	4.99E-01	2.01E-01	2.79E-02
MMF1_z	7.12E-02	9.13E-02	3.50E-02	2.87E-02	3.87E-02	7.38E-02	3.44E-02	2.73E-02	3.05E-02	2.94E-02	6.01E-02	3.12E-02	4.96E-02	3.26E-02	2.70E-02
	1.37E-02	4.11E-02	2.14E-03	9.80E-04	6.42E-03	1.21E-02	1.78E-03	1.03E-03	1.54E-03	1.18E-03	1.15E-02	1.67E-03	7.53E-03	2.86E-03	1.61E-03
MMF14_a	1.11E-01	1.20E-01	6.07E-02	6.02E-02	5.46E-02	5.71E-02	8.80E-02	5.09E-02	6.02E-02	6.07E-02	9.85E-02	7.74E-02	5.84E-02	5.68E-02	4.71E-02
	7.57E-03	8.81E-03	1.89E-03	1.35E-03	1.43E-03	2.02E-03	3.39E-03	5.10E-04	1.31E-03	1.42E-03	8.05E-03	3.42E-03	1.68E-03	1.23E-03	5.52E-04

TABLE III
AVERAGE AND VARIANCE OF RPSP RESULTS OF THE COMPARED ALGORITHMS ON PART OF THE CEC 2020 MULTIMODAL TEST SUITE, WHERE THE BEST MEAN FOR EACH TEST INSTANCE IS HIGHLIGHTED.

Problems	Omni-optimizer	DN-NSGAII	MO_Ring_PSO_SCD	MO_PSO_MM	DNEA	Tri-MOEA&TAR	DNEA-L	CPDEA	SS-MOPSO	MMODE_CSCD	MP-MMEA	MMOEA/DC	MMODE_ICD	MMEA-WI	HREA
MMF1	9.82E-02	9.86E-02	4.85E-02	4.04E-02	5.02E-02	7.42E-02	4.57E-02	3.73E-02	4.13E-02	4.27E-02	6.66E-02	4.49E-02	5.53E-02	4.46E-02	3.89E-02
	1.95E-02	1.52E-02	2.16E-03	1.39E-03	8.05E-03	1.12E-02	2.47E-03	1.06E-03	1.63E-03	1.61E-03	1.21E-02	1.42E-03	4.13E-03	2.13E-03	1.98E-03
MMF2	1.57E-01	1.63E-01	4.26E-02	3.00E-02	7.68E-02	8.32E-02	3.54E-02	2.82E-02	3.14E-02	2.00E-02	6.66E-02	1.71E-02	1.94E-02	4.10E-02	4.23E-02
	1.29E-01	1.11E-01	1.56E-02	7.55E-03	4.32E-02	6.89E-02	8.78E-03	4.62E-03	1.14E-02	1.02E-02	2.96E-02	4.39E-03	3.19E-03	2.22E-02	1.48E-02
MMF3	1.04E-01	1.15E-01	5.04E-02	4.39E-02	9.35E-02	9.11E-02	4.29E-02	4.52E-02	4.30E-02	4.02E-02	7.61E-02	3.71E-02	3.93E-02	5.15E-02	5.69E-02
	3.74E-02	4.40E-02	1.17E-02	6.71E-03	3.13E-02	4.48E-02	7.05E-03	4.07E-03	6.80E-03	7.25E-03	2.52E-02	7.64E-03	3.51E-03	9.53E-03	1.14E-02
MMF4	7.90E-02	8.63E-02	2.80E-02	2.37E-02	2.23E-02	1.26E-01	3.11E-02	1.96E-02	2.48E-02	2.22E-02	8.20E-02	2.66E-02	2.41E-02	2.52E-02	1.91E-02
	1.63E-02	1.87E-02	1.78E-03	1.27E-03	3.62E-03	2.11E-01	2.19E-03	5.14E-04	2.02E-03	8.70E-04	2.34E-02	3.08E-03	1.88E-03	1.77E-03	7.50E-04
MMF5	1.73E-01	1.81E-01	8.50E-02	7.37E-02	8.62E-02	1.20E-01	8.33E-02	6.49E-02	7.45E-02	7.34E-02	1.18E-01	7.87E-02	1.00E-01	7.49E-02	6.40E-02
	2.19E-02	2.61E-02	4.65E-03	3.68E-03	7.34E-03	1.71E-02	4.95E-03	1.82E-03	3.14E-03	3.15E-03	1.14E-02	3.17E-03	8.11E-03	3.88E-03	2.81E-03
MMF6	1.45E-01	1.46E-01	7.33E-02	6.38E-02	7.12E-02	9.40E-02	7.34E-02	5.75E-02	6.60E-02	6.44E-02	1.09E-01	6.78E-02	7.78E-02	6.80E-02	5.46E-02
	1.91E-02	1.52E-02	3.56E-03	2.83E-03	8.46E-03	9.26E-03	3.66E-03	1.54E-03	2.78E-03	3.09E-03	1.47E-02	2.21E-03	3.92E-03	3.66E-03	1.41E-03
MMF7	5.15E-02	5.32E-02	2.67E-02	2.13E-02	2.44E-02	6.35E-02	2.72E-02	1.95E-02	2.45E-02	2.31E-02	4.40E-02	2.81E-02	2.33E-02	2.52E-02	1.96E-02
	1.10E-02	1.38E-02	1.90E-03	8.90E-04	3.98E-03	4.88E-02	2.38E-03	9.15E-04	1.93E-03	2.21E-03	9.10E-03	2.36E-03	3.65E-03	2.31E-03	9.43E-04
MMF8	3.44E-01	3.11E-01	6.68E-02	5.45E-02	1.63E-01	4.03E-01	9.54E-02	5.26E-02	5.63E-02	5.53E-02	4.00E-01	6.62E-02	1.35E-01	8.11E-02	5.00E-02
	1.52E-01	1.19E-01	5.28E-03	3.94E-03	5.22E-02	1.21E-01	2.04E-02	4.60E-03	5.55E-03	6.88E-03	1.97E-01	1.21E-02	3.99E-02	1.62E-02	6.99E-03
MMF9	2.10E-02	2.31E-02	8.03E-03	5.93E-03	4.92E-03	3.02E-03	9.25E-03	4.73E-03	7.07E-03	5.88E-03	8.25E-03	4.93E-03	4.83E-03	4.55E-03	6.09E-03
	5.20E-03	9.68E-03	5.55E-04	2.99E-04	4.09E-04	8.68E-05	8.47E-04	1.90E-04	4.98E-04	3.59E-04	3.36E-03	1.88E-04	3.42E-04	1.38E-04	9.43E-04
MMF14	8.94E-02	9.68E-02	5.37E-02	5.37E-02	4.54E-02	3.65E-02	6.24E-02	3.96E-02	5.74E-02	5.10E-02	6.42E-02	5.14E-02	4.22E-02	4.17E-02	3.77E-02
	5.34E-03	7.16E-03	1.46E-03	1.27E-03	1.23E-03	4.77E-04	2.60E-03	5.61E-04	2.64E-03	1.47E-03	7.33E-03	1.09E-03	7.89E-04	6.92E-04	4.34E-04
MMF1_e	2.50E+00	2.46E+00	6.18E-01	5.36E-01	3.93E+00	2.64E+00	3.58E-01	3.35E-01	4.41E-01	7.10E-01	5.85E+00	6.02E-01	1.78E+00	9.93E-01	3.26E-01
	1.69E+00	2.19E+00	3.60E-01	2.08E-01	2.72E+00	1.33E+00	8.34E-02	3.76E-02	1.46E-01	7.04E-01	3.01E+00	3.02E-01	1.07E+00	3.96E-01	3.93E-02
MMF1_z	7.26E-02	9.41E-02	3.52E-02	2.89E-02	3.89E-02	7.51E-02	3.45E-02	2.73E-02	3.07E-02	2.96E-02	6.01E-02	3.13E-02	4.98E-02	3.27E-02	2.70E-02
	1.45E-02	4.41E-02	2.21E-03	1.04E-03	6.61E-03	1.24E-02	1.79E-03	1.03E-03	1.59E-03	1.21E-03	1.15E-02	1.69E-03	7.69E-03	2.92E-03	1.63E-03
MMF14_a	1.11E-01	1.20E-01	6.08E-02	6.03E-02	5.46E-02	5.71E-02	8.80E-02	5.09E-02	6.03E-02	6.07E-02	9.85E-02	7.74E-02	5.84E-02	5.68E-02	4.71E-02
	7.56E-03	8.81E-03	1.89E-03	1.34E-03	1.43E-03	2.02E-03	3.39E-03	5.10E-04	1.32E-03	1.42E-03	8.05E-03	3.40E-03	1.68E-03	1.23E-03	5.52E-04



(a) Omni-optimizer (b) DN-NSGAII (c) MO_R_PSO (d) MO_PSO_MM (e) DNEA

(f) Tri-MOEA&TAR (g) DNEA-L (h) CPDEA (i) SS-MOPSO (j) MMODE_CSCD

(k) MP-MMEA (l) MMOEA/DC (m) MMODE_ICD (n) MMEA-WI (o) HREA

Fig. 2. The distribution of solutions obtained by all algorithms (MO_R_PSO_SCD is the short name for MO_Ring_PSO_SCD) in the decision spaces on MMF1, where the red points and blue circles are true PS and obtained solutions respectively.

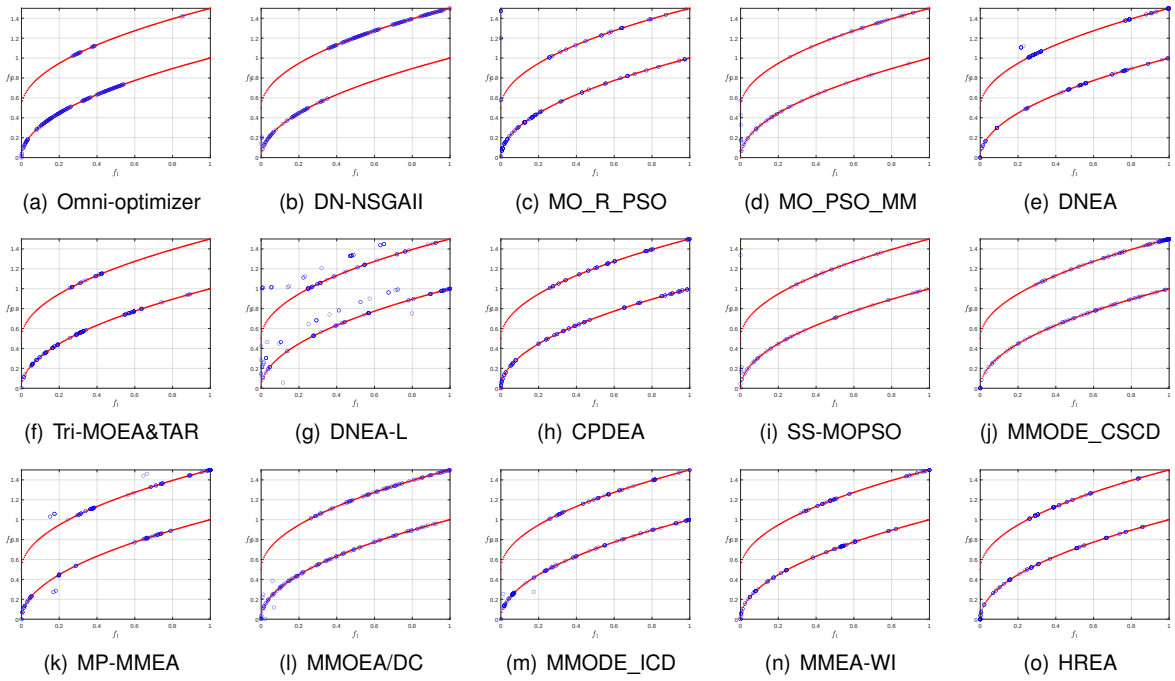


Fig. 3. The distribution of solutions obtained by all algorithms (MO_R_PSO_SCD is the short name for MO_Ring_PSO_SCD) in the decision spaces on MMF3, where the red points and blue circles are true PS and obtained solutions respectively.

TABLE IV
AVERAGE AND VARIANCE OF IGD RESULTS OF THE COMPARED ALGORITHMS ON IDMP TEST SUITE, WHERE THE BEST MEAN FOR EACH TEST INSTANCE IS HIGHLIGHTED.

Problems	Omni-optimizer	DN-NSGAII	MO_Ring_PSO_SCD	MO_PSO_MM	DNEA	Tri-MOEA&TAR	DNEA-L	CPDEA	SS-MOPSO	MMODE_CSCD	MP-MMEA	MMOEA/DC	MMODE_ICD	MMEA-WI	HREA
IDMPM2T1	6.73E-04	6.20E-04	3.07E-03	2.75E-03	3.91E-04	6.38E-04	7.85E-04	7.47E-04	2.39E-03	5.47E-04	8.09E-04	9.27E-04	4.68E-04	7.61E-04	5.83E-04
	1.37E-04	6.67E-05	2.36E-04	5.04E-04	2.21E-05	1.55E-05	1.61E-04	1.62E-04	1.98E-04	1.85E-05	1.23E-04	1.73E-04	2.79E-05	6.02E-05	1.12E-04
IDMPM2T2	5.63E-04	5.86E-04	1.52E-03	1.60E-03	4.02E-04	6.39E-04	6.23E-04	5.49E-04	1.26E-03	4.86E-04	5.80E-04	5.93E-04	4.63E-04	6.83E-04	5.36E-04
	5.22E-05	6.60E-05	1.45E-04	3.37E-04	1.66E-05	3.31E-05	1.55E-04	7.02E-05	1.40E-04	2.16E-05	4.15E-05	7.59E-05	1.45E-05	3.36E-05	2.45E-05
IDMPM2T3	5.70E-04	5.87E-04	1.66E-03	2.01E-03	4.25E-04	6.94E-03	6.16E-04	6.82E-04	1.20E-03	4.75E-04	6.01E-04	8.06E-04	4.60E-04	8.05E-04	5.42E-04
	4.15E-05	3.87E-05	1.83E-04	4.42E-04	2.15E-05	1.97E-02	8.77E-05	6.93E-05	9.87E-05	1.62E-05	6.09E-05	1.05E-04	1.72E-05	7.75E-05	2.59E-05
IDMPM2T4	1.04E-03	1.99E-03	3.42E-03	2.15E-03	3.84E-04	6.43E-04	5.30E-04	6.19E-04	3.24E-03	4.99E-04	6.26E-04	7.43E-04	4.74E-04	7.33E-04	5.07E-04
	8.70E-04	3.18E-03	7.52E-04	4.55E-04	2.91E-05	1.34E-05	1.90E-04	1.47E-04	6.59E-04	1.93E-05	8.76E-05	1.73E-04	3.57E-05	7.59E-05	9.27E-05
IDMPM3T1	6.64E-03	7.43E-03	1.33E-02	1.24E-02	3.92E-03	9.61E-03	5.70E-03	4.72E-03	1.07E-02	5.21E-03	5.91E-03	6.71E-03	4.50E-03	5.10E-03	4.99E-03
	5.06E-04	1.47E-03	8.88E-04	1.06E-03	1.67E-04	5.04E-04	4.16E-04	2.48E-04	3.59E-04	3.00E-04	3.83E-04	5.23E-04	1.20E-04	1.63E-04	2.08E-04
IDMPM3T2	6.93E-03	8.00E-03	1.11E-02	1.08E-02	3.80E-03	9.60E-03	5.11E-03	4.34E-03	1.08E-02	4.69E-03	5.43E-03	5.62E-03	4.50E-03	4.97E-03	4.57E-03
	1.10E-03	2.57E-03	1.18E-03	1.50E-03	8.66E-05	6.04E-04	4.08E-04	1.30E-04	9.32E-04	1.11E-04	2.46E-04	2.47E-04	1.35E-04	1.66E-04	1.17E-04
IDMPM3T3	5.99E-03	6.41E-03	1.05E-02	1.06E-02	3.93E-03	1.00E-02	5.34E-03	4.55E-03	9.46E-03	4.80E-03	5.40E-03	6.41E-03	4.61E-03	5.15E-03	4.62E-03
	6.00E-04	1.35E-03	9.43E-04	1.17E-03	1.28E-04	4.84E-03	3.37E-04	1.41E-04	8.28E-04	1.28E-04	2.84E-04	5.54E-04	1.97E-04	1.19E-04	1.51E-04
IDMPM3T4	1.60E-02	1.86E-02	2.10E-02	1.71E-02	3.71E-03	9.69E-03	4.73E-03	4.46E-03	2.56E-02	4.69E-03	5.47E-03	6.23E-03	4.52E-03	5.04E-03	4.52E-03
	1.53E-02	1.26E-02	4.55E-03	2.21E-03	8.39E-05	6.24E-04	6.00E-04	3.85E-04	8.22E-03	1.08E-04	3.99E-04	7.91E-04	2.75E-04	2.93E-04	2.09E-04
IDMPM4T1	1.73E-02	1.82E-02	3.46E-02	4.41E-02	4.96E-03	2.08E-02	5.58E-03	6.25E-03	3.88E-02	7.85E-03	8.78E-03	1.83E-02	6.09E-03	8.39E-03	9.13E-03
	6.89E-03	5.55E-03	3.10E-03	5.83E-03	2.30E-04	1.33E-03	4.30E-04	5.64E-04	4.39E-03	3.59E-04	7.89E-04	1.98E-03	4.47E-04	8.08E-04	1.66E-03
IDMPM4T2	1.84E-02	3.13E-02	3.20E-02	4.93E-02	4.70E-03	2.16E-02	5.41E-03	5.52E-03	4.57E-02	6.51E-03	7.27E-03	1.58E-02	7.10E-03	7.04E-03	6.57E-03
	6.57E-03	2.66E-02	6.18E-03	1.20E-02	1.88E-04	2.47E-03	5.30E-04	4.68E-04	1.38E-02	1.41E-04	3.01E-04	1.82E-03	1.57E-03	7.57E-04	1.31E-03
IDMPM4T3	1.14E-02	1.43E-02	3.17E-02	4.80E-02	5.03E-03	2.05E-02	5.79E-03	5.88E-03	3.80E-02	6.75E-03	7.64E-03	1.61E-02	7.39E-03	6.98E-03	6.29E-03
	3.38E-03	5.11E-03	5.62E-03	8.26E-03	3.08E-04	1.33E-02	6.03E-04	3.79E-04	9.34E-03	4.51E-04	6.49E-04	1.50E-03	2.58E-03	4.08E-04	8.44E-04
IDMPM4T4	7.13E-02	1.16E-01	6.72E-02	1.02E-01	4.72E-03	2.06E-02	5.54E-03	5.61E-03	1.31E-01	6.53E-03	7.68E-03	1.87E-02	1.04E-02	6.88E-03	7.59E-03
	6.28E-02	1.10E-01	1.73E-02	4.23E-02	2.00E-04	2.20E-03	5.96E-04	8.81E-04	8.06E-02	1.88E-04	6.44E-04	2.88E-03	5.25E-03	1.03E-03	2.12E-03

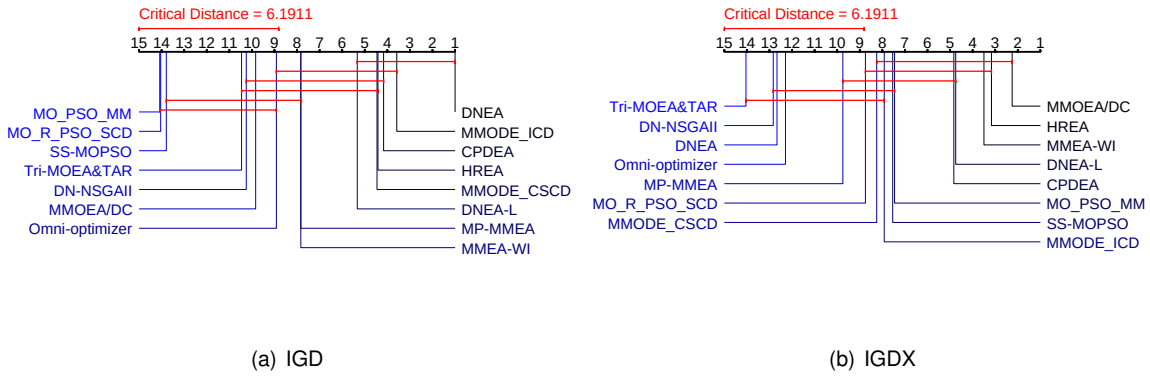
TABLE V
AVERAGE AND VARIANCE OF IGDX RESULTS OF THE COMPARED ALGORITHMS ON IDMP TEST SUITE, WHERE THE BEST MEAN FOR EACH TEST INSTANCE IS HIGHLIGHTED.

Problems	Omni-optimizer	DN-NSGAII	MO_Ring_PSO_SCD	MO_PSO_MM	DNEA	Tri-MOEA&TAR	DNEA-L	CPDEA	SS-MOPSO	MMODE_CSCD	MP-MMEA	MMOEA/DC	MMODE_ICD	MMEA-WI	HREA
IDMPM2T1	3.88E-01	2.84E-01	5.90E-02	5.19E-03	6.07E-01	6.30E-01	1.62E-03	1.03E-03	4.13E-03	2.25E-01	2.37E-01	8.76E-04	5.38E-02	9.32E-04	2.42E-03
	3.31E-01	3.24E-01	1.67E-01	1.79E-03	2.03E-01	1.63E-01	2.30E-03	5.41E-04	2.71E-03	3.22E-01	1.62E-01	1.15E-04	1.69E-01	7.13E-05	6.29E-03
IDMPM2T2	2.99E-01	2.99E-01	5.58E-03	3.88E-03	4.95E-01	5.39E-01	1.97E-03	9.55E-04	2.88E-03	2.70E-01	1.67E-01	1.03E-03	3.35E-03	1.12E-03	9.45E-04
	3.33E-01	3.34E-01	2.91E-03	1.95E-03	3.01E-01	2.72E-01	1.35E-03	1.33E-04	4.56E-04	3.35E-01	1.73E-01	1.14E-04	5.67E-03	8.61E-05	5.88E-04
IDMPM2T3	1.19E-01	1.19E-01	3.35E-03	5.87E-03	1.42E-01	1.98E-01	2.90E-03	3.70E-03	2.81E-03	2.67E-03	1.30E-01	1.85E-03	2.64E-03	1.99E-03	2.96E-03
	2.57E-01	2.55E-01	4.22E-04	4.03E-03	2.71E-01	2.92E-01	1.58E-03	1.47E-03	4.14E-04	5.63E-03	1.65E-01	1.92E-04	1.47E-03	2.49E-04	1.36E-03
IDMPM2T4	5.44E-01	6.10E-01	8.67E-02	3.89E-03	6.28E-01	5.63E-01	1.32E-02	2.32E-02	1.26E-02	5.61E-01	2.89E-01	9.06E-02	7.65E-02	4.58E-02	1.04E-02
	2.63E-01	1.94E-01	2.00E-01	1.61E-03	1.71E-01	2.50E-01	2.15E-02	1.23E-01	9.38E-03	2.55E-01	1.47E-01	2.32E-01	2.03E-01	1.71E-01	1.41E-02
IDMPM3T1	3.50E-01	3.49E-01	1.19E-01	3.88E-02	5.74E-01	7.50E-01	3.48E-02	1.53E-02	1.63E-02	2.60E-01	3.31E-01	8.41E-03	3.02E-01	7.48E-03	6.51E-03
	2.30E-01	2.42E-01	1.47E-01	6.41E-02	3.05E-01	2.63E-01	7.39E-02	4.42E-02	1.68E-03	2.06E-01	1.10E-01	3.97E-04	1.88E-01	1.78E-04	2.16E-04
IDMPM3T2	6.00E-01	6.14E-01	1.45E-01	6.66E-02	4.55E-01	5.61E-01	3.69E-02	7.23E-03	3.06E-02	4.12E-01	2.58E-01	8.17E-03	2.63E-01	7.69E-03	6.65E-03
	2.29E-01	2.90E-01	1.25E-01	1.29E-01	2.20E-01	2.44E-01	7.35E-02	2.56E-04	4.38E-02	2.11E-01	1.64E-01	2.71E-04	1.41E-01	2.01E-04	6.23E-04
IDMPM3T3	3.71E-01	4.75E-01	2.65E-02	2.05E-02	2.87E-01	3.42E-01	3.87E-02	2.65E-02	1.71E-02	8.02E-02	3.60E-01	1.01E-02	2.37E-01	2.55E-02	9.14E-03
	2.03E-01	2.32E-01	4.34E-02	3.52E-03	2.10E-01	2.57E-01	7.37E-02	6.09E-02	2.06E-03	1.46E-01	1.38E-01	6.01E-04	1.92E-01	6.29E-02	1.56E-03
IDMPM3T4	8.24E-01	8.13E-01	2.64E-01	1.21E-01	7.03E-01	6.86E-01	8.36E-02	5.71E-02	3.60E-01	7.40E-01	4.02E-01	1.84E-02	2.50E-01	1.54E-01	1.07E-02
	2.16E-01	2.27E-01	1.82E-01	1.47E-01	2.37E-01	2.58E-01	1.08E-01	9.87E-02	2.29E-01	2.54E-01	1.70E-01	3.13E-02	1.66E-01	1.52E-01	5.48E-03
IDMPM4T1	7.94E-01	6.36E-01	9.36E-01	5.15E-01	1.17E+00	1.18E+00	1.09E-01	7.03E-01	2.32E-01	8.58E-01	5.81E-01	4.44E-02	7.54E-01	2.68E-02	6.00E-02
	3.07E-01	3.33E-01	2.75E-01	2.93E-01	8.28E-02	8.14E-02	1.50E-01	2.89E-01	2.18E-01	3.23E-01	1.72E-01	7.50E-02	2.04E-01	6.77E-02	8.70E-02
IDMPM4T2	9.72E-01	9.24E-01	5.59E-01	5.25E-01	9.95E-01	1.11E+00	2.99E-01	5.47E-01	6.35E-01	8.83E-01	5.73E-01	2.62E-02	5.00E-01	3.62E-01	4.48E-01
	2.28E-01	2.37E-01	2.64E-01	3.07E-01	2.34E-01	1.80E-01	2.46E-01	2.36E-01	2.80E-01	2.35E-01	1.27E-01	5.25E-02	1.97E-01	2.81E-01	3.20E-01
IDMPM4T3	7.44E-01	7.25E-01	8.04E-02	1.35E-01	7.61E-01	7.70E-01	1.41E-01	4.07E-01	1.68E-01	2.31E-01	4.64E-01	1.66E-02	5.46E-01	4.16E-01	5.16E-01
	3.18E-01	3.05E-01	8.42E-02	1.54E-01	2.85E-01	2.94E-01	1.60E-01	2.56E-01	1.62E-01	2.53E-01	1.80E-01	1.33E-03	2.66E-01	2.92E-01	3.36E-01
IDMPM4T4	1.08E+00	1.11E+00	6.86E-01	6.77E-01	1.09E+00	1.06E+00	1.79E-01	7.94E-01	8.83E-01	9.92E-01	4.56E-01	3.87E-02	5.57E-01	7.28E-01	6.12E-01
	1.68E-01	1.53E-01	3.44E-01	3.31E-01	1.78E-01	1.87E-01	2.36E-01	3.19E-01	3.27E-01	2.97E-01	1.45E-01	6.08E-02	2.81E-01	3.28E-01	2.77E-01

TABLE VI
AVERAGE AND VARIANCE OF RPSP RESULTS OF THE COMPARED ALGORITHMS ON IDMP TEST SUITE, WHERE THE BEST MEAN FOR EACH TEST INSTANCE IS HIGHLIGHTED.

Problems	Omni-optimizer	DN-NSGAII	MO_Ring_PSO_SCD	MO_PSO_MM	DNEA	Tri-MOEA&TAR	DNEA-L	CPDEA	SS-MOPSO	MMODE_CSCD	MP-MMEA	MMOEA/DC	MMODE_ICD	MMEA-WI	HREA
IDMPM2T1	3.35E+01	3.03E+01	1.80E+00	5.23E-03	1.19E+02	Inf	1.62E-03	1.03E-03	4.15E-03	2.09E+01	4.41E-01	8.76E-04	1.75E+01	9.33E-04	2.50E-03
	3.08E+01	4.13E+01	6.82E+00	1.81E-03	8.63E+01	NaN	2.31E-03	5.42E-04	2.74E-03	3.03E+01	3.31E-01	1.15E-04	7.07E+01	7.15E-05	6.58E-03
IDMPM2T2	1.48E+01	1.45E+01	5.65E-03	3.90E-03	3.11E+01	5.22E+01	1.97E-03	9.56E-04	2.89E-03	1.34E+01	9.23E-01	1.03E-03	3.46E-03	1.12E-03	9.47E-04
	1.74E+01	1.70E+01	3.04E-03	1.96E-03	1.94E+01	4.51E+01	1.35E-03	1.33E-04	4.58E-04	1.67E+01	3.55E+00	1.14E-04	6.04E-03	8.64E-05	5.93E-04
IDMPM2T3	3.07E+00	4.27E+00	3.36E-03	5.98E-03	8.61E+00	1.73E+01	2.90E-03	3.74E-03	2.82E-03	2.77E-03	7.96E-01	1.85E-03	2.66E-03	2.00E-03	2.99E-03
	9.37E+00	1.17E+01	4.24E-04	4.27E-03	1.75E+01	3.42E+01	1.58E-03	1.51E-03	4.22E-04	6.02E-03	3.26E+00	1.92E-04	1.50E-03	2.50E-04	1.38E-03
IDMPM2T4	4.56E+01	6.07E+01	4.46E+00	3.92E-03	1.01E+02	1.42E+02	1.34E-02	2.23E+00	1.29E-02	5.97E+01	2.91E+00	7.66E+00	5.03E+01	5.28E+00	1.06E-02
	2.45E+01	3.49E+01	1.37E+01	1.63E-03	4.45E+01	1.17E+02	2.17E-02	1.22E+01	9.77E-03	2.75E+01	9.19E+00	1.99E+01	1.57E+02	2.01E+01	1.44E-02
IDMPM3T1	1.18E+00	1.11E+00	1.66E-01	4.07E-02	8.15E+00	1.79E+01	3.73E-02	1.53E-02	1.63E-02	4.75E-01	4.99E-01	8.41E-03	5.63E-01	7.49E-03	6.51E-03
	3.52E+00	3.06E+00	3.35E-01	7.12E-02	1.33E+01	2.08E+01	8.17E-02	4.46E-02	1.70E-03	6.10E-01	2.43E-01	3.96E-04	6.36E-01	1.78E-04	2.17E-04
IDMPM3T2	4.69E+00	6.62E+00	1.66E-01	1.10E-01	1.79E+00	4.20E+00	3.95E-02	7.24E-03	3.08E-02	9.63E-01	5.93E-01	8.17E-03	4.40E-01	7.70E-03	6.66E-03
	7.59E+00	9.10E+00	1.47E-01	3.30E-01	4.34E+00	8.82E+00	8.17E-02	2.57E-04	4.40E-02	7.73E-01	1.56E+00	2.71E-04	4.44E-01	2.00E-04	6.24E-04
IDMPM3T3	9.11E-01	1.64E+00	2.66E-02	2.07E-02	5.64E-01	1.11E+00	4.13E-02	2.67E-02	1.71E-02	1.20E-01	5.55E-01	1.01E-02	4.18E-01	2.69E-02	9.18E-03
	2.09E+00	2.71E+00	4.35E-02	3.60E-03	6.68E-01	2.31E+00	8.16E-02	6.13E-02	2.08E-03	3.16E-01	3.03E-01	6.00E-04	5.67E-01	6.85E-02	1.58E-03
IDMPM3T4	2.05E+01	1.83E+01	4.09E-01	1.70E-01	1.68E+01	1.85E+01	9.13E-02	5.85E-02	1.40E+00	1.58E+01	9.60E-01	1.89E-02	4.53E-01	1.60E-01	1.07E-02
	1.72E+01	1.54E+01	5.39E-01	3.47E-01	2.26E+01	2.54E+01	1.22E-01	1.02E-01	4.55E+00	1.79E+01	1.80E+00	3.30E-02	4.95E-01	1.65E-01	5.49E-03
IDMPM4T1	1.13E+01	6.83E+00	1.15E+01	2.13E+00	6.83E+01	8.98E+01	1.48E-01	1.49E+01	3.87E-01	2.19E+01	2.90E+00	4.97E-02	1.09E+01	3.09E-02	6.05E-02
	1.29E+01	1.11E+01	9.96E+00	4.47E+00	1.45E+01	2.60E+01	3.32E-01	2.60E+01	5.90E-01	2.37E+01	5.75E+00	8.70E-02	2.31E+01	8.34E-02	8.80E-02
IDMPM4T2	2.31E+01	1.77E+01	3.06E+00	3.48E+00	3.29E+01	5.70E+01	5.39E-01	2.59E+00	4.89E+00	1.71E+01	4.08E+00	2.92E-02	2.52E+00	3.48E+00	5.23E+00
	1.38E+01	1.55E+01	7.53E+00	7.94E+00	2.42E+01	2.36E+01	6.54E-01	7.79E+00	9.85E+00	2.01E+01	5.16E+00	6.47E-02	7.43E+00	1.13E+01	1.38E+01
IDMPM4T3	9.17E+00	7.23E+00	8.34E-02	1.89E-01	1.36E+01	1.87E+01	1.88E-01	8.90E-01	2.18E-01	8.62E-01	1.53E+00	1.66E-02	4.67E+00	2.86E+00	8.77E+00
	1.05E+01	1.06E+01	9.13E-02	3.86E-01	1.88E+01	2.68E+01	3.28E-01	8.50E-01	3.61E-01	2.85E+00	1.95E+00	1.33E-03	8.16E+00	9.75E+00	1.71E+01
IDMPM4T4	Inf	Inf	1.21E+01	1.83E+01	6.68E+01	7.29E+01	2.46E+00	Inf	Inf	4.34E+01	1.92E+00	3.87E-02	1.09E+01	2.48E+01	1.14E+01
	NaN	NaN	1.94E+01	3.96E+01	2.93E+01	3.53E+01	1.24E+01	NaN	NaN	3.02E+01	4.25E+00	6.08E-02	2.30E+01	3.60E+01	2.35E+01

The final distribution of solutions in the decision space are presented in Fig. 5 and Fig. 6.



(a) IGD (b) IGDX

Fig. 4. The critical difference of all compared MMEAs on IDMP test suite, where the red lines indicate that there is no significant difference in the Friedman ranks of the two MMEAs.

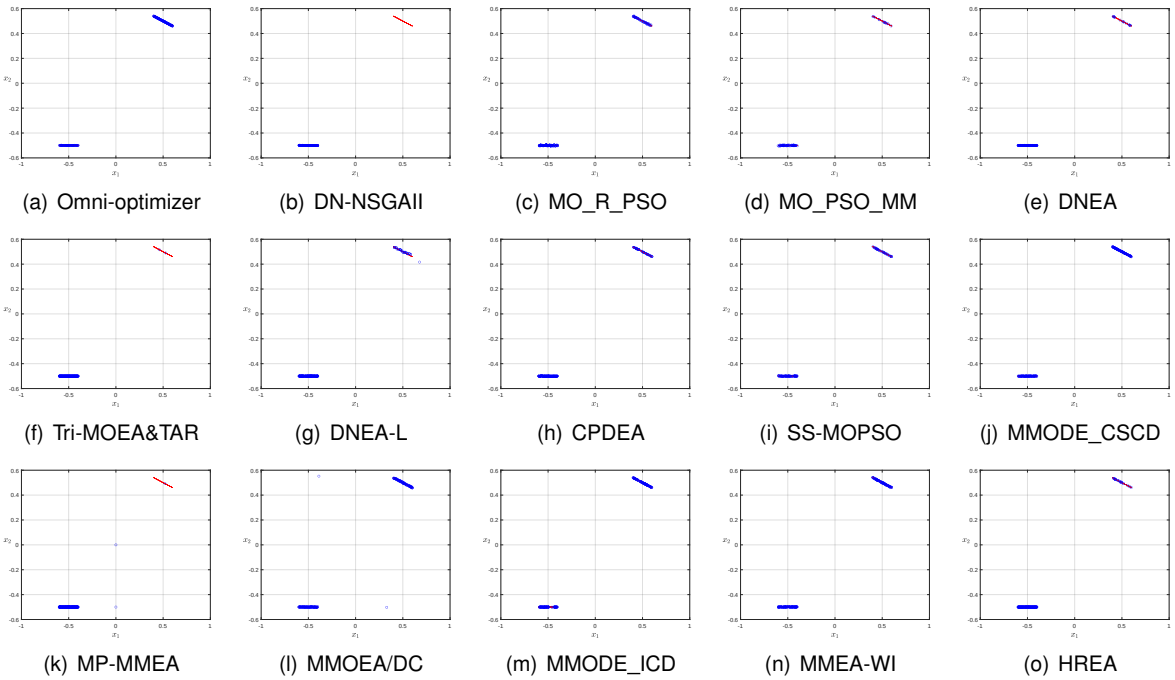


Fig. 5. The distribution of solutions obtained by all algorithms (MO_R_PSO_SCD is the short name for MO_Ring_PSO_SCD) in the decision spaces on IDMPM2T3, where the red points and blue circles are true PS and obtained solutions respectively.

V. Performance Comparison on Problems with Local PFs

In this part, the performance of MMEAs on MMOPLs is discussed. Since there is no performance indicator designed for MMOPLs, we regard both global and local PSs as the true PS for calculating IGD, $IGDX$ and $RPSP$.

VI. Performance Comparison on Multi-polygon Problems

To study the performance of MMEAs on problems with many objectives and many decision variables, Multi-polygon problems are chosen as the benchmark, where M is set to 3, 4, 6, 8 and D is set to 2, 4, 8, 10 ,20 respectively.

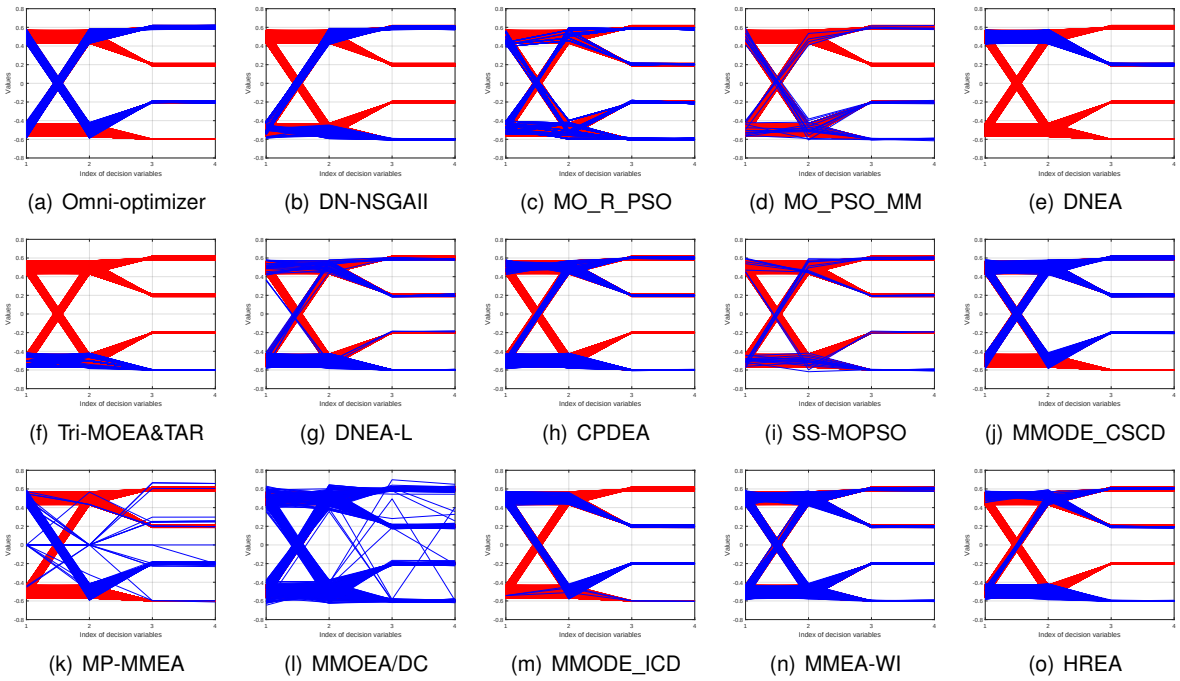


Fig. 6. The distribution of solutions obtained by all algorithms (MO_R_PSO_SCD is the short name for MO_Ring_PSO_SCD) in the decision spaces on IDMPM4T3.

TABLE VII
AVERAGE AND VARIANCE OF IGD RESULTS OF THE COMPARED ALGORITHMS ON MMOPL TEST SUITE, WHERE THE BEST MEAN FOR EACH TEST INSTANCE IS HIGHLIGHTED.

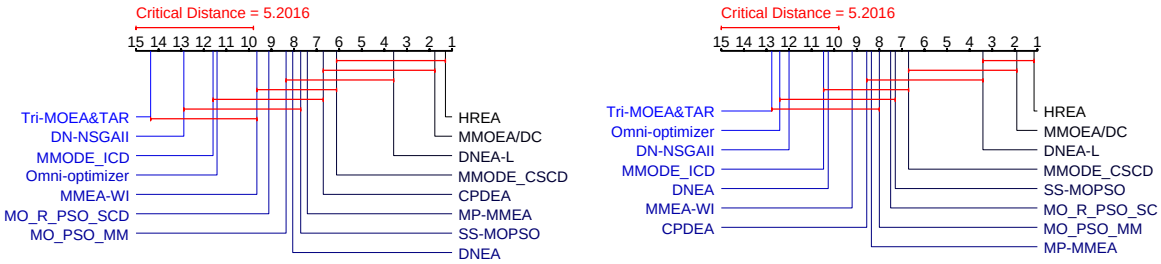
Problems	Omni-optimizer	DN-NSGAII	MO_Ring_PSO_SCD	MO_PSO_MM	DNEA	Tri-MOEA&TAR	DNEA-L	CPDEA	SS-MOPSO	MMODE_CSCD	MP-MMEA	MMOEA/DC	MMODE_ICD	MMEA-WI	HREA
IDMPM2T1e	7.20E-03	7.21E-03	7.18E-03	7.57E-03	7.20E-03	7.38E-03	3.42E-03	7.18E-03	7.12E-03	7.12E-03	7.00E-03	1.36E-03	7.31E-03	7.16E-03	1.02E-03
	2.76E-05	3.85E-05	1.66E-04	2.96E-04	3.75E-05	1.78E-05	1.72E-03	5.60E-05	1.13E-04	2.15E-05	2.40E-04	1.69E-04	1.31E-05	6.13E-05	1.38E-04
IDMPM2T2e	7.27E-03	7.27E-03	7.24E-03	7.52E-03	7.22E-03	7.40E-03	2.88E-03	7.22E-03	7.24E-03	7.19E-03	7.18E-03	9.65E-04	7.32E-03	7.26E-03	9.13E-04
	7.52E-05	2.06E-05	1.17E-04	2.98E-04	1.46E-05	9.15E-06	1.66E-03	3.84E-05	9.37E-05	2.20E-05	7.50E-05	1.49E-04	1.99E-05	6.04E-05	4.36E-05
IDMPM2T3e	5.80E-03	5.35E-03	8.67E-03	6.11E-03	5.09E-03	3.18E-02	1.64E-03	4.98E-03	6.08E-03	8.45E-03	4.09E-03	1.11E-03	6.99E-03	5.11E-03	1.16E-03
	1.75E-03	1.17E-03	8.51E-04	6.54E-04	8.68E-04	2.81E-02	1.86E-04	2.45E-05	3.13E-04	1.72E-03	2.18E-03	9.26E-05	1.36E-03	4.87E-05	7.46E-05
IDMPM2T4e	1.28E-02	1.42E-02	1.39E-02	1.42E-02	1.47E-02	1.49E-02	4.92E-03	1.60E-02	1.41E-02	1.60E-02	5.81E-03	1.61E-03	1.08E-02	1.58E-02	1.50E-03
	4.59E-03	3.13E-03	1.25E-03	1.17E-03	3.42E-03	3.37E-03	3.49E-04	3.10E-04	1.01E-03	3.99E-05	7.01E-04	8.97E-04	2.96E-03	8.12E-04	7.18E-05
IDMPM3T1e	2.53E-02	2.55E-02	2.51E-02	2.51E-02	2.47E-02	2.79E-02	7.71E-03	2.46E-02	2.43E-02	2.46E-02	1.68E-02	7.61E-03	2.56E-02	2.47E-02	6.89E-03
	3.57E-04	6.14E-04	7.53E-04	8.26E-04	1.23E-04	4.42E-04	8.30E-04	1.75E-04	5.43E-04	1.63E-04	6.34E-03	3.07E-04	1.24E-04	1.75E-04	2.51E-04
IDMPM3T2e	3.89E-02	3.87E-02	3.85E-02	3.75E-02	3.69E-02	4.02E-02	1.59E-02	3.66E-02	3.79E-02	3.70E-02	3.45E-02	8.12E-03	3.78E-02	3.67E-02	7.81E-03
	1.09E-03	1.29E-03	1.32E-03	1.01E-03	1.70E-04	3.72E-04	1.44E-03	2.20E-04	1.16E-03	2.75E-04	5.58E-03	2.08E-04	1.07E-04	2.59E-04	2.04E-04
IDMPM3T3e	3.80E-02	3.87E-02	3.72E-02	3.68E-02	3.68E-02	4.00E-02	1.65E-02	3.67E-02	3.70E-02	3.70E-02	3.59E-02	9.09E-03	3.77E-02	3.66E-02	8.32E-03
	6.44E-04	1.10E-03	8.40E-04	8.17E-04	1.80E-04	8.33E-04	1.45E-03	2.13E-04	7.26E-04	1.89E-04	3.69E-03	1.38E-03	2.73E-04	1.91E-04	4.97E-04
IDMPM3T4e	4.40E-02	4.34E-02	4.20E-02	4.12E-02	3.69E-02	3.98E-02	1.72E-02	3.67E-02	4.06E-02	3.70E-02	2.98E-02	9.31E-03	3.78E-02	3.67E-02	8.55E-03
	1.09E-02	7.17E-03	2.24E-03	3.74E-03	2.01E-04	4.97E-04	1.48E-03	2.10E-04	2.41E-03	2.54E-04	8.59E-03	4.86E-04	1.22E-04	3.59E-04	2.73E-04
MMF10	1.83E-01	1.93E-01	2.03E-01	1.62E-01	1.93E-01	2.26E-01	3.25E-02	1.92E-01	1.92E-01	1.62E-01	1.15E-01	1.67E-02	1.91E-01	1.91E-01	2.42E-02
	3.60E-02	4.93E-02	1.81E-02	1.53E-02	5.86E-04	3.81E-03	5.88E-03	1.38E-03	1.59E-02	1.19E-02	8.21E-02	2.59E-02	1.39E-02	1.40E-02	6.05E-03
MMF11	9.61E-02	9.81E-02	8.46E-02	8.93E-02	9.17E-02	1.61E-01	3.85E-02	9.13E-02	8.87E-02	8.56E-02	9.35E-02	1.42E-02	9.71E-02	9.50E-02	2.74E-02
	1.07E-03	1.69E-03	5.61E-03	5.74E-03	3.14E-04	7.42E-03	5.72E-03	2.02E-04	6.75E-03	6.95E-03	1.68E-03	4.25E-04	1.76E-03	1.18E-03	4.10E-03
MMF12	8.37E-02	8.32E-02	6.80E-02	7.77E-02	8.25E-02	8.52E-02	4.59E-02	8.28E-02	6.35E-02	6.96E-02	8.27E-02	2.56E-03	8.46E-02	8.31E-02	6.16E-03
	4.47E-03	2.35E-04	1.37E-02	1.07E-02	1.29E-04	5.22E-04	1.32E-02	2.58E-04	1.33E-02	1.73E-02	1.94E-04	7.92E-05	9.89E-04	3.04E-04	3.43E-04
MMF13	1.47E-01	1.50E-01	1.04E-01	1.04E-01	1.45E-01	2.44E-01	1.49E-01	1.38E-01	9.25E-02	8.13E-02	1.27E-01	2.56E-02	1.51E-01	1.51E-01	2.45E-02
	1.21E-03	4.20E-03	2.25E-02	3.01E-02	7.94E-04	5.05E-03	1.58E-02	2.19E-02	1.81E-02	2.57E-02	1.60E-02	6.33E-03	6.57E-03	6.18E-03	5.04E-03
MMF15	2.01E-01	2.11E-01	1.72E-01	1.70E-01	1.80E-01	2.07E-01	1.43E-01	1.71E-01	1.75E-01	1.66E-01	1.99E-01	1.00E-01	1.93E-01	1.85E-01	9.65E-02
	6.74E-03	7.19E-03	2.23E-03	3.16E-03	4.03E-03	8.87E-04	6.72E-03	2.99E-03	2.99E-03	3.87E-03	4.93E-03	1.82E-03	1.26E-03	1.65E-03	2.18E-03
MMF15_a	2.05E-01	2.21E-01	1.76E-01	1.71E-01	1.73E-01	1.97E-01	1.58E-01	1.69E-01	1.76E-01	1.66E-01	1.93E-01	1.35E-01	1.87E-01	1.78E-01	1.10E-01
	6.57E-03	7.55E-03	3.91E-03	2.91E-03	2.78E-03	2.21E-03	4.12E-03	2.58E-03	3.83E-03	3.57E-03	7.70E-03	1.35E-02	2.82E-03	3.41E-03	3.70E-03
MMF16_l1	1.77E-01	1.90E-01	1.48E-01	1.44E-01	1.47E-01	1.72E-01	1.41E-01	1.42E-01	1.49E-01	1.43E-01	1.68E-01	9.87E-02	1.60E-01	1.54E-01	9.46E-02
	7.09E-03	8.84E-03	2.19E-03	1.92E-03	2.29E-03	8.49E-04	4.98E-03	3.45E-03	2.69E-03	2.64E-03	4.22E-03	2.49E-03	1.13E-03	2.72E-03	1.73E-03
MMF16_l2	2.46E-01	2.54E-01	2.13E-01	2.10E-01	2.35E-01	2.61E-01	1.67E-01	2.24E-01	2.17E-01	2.09E-01	2.48E-01	1.34E-01	2.50E-01	2.39E-01	1.30E-01
	8.21E-03	7.50E-03	4.23E-03	3.52E-03	5.02E-03	6.42E-04	5.57E-03	4.30E-03	5.87E-03	5.70E-03	6.97E-03	3.65E-03	9.49E-04	2.62E-03	4.94E-03
MMF16_l3	2.14E-01	2.24E-01	1.82E-01	1.77E-01	1.92E-01	2.17E-01	1.68E-01	1.84E-01	1.83E-01	1.76E-01	2.07E-01	1.28E-01	2.06E-01	1.99E-01	1.24E-01
	6.98E-03	6.65E-03	3.99E-03	2.20E-03	3.56E-03	7.16E-04	5.08E-03	2.50E-03	3.39E-03	3.24E-03	6.01E-03	6.89E-03	1.17E-03	2.75E-03	3.66E-03

TABLE VIII
AVERAGE AND VARIANCE OF IGDX RESULTS OF THE COMPARED ALGORITHMS ON MMOPL TEST SUITE, WHERE THE BEST MEAN FOR EACH TEST INSTANCE IS HIGHLIGHTED.

Problems	Omni-optimizer	DN-NSGAII	MO_Ring_PSO_SCD	MO_PSO_MM	DNEA	Tri-MOEA&TAR	DNEA-L	CPDEA	SS-MOPSO	MMODE_CSCD	MP-MMEA	MMOEA/DC	MMODE_ICD	MMEA-WI	HREA
IDMPM2T1e	6.73E-01	6.73E-01	6.74E-01	6.53E-01	6.73E-01	6.73E-01	2.05E-03	6.73E-01	6.74E-01	6.73E-01	3.30E-01	8.92E-04	6.73E-01	6.73E-01	6.28E-04
	2.31E-04	2.31E-04	8.52E-04	1.16E-01	8.16E-05	6.28E-05	1.18E-03	1.92E-04	1.00E-03	4.97E-05	6.44E-02	1.11E-04	1.91E-04	1.83E-04	5.44E-05
IDMPM2T2e	6.74E-01	6.74E-01	6.74E-01	6.52E-01	6.73E-01	6.73E-01	3.10E-03	6.73E-01	6.74E-01	6.73E-01	3.37E-01	1.02E-03	6.73E-01	6.73E-01	9.22E-04
	5.17E-04	5.77E-04	7.36E-04	1.18E-01	1.81E-04	1.04E-04	4.91E-03	3.20E-04	8.59E-04	2.08E-04	3.95E-02	1.05E-04	1.54E-04	3.84E-04	8.29E-05
IDMPM2T3e	6.12E-01	5.87E-01	1.18E-01	2.95E-01	4.71E-01	4.02E-01	3.16E-03	3.01E-01	2.99E-01	4.94E-01	1.92E-01	1.38E-03	1.22E-01	3.01E-01	1.40E-03
	1.60E-01	1.77E-01	1.49E-01	4.88E-02	1.75E-01	1.94E-01	4.01E-03	4.29E-04	5.02E-02	2.46E-01	1.56E-01	6.44E-05	1.38E-01	5.04E-04	7.42E-05
IDMPM2T4e	9.45E-01	9.21E-01	7.02E-01	7.11E-01	9.77E-01	9.94E-01	2.67E-01	1.01E+00	7.88E-01	1.01E+00	3.89E-01	1.28E-01	4.17E-01	1.00E+00	3.65E-03
	1.76E-01	1.67E-01	2.51E-01	2.79E-01	1.10E-01	8.42E-02	9.08E-02	2.00E-04	2.74E-01	6.63E-05	8.64E-02	9.28E-02	1.45E-01	3.64E-02	2.45E-03
IDMPM3T1e	7.47E-01	7.49E-01	6.42E-01	6.36E-01	7.69E-01	7.78E-01	3.51E-02	6.26E-01	6.31E-01	6.25E-01	2.97E-01	8.08E-03	6.28E-01	6.25E-01	6.97E-03
	1.62E-01	1.72E-01	1.09E-02	6.43E-03	1.83E-01	1.85E-01	7.43E-02	1.53E-03	3.72E-03	8.44E-04	8.85E-02	2.09E-04	3.10E-03	1.15E-03	1.32E-04
IDMPM3T2e	8.47E-01	7.35E-01	5.38E-01	4.95E-01	8.23E-01	8.64E-01	1.79E-01	4.96E-01	5.02E-01	8.48E-01	4.20E-01	7.84E-03	8.12E-01	4.96E-01	7.46E-03
	1.27E-01	1.91E-01	1.54E-01	1.00E-01	1.47E-01	9.51E-02	1.11E-01	9.46E-04	9.21E-02	1.19E-01	9.77E-02	1.38E-04	1.55E-01	9.61E-04	3.37E-04
IDMPM3T3e	7.17E-01	8.09E-01	5.05E-01	5.05E-01	6.99E-01	7.83E-01	2.44E-01	5.01E-01	5.03E-01	5.42E-01	4.72E-01	1.20E-02	5.46E-01	5.00E-01	9.25E-03
	2.46E-01	2.25E-01	6.09E-03	5.25E-03	2.38E-01	2.47E-01	5.54E-02	3.44E-03	3.89E-03	1.34E-01	1.10E-01	1.55E-02	1.28E-01	2.95E-03	1.75E-03
IDMPM3T4e	1.02E+00	1.02E+00	7.12E-01	7.29E-01	9.38E-01	9.60E-01	4.84E-01	8.50E-01	7.44E-01	9.43E-01	5.27E-01	1.32E-02	8.51E-01	9.49E-01	1.07E-02
	1.61E-01	1.55E-01	1.25E-01	1.64E-01	1.30E-01	1.23E-01	1.27E-01	1.61E-03	1.31E-01	1.40E-01	1.17E-01	6.90E-03	2.63E-03	1.65E-01	4.52E-04
MMF10	1.76E-01	1.48E-01	1.69E-01	1.64E-01	2.00E-01	2.01E-01	1.37E-02	2.01E-01	1.63E-01	1.64E-01	1.07E-01	1.28E-02	1.89E-01	1.98E-01	7.22E-03
	3.11E-02	2.97E-02	8.40E-03	1.03E-02	1.18E-03	5.18E-05	2.71E-03	5.26E-05	1.80E-02	1.37E-02	9.58E-02	3.21E-02	2.32E-02	1.02E-02	7.64E-04
MMF11	2.50E-01	2.50E-01	2.10E-01	2.40E-01	2.49E-01	2.52E-01	1.94E-02	2.49E-01	2.05E-01	2.11E-01	2.47E-01	5.62E-03	2.52E-01	2.49E-01	7.16E-03
	3.63E-04	4.16E-04	2.49E-02	2.08E-02	2.15E-04	7.16E-05	1.00E-02	1.45E-04	2.26E-02	2.99E-02	3.40E-03	1.82E-04	1.07E-04	1.81E-04	1.01E-03
MMF12	2.45E-01	2.47E-01	1.90E-01	2.26E-01	2.46E-01	2.48E-01	1.88E-01	2.45E-01	1.76E-01	2.08E-01	2.45E-01	2.50E-03	2.47E-01	2.45E-01	2.74E-03
	9.24E-03	5.35E-04	4.29E-02	3.31E-02	2.15E-04	6.14E-04	7.19E-02	1.95E-04	4.20E-02	4.96E-02	3.76E-04	1.18E-04	1.57E-04	2.57E-04	1.35E-04
MMF13	2.86E-01	2.86E-01	2.35E-01	2.47E-01	2.58E-01	2.72E-01	2.55E-01	2.50E-01	2.32E-01	2.31E-01	2.69E-01	8.97E-02	2.54E-01	2.52E-01	4.13E-02
	9.28E-03	9.59E-03	1.57E-02	1.35E-02	2.96E-03	8.09E-03	1.36E-02	8.60E-03	1.74E-02	1.60E-02	1.38E-02	2.68E-02	6.28E-04	5.98E-04	6.00E-04
MMF15	2.44E-01	2.26E-01	1.51E-01	1.50E-01	2.60E-01	2.71E-01	6.65E-02	2.30E-01	1.53E-01	1.37E-01	2.66E-01	5.41E-02	2.66E-01	2.58E-01	4.34E-02
	2.05E-02	2.38E-02	1.04E-02	1.47E-02	1.47E-03	3.23E-04	4.10E-03	1.82E-02	1.50E-02	1.33E-02	2.66E-03	1.61E-03	9.96E-04	1.04E-03	9.11E-04
MMF15_a	2.15E-01	2.10E-01	1.67E-01	1.60E-01	2.08E-01	2.20E-01	9.54E-02	2.05E-01	1.60E-01	1.55E-01	2.20E-01	9.17E-02	2.14E-01	2.08E-01	5.33E-02
	1.30E-02	1.69E-02	1.21E-02	1.60E-02	1.97E-03	1.52E-03	4.87E-03	4.26E-03	1.21E-02	9.35E-03	3.63E-03	1.45E-02	1.21E-03	3.76E-03	2.09E-03
MMF16_l1	1.85E-01	1.84E-01	1.16E-01	1.16E-01	1.53E-01	1.50E-01	8.12E-02	1.44E-01	1.16E-01	1.10E-01	1.70E-01	6.85E-02	1.54E-01	1.52E-01	4.77E-02
	9.03E-03	9.43E-03	8.55E-03	6.74E-03	1.19E-03	3.72E-04	4.31E-03	5.34E-03	7.24E-03	6.74E-03	5.78E-03	2.57E-03	5.12E-04	6.21E-04	1.01E-03
MMF16_l2	2.99E-01	2.87E-01	1.94E-01	1.99E-01	3.33E-01	3.47E-01	8.35E-02	2.96E-01	2.00E-01	1.81E-01	3.37E-01	1.07E-01	3.42E-01	3.31E-01	6.14E-02
	3.55E-02	2.85E-02	1.86E-02	2.12E-02	3.08E-03	2.54E-04	5.00E-03	1.96E-02	1.65E-02	1.52E-02	4.17E-03	1.82E-02	1.02E-03	1.66E-03	1.03E-02
MMF16_l3	2.32E-01	2.25E-01	1.55E-01	1.48E-01	2.09E-01	2.07E-01	1.24E-01	1.94E-01	1.55E-01	1.44E-01	2.22E-01	1.07E-01	2.10E-01	2.07E-01	5.89E-02
	1.23E-02	1.36E-02	1.30E-02	7.06E-03	8.87E-04	3.02E-04	4.78E-03	7.64E-03	7.86E-03	1.12E-02	1.09E-02	9.86E-03	6.09E-04	8.23E-04	2.73E-03

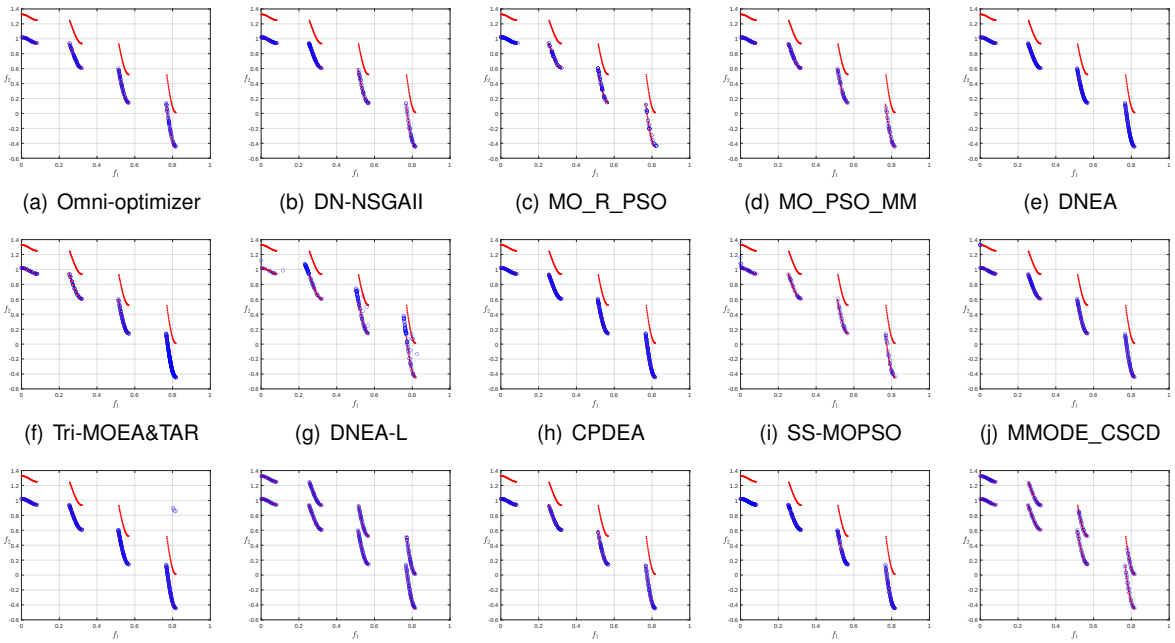
TABLE IX
AVERAGE AND VARIANCE OF RPSP RESULTS OF THE COMPARED ALGORITHMS ON MMOPL TEST SUITE, WHERE THE BEST MEAN FOR EACH TEST INSTANCE IS HIGHLIGHTED.

Problems	Omni-optimizer	DN-NSGAII	MO_Ring_PSO_SCD	MO_PSO_MM	DNEA	Tri-MOEA&TAR	DNEA-L	CPDEA	SS-MOPSO	MMODE_CSCD	MP-MMEA	MMOEA/DC	MMODE_ICD	MMEA-WI	HREA
IDMPM2T1e	5.42E+01	5.82E+01	2.39E+01	2.23E+01	1.09E+02	Inf	2.05E-03	7.50E+01	2.55E+01	6.35E+01	6.16E-01	8.92E-04	2.63E+02	4.91E+01	6.29E-04
	8.91E+00	1.14E+01	2.80E+00	5.66E+00	3.94E+01	NaN	1.19E-03	4.35E+01	3.28E+00	6.60E+00	1.89E-01	1.11E-04	5.67E+01	6.98E+00	5.44E-05
IDMPM2T2e	3.66E+01	3.50E+01	2.28E+01	2.30E+01	4.31E+01	8.45E+01	3.10E-03	3.46E+01	2.34E+01	3.43E+01	6.50E-01	1.02E-03	7.53E+01	3.21E+01	9.22E-04
	9.17E+00	2.44E+00	1.57E+00	5.00E+00	6.05E+00	7.60E+01	4.91E-03	4.79E+00	1.54E+00	2.32E+00	1.35E-01	1.05E-04	2.51E+01	4.90E+00	8.29E-05
IDMPM2T3e	3.69E+01	4.05E+01	4.69E-01	7.37E-01	3.02E+01	1.64E+01	3.17E-03	7.52E-01	7.46E-01	7.44E+00	3.79E-01	1.38E-03	4.50E-01	7.52E-01	1.40E-03
	2.74E+01	3.03E+01	7.49E-01	1.32E-01	3.26E+01	2.91E+01	4.01E-03	1.67E-03	1.35E-01	1.30E+01	5.20E-01	6.45E-05	1.02E+00	1.63E-03	7.43E-05
IDMPM2T4e	1.43E+02	8.68E+01	1.98E+01	2.72E+01	1.39E+02	Inf	3.20E-01	1.17E+02	3.70E+01	1.06E+02	6.50E-01	1.37E-01	1.58E+01	1.03E+02	3.65E-03
	1.97E+02	9.73E+01	2.84E+01	3.26E+01	7.65E+01	NaN	1.28E-01	2.23E+01	3.03E+01	4.90E+00	2.56E-01	1.16E-01	8.31E+01	2.38E+01	2.45E-03
IDMPM3T1e	7.08E+00	6.61E+00	1.82E+00	1.81E+00	1.30E+01	1.42E+01	3.75E-02	1.78E+00	1.79E+00	1.78E+00	3.93E-01	8.08E-03	1.80E+00	1.78E+00	6.97E-03
	7.62E+00	7.48E+00	6.39E-02	4.33E-02	1.51E+01	1.70E+01	8.19E-02	1.41E-02	3.85E-02	5.80E-03	1.98E-01	2.09E-04	1.69E-02	1.31E-02	1.33E-04
IDMPM3T2e	1.55E+01	1.01E+01	2.48E+00	1.03E+00	1.84E+01	2.27E+01	2.02E-01	5.68E-01	1.03E+00	1.71E+01	7.38E-01	7.84E-03	2.07E+01	5.67E-01	7.46E-03
	7.34E+00	8.17E+00	4.97E+00	2.60E+00	8.20E+00	6.47E+00	1.28E-01	1.37E-03	2.57E+00	5.69E+00	4.53E-01	1.38E-04	1.04E+01	1.10E-03	3.37E-04
IDMPM3T3e	8.08E+00	1.06E+01	5.82E-01	5.83E-01	9.17E+00	1.59E+01	2.80E-01	5.77E-01	5.79E-01	1.91E+00	9.77E-01	1.23E-02	2.55E+00	5.74E-01	9.26E-03
	9.20E+00	8.41E+00	8.88E-03	8.67E-03	1.18E+01	1.52E+01	6.51E-02	5.74E-03	6.36E-03	4.61E+00	1.18E+00	1.73E-02	7.42E+00	4.22E-03	1.75E-03
IDMPM3T4e	2.33E+01	2.37E+01	2.10E+00	2.42E+00	2.00E+01	2.60E+01	8.73E-01	3.72E+00	2.38E+00	1.71E+01	1.58E+00	1.32E-02	3.74E+00	1.75E+01	1.07E-02
	1.76E+01	1.72E+01	1.23E+00	1.37E+00	2.28E+01	2.70E+01	3.17E-01	2.61E-02	1.28E+00	1.86E+01	3.18E+00	6.90E-03	3.69E-02	2.35E+01	4.52E-04
MMF10	2.54E+00	6.31E-01	1.76E-01	4.43E-01	9.28E+00	Inf	1.38E-02	7.48E+00	1.66E-01	3.97E-01	2.67E+00	2.29E-02	1.73E+01	5.84E+00	7.22E-03
	3.29E+00	1.70E+00	1.15E-02	1.09E+00	2.71E+00	NaN	2.71E-03	1.09E+00	1.90E-02	1.05E+00	2.79E+00	8.72E-02	1.20E+01	2.19E+00	7.64E-04
MMF11	1.81E+00	1.74E+00	4.10E-01	1.26E+00	2.08E+00	Inf	1.97E-02	1.84E+00	3.76E-01	7.89E-01	1.43E+00	5.62E-03	Inf	1.68E+00	7.16E-03
	1.31E-01	1.97E-01	3.74E-01	4.89E-01	1.51E-01	NaN	1.01E-02	9.53E-02	3.88E-01	8.12E-01	3.30E-01	1.82E-04	NaN	1.40E-01	1.01E-03
MMF12	2.15E+00	2.23E+00	5.12E-01	1.06E+00	2.68E+00	Inf	5.56E-01	2.19E+00	4.28E-01	1.41E+00	2.10E+00	2.50E-03	Inf	1.98E+00	2.74E-03
	3.98E-01	2.34E-01	4.59E-01	5.37E-01	2.97E-01	NaN	3.42E-01	1.30E-01	4.70E-01	1.00E+00	2.08E-01	1.18E-04	NaN	1.78E-01	1.35E-04
MMF13	6.06E-01	6.16E-01	3.32E-01	4.79E-01	5.49E-01	6.51E-01	5.18E-01	5.12E-01	3.19E-01	3.72E-01	5.50E-01	9.75E-02	5.39E-01	5.28E-01	4.42E-02
	2.32E-02	6.83E-02	6.12E-02	8.98E-02	1.77E-02	8.26E-02	6.29E-02	5.53E-02	8.79E-02	9.74E-02	4.56E-02	3.25E-02	2.50E-03	4.07E-03	6.38E-04
MMF15	3.20E-01	2.40E-01	1.51E-01	1.50E-01	5.62E-01	Inf	6.66E-02	3.05E-01	1.53E-01	1.37E-01	5.94E-01	5.41E-02	9.47E-01	5.50E-01	4.34E-02
	1.29E-01	6.52E-02	1.04E-02	1.47E-02	7.27E-02	NaN	4.12E-03	1.52E-01	1.50E-02	1.33E-02	5.52E-02	1.61E-03	3.55E-01	6.37E-02	9.11E-04
MMF15_a	2.38E-01	2.24E-01	1.70E-01	1.61E-01	2.56E-01	2.74E-01	9.54E-02	2.36E-01	1.62E-01	1.56E-01	2.71E-01	9.17E-02	2.68E-01	2.55E-01	5.33E-02
	2.98E-02	3.22E-02	1.56E-02	1.65E-02	4.80E-03	3.35E-03	4.87E-03	2.54E-02	1.28E-02	9.31E-03	5.23E-03	1.45E-02	2.26E-03	5.26E-03	2.09E-03
MMF16_l1	2.10E-01	1.92E-01	1.16E-01	1.16E-01	1.99E-01	2.04E-01	8.12E-02	1.64E-01	1.16E-01	1.10E-01	2.24E-01	6.85E-02	2.08E-01	1.98E-01	4.77E-02
	3.44E-02	2.67E-02	8.55E-03	6.74E-03	7.71E-03	5.06E-04	4.31E-03	2.82E-02	7.24E-03	6.74E-03	8.32E-03	2.57E-03	8.87E-04	5.15E-03	1.01E-03
MMF16_l2	4.30E-01	3.46E-01	1.94E-01	1.99E-01	7.30E-01	Inf	8.36E-02	3.97E-01	2.00E-01	1.81E-01	7.74E-01	1.20E-01	1.20E+00	7.37E-01	6.14E-02
	1.77E-01	1.03E-01	1.86E-02	2.12E-02	1.06E-01	NaN	5.21E-03	1.76E-01	1.65E-02	1.52E-02	8.84E-02	2.54E-02	2.23E-01	6.32E-02	1.03E-02
MMF16_l3	2.82E-01	2.55E-01	1.55E-01	1.48E-01	2.92E-01	2.99E-01	1.27E-01	2.17E-01	1.56E-01	1.44E-01	3.08E-01	1.13E-01	3.01E-01	2.86E-01	5.89E-02
	4.92E-02	3.75E-02	1.32E-02	7.05E-03	6.65E-03	4.36E-04	8.96E-03	3.30E-02	7.86E-03	1.12E-02	2.20E-02	1.49E-02	1.54E-03	8.50E-03	2.73E-03



(a) IGD (b) IGDX

Fig. 7. The critical difference of all compared MMEAs on MMOPL test suite, where the red lines indicate that there is no significant difference in the Friedman ranks of the two MMEAs.



(a) Omni-optimizer (b) DN-NSGAII (c) MO_R_PSO (d) MO_PSO_MM (e) DNEA

(f) Tri-MOEA&TAR (g) DNEA-L (h) CPDEA (i) SS-MOPSO (j) MMODE_CSCD

(k) MP-MMEA (l) MMOEA/DC (m) MMODE_ICD (n) MMEA-WI (o) HREA

Fig. 8. The distribution of solutions obtained by all algorithms (MO_R_PSO_SCD is the short name for MO_Ring_PSO_SCD) in the objective space on MMF12.

TABLE X
AVERAGE IGD RESULTS OF THE COMPARED ALGORITHMS ON MULTI-POLYGON TEST SUITE, WHERE THE BEST MEAN FOR EACH TEST INSTANCE IS HIGHLIGHTED.

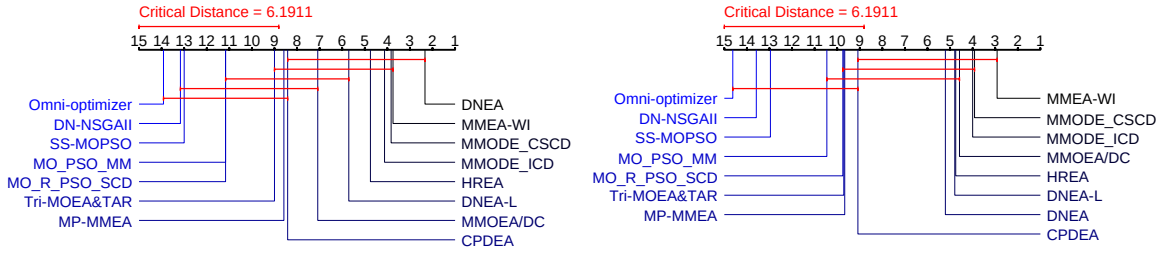
M	D	Omni-optimizer	DN-NSGAII	MO_Ring_PSO_SCD	MO_PSO_MM	DNEA	Tri-MOEA&TAR	DNEA-L	CPDEA	SS-MOPSO	MMODE_CSCD	MP-MMEA	MMOEA/DC	MMODE_ICD	MMEA-WI	HREA
3	2	2.96E+00	3.17E+00	2.17E-01	1.48E-01	7.80E-02	3.53E-01	1.24E-01	7.37E-02	2.26E-01	6.52E-02	1.67E-01	9.15E-02	6.72E-02	9.36E-02	5.11E-02
	4	1.90E+01	1.69E+01	2.38E+00	2.77E+00	1.76E+00	4.81E+00	2.93E-01	6.30E+00	7.69E+00	1.69E-01	4.23E+00	5.86E-01	7.11E-01	8.44E-01	1.87E+00
	8	5.37E+01	4.77E+01	8.67E+00	1.56E+01	7.60E+00	7.51E+00	5.88E+00	7.24E+01	4.24E+01	2.23E+00	7.96E+00	1.60E+00	4.68E+00	2.37E+00	6.87E+00
	10	6.45E+01	5.73E+01	1.22E+01	2.66E+01	8.54E+00	8.70E+00	8.01E+00	4.85E+01	6.40E+01	4.06E+00	9.05E+00	8.85E+00	5.90E+00	8.05E+00	8.03E+00
	20	1.36E+02	1.24E+02	4.62E+01	8.90E+01	1.24E+01	1.25E+01	1.24E+01	9.19E+01	1.40E+02	1.88E+01	1.33E+01	1.27E+01	9.92E+00	1.16E+01	1.24E+01
4	2	3.80E+00	3.25E+00	1.77E-01	1.23E-01	7.50E-02	7.73E-01	1.06E-01	8.14E-02	2.04E-01	9.73E-02	1.66E-01	8.80E-02	9.10E-02	8.69E-02	7.14E-02
	4	2.20E+01	1.70E+01	1.69E+00	2.07E+00	1.56E+00	3.84E+00	3.07E-01	3.06E+00	7.84E+00	2.20E-01	3.69E+00	5.09E-01	3.47E-01	6.27E-01	2.33E+00
	8	5.13E+01	4.68E+01	7.42E+00	1.48E+01	6.87E+00	7.26E+00	5.20E+00	6.50E+01	4.22E+01	3.84E+00	7.59E+00	1.34E+00	4.24E+00	9.59E-01	6.66E+00
	10	7.43E+01	5.45E+01	1.05E+01	2.52E+01	8.18E+00	8.37E+00	7.27E+00	8.22E+00	6.59E+01	5.29E+00	8.68E+00	5.33E+00	5.98E+00	7.74E+00	7.72E+00
	20	1.27E+02	1.21E+02	4.10E+01	8.55E+01	1.20E+01	1.21E+01	1.22E+01	9.00E+01	1.43E+02	2.19E+01	1.30E+01	8.17E+00	1.09E+01	1.11E+01	1.19E+01
6	2	3.25E+00	2.84E+00	2.25E-01	1.48E-01	7.12E-02	5.34E-01	8.98E-02	7.85E-02	2.37E-01	9.08E-02	1.23E-01	8.31E-02	8.88E-02	8.19E-02	6.83E-02
	4	1.95E+01	1.71E+01	1.87E+00	2.20E+00	4.10E-01	2.07E+00	3.43E-01	1.12E+01	6.12E+00	2.17E-01	3.67E+00	3.91E-01	6.71E-01	2.42E-01	2.35E+00
	8	5.57E+01	4.94E+01	8.55E+00	1.54E+01	6.78E+00	7.36E+00	5.50E+00	6.62E+01	3.80E+01	1.37E+00	7.73E+00	1.67E+00	3.28E+00	1.19E+00	6.67E+00
	10	5.65E+01	4.84E+01	1.19E+01	2.62E+01	8.01E+00	8.54E+00	7.83E+00	8.72E+01	6.11E+01	3.95E+00	8.89E+00	2.76E+00	5.97E+00	4.74E+00	7.52E+00
	20	1.20E+02	1.30E+02	4.72E+01	8.78E+01	1.21E+01	1.28E+01	1.29E+01	1.72E+02	1.43E+02	1.69E+01	1.31E+01	5.06E+00	9.90E+00	4.86E+00	1.17E+01
8	2	2.75E+00	2.35E+00	2.28E-01	1.48E-01	7.40E-02	7.16E-01	9.16E-02	8.06E-02	2.37E-01	9.40E-02	1.37E-01	8.58E-02	9.25E-02	8.44E-02	7.07E-02
	4	1.99E+01	1.72E+01	2.09E+00	2.19E+00	1.42E+00	4.70E+00	3.22E-01	2.89E+00	7.19E+00	2.20E-01	3.63E+00	3.72E-01	6.68E-01	5.74E-01	2.31E+00
	8	4.81E+01	4.40E+01	8.27E+00	1.55E+01	7.04E+00	7.41E+00	5.47E+00	6.17E+01	4.33E+01	1.61E+00	7.67E+00	1.76E+00	4.09E+00	2.16E+00	6.55E+00
	10	7.10E+01	6.18E+01	1.22E+01	2.56E+01	8.22E+00	8.39E+00	6.91E+00	8.19E+00	6.26E+01	5.20E+00	8.81E+00	5.60E+00	5.68E+00	7.72E+00	7.54E+00
	20	1.28E+02	1.15E+02	4.67E+01	8.31E+01	1.13E+01	1.22E+01	1.25E+01	1.16E+01	1.41E+02	1.62E+01	1.30E+01	1.16E+01	9.62E+00	1.11E+01	1.18E+01

TABLE XI
AVERAGE IGDX RESULTS OF THE COMPARED ALGORITHMS ON MULTI-POLYGON TEST SUITE, WHERE THE BEST MEAN FOR EACH TEST INSTANCE IS HIGHLIGHTED.

M	D	Omni-optimizer	DN-NSGAII	MO_Ring_PSO_SCD	MO_PSO_MM	DNEA	Tri-MOEA&TAR	DNEA-L	CPDEA	SS-MOPSO	MMODE_CSCD	MP-MMEA	MMOEA/DC	MMODE_ICD	MMEA-WI	HREA
3	2	2.96E+00	3.17E+00	2.17E-01	1.48E-01	7.80E-02	3.53E-01	1.24E-01	7.37E-02	2.26E-01	6.52E-02	1.67E-01	9.15E-02	6.72E-02	9.36E-02	5.11E-02
	4	1.90E+01	1.69E+01	2.38E+00	2.77E+00	1.76E+00	4.81E+00	2.93E-01	6.30E+00	7.69E+00	1.69E-01	4.23E+00	5.86E-01	7.11E-01	8.44E-01	1.87E+00
	8	5.37E+01	4.77E+01	8.67E+00	1.56E+01	7.60E+00	7.51E+00	5.88E+00	7.24E+01	4.24E+01	2.23E+00	7.96E+00	1.60E+00	4.68E+00	2.37E+00	6.87E+00
	10	6.45E+01	5.73E+01	1.22E+01	2.66E+01	8.54E+00	8.70E+00	8.01E+00	4.85E+01	6.40E+01	4.06E+00	9.05E+00	8.85E+00	5.90E+00	8.05E+00	8.03E+00
	20	1.36E+02	1.24E+02	4.62E+01	8.90E+01	1.24E+01	1.25E+01	1.24E+01	9.19E+01	1.40E+02	1.88E+01	1.33E+01	1.27E+01	9.92E+00	1.16E+01	1.24E+01
4	2	3.80E+00	3.25E+00	1.77E-01	1.23E-01	7.50E-02	7.73E-01	1.06E-01	8.14E-02	2.04E-01	9.73E-02	1.66E-01	8.80E-02	9.10E-02	8.69E-02	7.14E-02
	4	2.20E+01	1.70E+01	1.69E+00	2.07E+00	1.56E+00	3.84E+00	3.07E-01	3.06E+00	7.84E+00	2.20E-01	3.69E+00	5.09E-01	3.47E-01	6.27E-01	2.33E+00
	8	5.13E+01	4.68E+01	7.42E+00	1.48E+01	6.87E+00	7.26E+00	5.20E+00	6.50E+01	4.22E+01	3.84E+00	7.59E+00	1.34E+00	4.24E+00	9.59E-01	6.66E+00
	10	7.43E+01	5.45E+01	1.05E+01	2.52E+01	8.18E+00	8.37E+00	7.27E+00	8.22E+00	6.59E+01	5.29E+00	8.68E+00	5.33E+00	5.98E+00	7.74E+00	7.72E+00
	20	1.27E+02	1.21E+02	4.10E+01	8.55E+01	1.20E+01	1.21E+01	1.22E+01	9.00E+01	1.43E+02	2.19E+01	1.30E+01	8.17E+00	1.09E+01	1.11E+01	1.19E+01
6	2	3.25E+00	2.84E+00	2.25E-01	1.48E-01	7.12E-02	5.34E-01	8.98E-02	7.85E-02	2.37E-01	9.08E-02	1.23E-01	8.31E-02	8.88E-02	8.19E-02	6.83E-02
	4	1.95E+01	1.71E+01	1.87E+00	2.20E+00	4.10E-01	2.07E+00	3.43E-01	1.12E+01	6.12E+00	2.17E-01	3.67E+00	3.91E-01	6.71E-01	2.42E-01	2.35E+00
	8	5.57E+01	4.94E+01	8.55E+00	1.54E+01	6.78E+00	7.36E+00	5.50E+00	6.62E+01	3.80E+01	1.37E+00	7.73E+00	1.67E+00	3.28E+00	1.19E+00	6.67E+00
	10	5.65E+01	4.84E+01	1.19E+01	2.62E+01	8.01E+00	8.54E+00	7.83E+00	8.72E+01	6.11E+01	3.95E+00	8.89E+00	2.76E+00	5.97E+00	4.74E+00	7.52E+00
	20	1.20E+02	1.30E+02	4.72E+01	8.78E+01	1.21E+01	1.28E+01	1.29E+01	1.72E+02	1.43E+02	1.69E+01	1.31E+01	5.06E+00	9.90E+00	4.86E+00	1.17E+01
8	2	2.75E+00	2.35E+00	2.28E-01	1.48E-01	7.40E-02	7.16E-01	9.16E-02	8.06E-02	2.37E-01	9.40E-02	1.37E-01	8.58E-02	9.25E-02	8.44E-02	7.07E-02
	4	1.99E+01	1.72E+01	2.09E+00	2.19E+00	1.42E+00	4.70E+00	3.22E-01	2.89E+00	7.19E+00	2.20E-01	3.63E+00	3.72E-01	6.68E-01	5.74E-01	2.31E+00
	8	4.81E+01	4.40E+01	8.27E+00	1.55E+01	7.04E+00	7.41E+00	5.47E+00	6.17E+01	4.33E+01	1.61E+00	7.67E+00	1.76E+00	4.09E+00	2.16E+00	6.55E+00
	10	7.10E+01	6.18E+01	1.22E+01	2.56E+01	8.22E+00	8.39E+00	6.91E+00	8.19E+00	6.26E+01	5.20E+00	8.81E+00	5.60E+00	5.68E+00	7.72E+00	7.54E+00
	20	1.28E+02	1.15E+02	4.67E+01	8.31E+01	1.13E+01	1.22E+01	1.25E+01	1.16E+01	1.41E+02	1.62E+01	1.30E+01	1.16E+01	9.62E+00	1.11E+01	1.18E+01

TABLE XII
AVERAGE RPSP RESULTS OF THE COMPARED ALGORITHMS ON MULTI-POLYGON TEST SUITE, WHERE THE BEST MEAN FOR EACH TEST INSTANCE IS HIGHLIGHTED.

M	D	Omni-optimizer	DN-NSGAII	MO_Ring_PSO_SCD	MO_PSO_MM	DNEA	Tri-MOEA&TAR	DNEA-L	CPDEA	SS-MOPSO	MMODE_CSCD	MP-MMEA	MMOEA/DC	MMODE_ICD	MMEA-WI	HREA
3	2	Inf	Inf	2.19E-01	1.49E-01	7.80E-02	3.61E-01	1.24E-01	7.37E-02	2.27E-01	6.52E-02	1.67E-01	9.15E-02	6.73E-02	9.36E-02	5.11E-02
	4	Inf	Inf	3.22E+00	4.51E+00	3.32E+00	Inf	2.93E-01	Inf	Inf	1.69E-01	7.08E+00	7.54E-01	8.93E-01	1.46E+00	3.89E+00
	8	Inf	Inf	Inf	Inf	3.43E+01	Inf	1.39E+01	Inf	Inf	6.25E+00	3.49E+01	1.60E+00	1.09E+01	3.65E+00	2.95E+01
	10	Inf	Inf	Inf	Inf	4.03E+01	Inf	2.21E+01	Inf	Inf	1.01E+01	Inf	3.33E+01	1.88E+01	3.55E+01	4.00E+01
	20	Inf	Inf	Inf	Inf	6.55E+01	Inf	4.29E+01	Inf	Inf	Inf	Inf	4.70E+01	2.05E+01	5.21E+01	Inf
4	2	Inf	Inf	1.78E-01	1.24E-01	7.50E-02	Inf	1.06E-01	8.14E-02	2.04E-01	9.74E-02	1.66E-01	8.80E-02	9.10E-02	8.69E-02	7.14E-02
	4	Inf	Inf	1.96E+00	2.30E+00	3.10E+00	1.08E+01	3.08E-01	7.23E+00	Inf	2.20E-01	8.30E+00	6.37E-01	3.58E-01	8.77E-01	4.76E+00
	8	Inf	Inf	Inf	Inf	2.47E+01	2.93E+01	7.19E+00	Inf	Inf	9.70E+00	Inf	1.34E+00	8.73E+00	9.65E-01	2.50E+01
	10	Inf	Inf	Inf	Inf	3.19E+01	Inf	1.38E+01	3.13E+01	Inf	1.36E+01	Inf	1.37E+01	1.57E+01	2.86E+01	3.05E+01
	20	Inf	Inf	Inf	Inf	5.41E+01	Inf	2.35E+01	Inf	Inf	Inf	Inf	2.19E+01	3.66E+01	4.15E+01	5.98E+01
6	2	Inf	1.06E+01	2.25E-01	1.48E-01	7.12E-02	Inf	8.98E-02	7.85E-02	2.38E-01	9.08E-02	1.23E-01	8.31E-02	8.88E-02	8.19E-02	6.83E-02
	4	Inf	Inf	2.01E+00	2.44E+00	5.51E-01	3.89E+00	3.43E-01	Inf	Inf	2.17E-01	8.99E+00	3.91E-01	8.29E-01	2.42E-01	5.51E+00
	8	Inf	Inf	Inf	Inf	2.36E+01	Inf	7.68E+00	Inf	Inf	2.71E+00	2.81E+01	1.67E+00	5.15E+00	1.20E+00	2.49E+01
	10	Inf	Inf	Inf	Inf	3.02E+01	Inf	1.24E+01	Inf	Inf	9.14E+00	Inf	2.76E+00	1.59E+01	1.06E+01	2.81E+01
	20	Inf	Inf	Inf	Inf	5.03E+01	Inf	1.29E+01	Inf	Inf	Inf	Inf	5.06E+00	2.17E+01	6.47E+00	5.29E+01
8	2	8.37E+00	7.81E+00	2.28E-01	1.48E-01	7.40E-02	7.71E-01	9.16E-02	8.06E-02	2.38E-01	9.40E-02	1.37E-01	8.58E-02	9.25E-02	8.44E-02	7.07E-02
	4	Inf	Inf	2.44E+00	2.54E+00	2.05E+00	1.66E+01	3.23E-01	6.34E+00	Inf	2.20E-01	9.17E+00	3.73E-01	6.87E-01	8.16E-01	4.83E+00
	8	Inf	Inf	Inf	Inf	2.48E+01	Inf	7.61E+00	Inf	Inf	2.63E+00	Inf	1.76E+00	7.89E+00	3.20E+00	2.31E+01
	10	Inf	Inf	Inf	Inf	3.07E+01	4.29E+01	1.05E+01	2.98E+01	Inf	1.36E+01	Inf	1.36E+01	1.41E+01	2.76E+01	2.71E+01
	20	Inf	Inf	Inf	Inf	4.31E+01	Inf	2.06E+01	4.21E+01	Inf	Inf	Inf	3.41E+01	1.83E+01	4.07E+01	Inf



(a) IGD (b) IGDX

Fig. 9. The critical difference of all compared MMEAs on multi Polygon test suite, where the red lines indicate that there is no significant difference in the Friedman ranks of the two MMEAs.

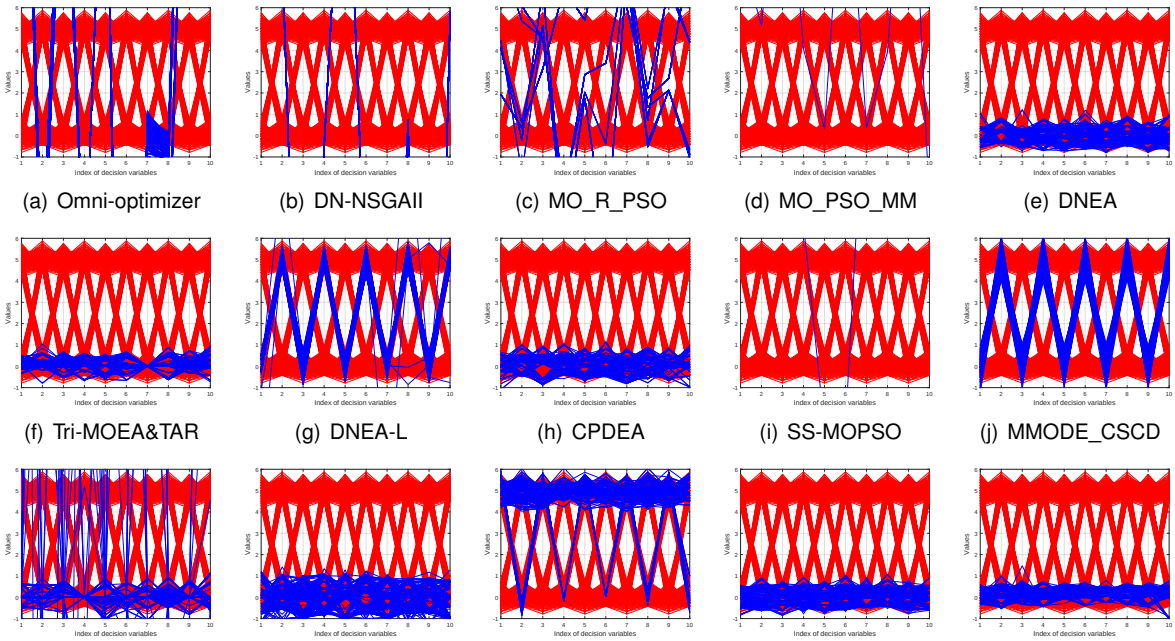


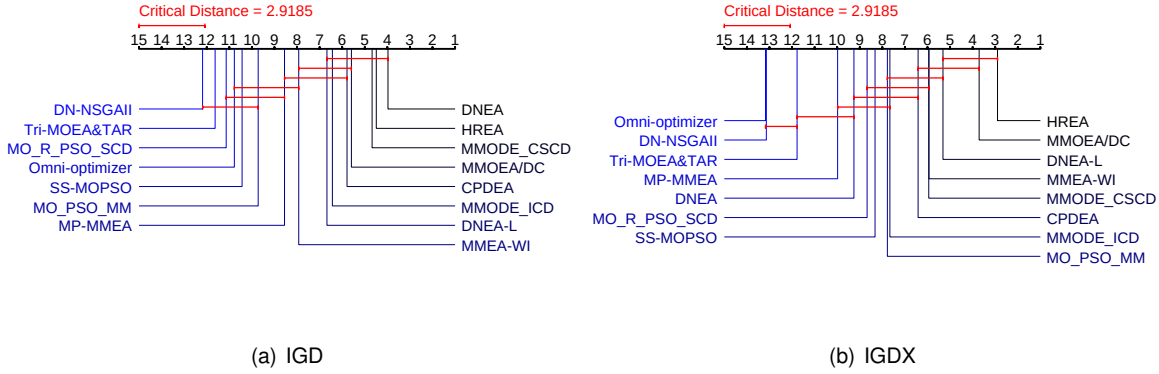
Fig. 10. The distribution of solutions obtained by all algorithms (MO_R_PSO_SCD is the short name for MO_Ring_PSO_SCD) in the decision space on Multi-polygon problem with 3 objectives and 10 decision variables.

TABLE XIII
AVERAGE RANKS R OF IGD, IGDX AND RPSP FOR 15 COMPARED MMEAS ON FOUR DIFFERENT MMOP TEST SUITES, WHERE THE BEST RANK IS HIGHLIGHTED WITH GRAY BACKGROUND.

Problems	Indicators	Omni-optimizer	DN-NSGAII	MO_Ring_PSO_SCD	MO_PSO_MM	DNEA	Tri-MOEA&TAR	DNEA-L	CPDEA	SS-MOPSO	MMODE_CSCD	MP-MMEA	MMOEA/DC	MMODE_ICD	MMEA-WI	HREA
MMF	IGD	8.71	11.53	10.88	6.10	3.10	11.29	12.36	3.83	8.61	4.10	10.49	5.69	5.08	9.40	8.83
	IGDX	13.73	14.05	8.59	5.45	8.21	10.23	8.84	2.86	6.29	5.23	12.53	6.59	7.53	6.49	3.35
	RPSP	13.71	14.02	8.63	5.51	8.24	10.32	8.84	2.80	6.37	5.23	12.51	6.54	7.48	6.45	3.35
IDMP	IGD	9.40	10.04	13.84	13.95	1.11	10.36	5.42	4.57	13.60	4.58	7.51	9.71	3.68	7.49	4.75
	IGDX	11.53	11.68	8.72	7.66	11.90	13.04	5.24	5.19	7.47	8.32	9.72	2.96	8.39	4.29	3.88
	RPSP	11.03	11.18	8.48	7.44	12.41	13.34	5.22	5.30	7.28	8.39	9.97	2.94	8.70	4.37	3.95
MMOPL	IGD	11.22	12.27	8.70	8.26	8.12	13.97	3.67	7.25	8.10	6.62	7.87	1.67	11.49	9.40	1.39
	IGDX	11.89	11.68	7.54	7.91	10.56	12.42	3.49	8.50	7.45	7.33	8.46	1.90	10.50	9.14	1.23
	RPSP	10.80	10.44	6.53	6.92	11.97	13.74	3.43	9.24	6.52	7.61	8.46	1.91	11.94	9.27	1.23
Polygon	IGD	13.49	13.31	10.86	11.25	2.33	8.52	6.07	8.67	13.01	4.11	8.19	7.27	4.35	3.55	5.05
	IGDX	14.02	13.65	9.78	10.48	5.25	9.13	5.31	9.35	12.83	4.25	9.37	4.43	4.25	3.05	4.88
	RPSP	13.17	12.97	9.89	10.93	5.90	10.15	4.18	8.92	12.45	4.68	9.07	3.54	4.29	3.75	6.11
Overall	IGD	11.07	12.02	10.85	9.87	3.84	10.95	6.61	6.47	10.85	4.89	8.45	5.88	6.33	7.14	4.78
	IGDX	12.89	12.82	8.71	8.17	8.61	11.02	5.54	6.95	8.95	6.09	9.85	3.90	7.45	5.68	3.36
	RPSP	12.22	12.15	8.43	8.02	9.32	11.79	5.15	7.02	8.55	6.32	9.80	3.61	7.91	5.95	3.78

VII. OVERALL PERFORMANCE AND TIME COMPLEXITY

This section listed the average ranks of all algorithms on all test problems. In addition, the detailed running time on problems with different numbers of objectives and decision variables are given.



(a) IGD (b) IGDX

Fig. 11. The critical difference of all compared MMEAs on multi Polygon test suite, where the red lines indicate that there is no significant difference in the Friedman ranks of the two MMEAs.

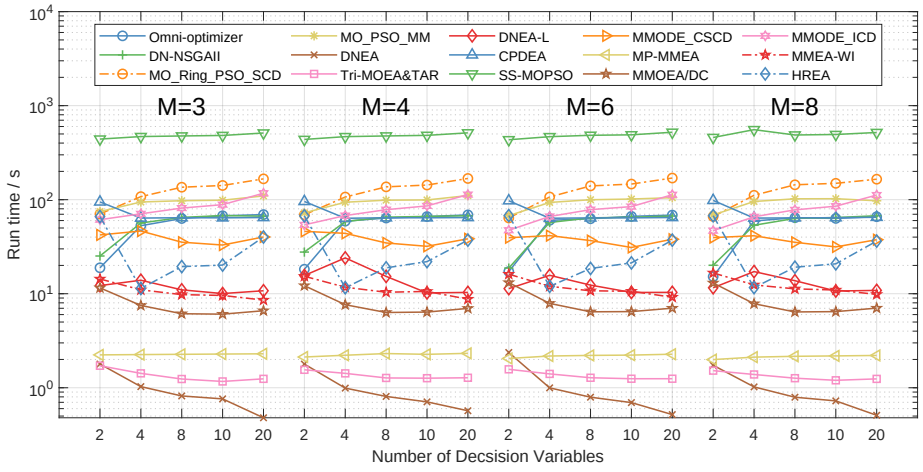


Fig. 12. The average running time of all algorithms on Multi-polygon problems with different numbers of objectives and decision variables.

TABLE XIV
AVERAGE RUNNING TIME (IN SECOND) OF THE COMPARED ALGORITHMS ON MULTI-POLYGON TEST SUITE, WHERE POPULATION SIZE AND FUNCTION EVALUATIONS ARE SET TO 200 AND 20000 RESPECTIVELY.

M	D	Omni-optimizer	DN-NSGAII	MO_Ring_PSO_SCD	MO_PSO_MM	DNEA	Tri-MOEA&TAR	DNEA-L	CPDEA	SS-MOPSO	MMODE_CSCD	MP-MMEA	MMOEA/DC	MMODE_ICD	MMEA-WI	HREA
3	2	1.89E+01	2.52E+01	7.05E+01	7.48E+01	1.79E+00	1.71E+00	1.22E+01	9.46E+01	4.41E+02	4.22E+01	2.24E+00	1.15E+01	6.13E+01	1.43E+01	6.61E+01
	4	5.29E+01	5.65E+01	1.08E+02	9.45E+01	1.03E+00	1.42E+00	1.39E+01	6.37E+01	4.69E+02	4.64E+01	2.25E+00	7.50E+00	7.08E+01	1.10E+01	1.14E+01
	8	6.31E+01	6.48E+01	1.36E+02	9.75E+01	8.18E-01	1.24E+00	1.10E+01	6.43E+01	4.76E+02	3.53E+01	2.27E+00	6.13E+00	8.14E+01	9.78E+00	1.94E+01
	10	6.74E+01	6.78E+01	1.42E+02	9.87E+01	7.61E-01	1.17E+00	1.00E+01	6.41E+01	4.82E+02	3.29E+01	2.28E+00	6.06E+00	8.86E+01	9.59E+00	2.02E+01
	20	6.94E+01	6.67E+01	1.67E+02	1.10E+02	4.79E-01	1.24E+00	1.08E+01	6.46E+01	5.12E+02	4.01E+01	2.30E+00	6.59E+00	1.17E+02	8.56E+00	4.01E+01
4	2	1.82E+01	2.77E+01	6.91E+01	7.25E+01	1.79E+00	1.55E+00	1.56E+01	9.57E+01	4.37E+02	4.60E+01	2.12E+00	1.22E+01	5.40E+01	1.53E+01	6.73E+01
	4	5.91E+01	5.86E+01	1.07E+02	9.40E+01	9.92E-01	1.42E+00	2.40E+01	6.34E+01	4.68E+02	4.39E+01	2.22E+00	7.64E+00	6.78E+01	1.17E+01	1.16E+01
	8	6.38E+01	6.52E+01	1.37E+02	9.88E+01	8.09E-01	1.27E+00	1.53E+01	6.42E+01	4.76E+02	3.47E+01	2.31E+00	6.32E+00	7.83E+01	1.04E+01	1.88E+01
	10	6.62E+01	6.64E+01	1.43E+02	9.94E+01	7.08E-01	1.26E+00	1.02E+01	6.42E+01	4.83E+02	3.19E+01	2.27E+00	6.38E+00	8.59E+01	1.06E+01	2.19E+01
	20	6.89E+01	6.74E+01	1.68E+02	1.11E+02	5.70E-01	1.28E+00	1.03E+01	6.46E+01	5.14E+02	3.84E+01	2.32E+00	6.98E+00	1.13E+02	8.75E+00	3.72E+01
6	2	1.72E+01	1.87E+01	6.39E+01	6.76E+01	2.37E+00	1.57E+00	1.13E+01	9.74E+01	4.34E+02	3.94E+01	2.05E+00	1.31E+01	4.73E+01	1.61E+01	6.78E+01
	4	6.04E+01	5.72E+01	1.07E+02	9.35E+01	9.98E-01	1.40E+00	1.57E+01	6.35E+01	4.68E+02	4.15E+01	2.18E+00	7.89E+00	6.63E+01	1.20E+01	1.20E+01
	8	6.27E+01	6.41E+01	1.40E+02	9.99E+01	7.94E-01	1.28E+00	1.24E+01	6.40E+01	4.84E+02	3.67E+01	2.21E+00	6.42E+00	7.84E+01	1.07E+01	1.86E+01
	10	6.65E+01	6.51E+01	1.47E+02	1.02E+02	6.96E-01	1.25E+00	1.03E+01	6.41E+01	4.90E+02	3.10E+01	2.23E+00	6.46E+00	8.44E+01	1.06E+01	2.13E+01
	20	6.86E+01	6.70E+01	1.70E+02	1.05E+02	5.18E-01	1.25E+00	1.03E+01	6.46E+01	5.21E+02	3.80E+01	2.27E+00	7.02E+00	1.13E+02	9.18E+00	3.71E+01
8	2	1.52E+01	2.01E+01	6.62E+01	6.88E+01	1.73E+00	1.52E+00	1.16E+01	9.83E+01	4.59E+02	3.95E+01	1.99E+00	1.30E+01	4.68E+01	1.66E+01	6.75E+01
	4	5.94E+01	5.35E+01	1.11E+02	9.57E+01	1.02E+00	1.38E+00	1.72E+01	6.37E+01	5.55E+02	4.14E+01	2.12E+00	7.83E+00	6.58E+01	1.24E+01	1.16E+01
	8	6.43E+01	6.32E+01	1.44E+02	1.02E+02	7.93E-01	1.26E+00	1.38E+01	6.41E+01	4.87E+02	3.52E+01	2.16E+00	6.40E+00	7.80E+01	1.13E+01	1.91E+01
	10	6.32E+01	6.46E+01	1.49E+02	1.02E+02	7.25E-01	1.20E+00	1.07E+01	6.43E+01	4.94E+02	3.15E+01	2.18E+00	6.45E+00	8.52E+01	1.09E+01	2.08E+01
	20	6.59E+01	6.75E+01	1.65E+02	9.74E+01	5.10E-01	1.24E+00	1.08E+01	6.50E+01	5.18E+02	3.76E+01	2.21E+00	7.03E+00	1.12E+02	9.83E+00	3.63E+01