Monte Carlo-driven Adaptive Resource Allocation for Dynamic Multi-objective Optimization

Zhenzhong Wang, Haokai Hong, Min Jiang, *Senior Member, IEEE,* and Kay Chen Tan, *Fellow, IEEE*

Abstract

This supplemental file includes six tables and six figures.

Table S-I reports the average MHV values of the seven compared algorithms.

To validate the effectiveness of the proposed method in adjusting the genetic operators, Tables S-II and S-III report the average MIGD and average MHV values of MCTS-DMOEA, MCTS-DMOEA-SBX, MCTS-DMOEA-DE, and MCTS-DMOEA-Rand.

To investigate the runtime of the proposed MCTS-DMOEA, Table S-IV lists the running time of the seven compared algorithms.

Table S-V lists the five operational conditions for the raw ore allocation problem. Table S-VI enumerates the properties of the six types of raw ore.

Fig. S-1 presents the convergence traces of MIGD values obtained by competing algorithms under test problems DF8-DF14.

Fig. S-2 and Fig. S-3 plot the convergence profiles of MIGD values obtained by MCTS-DMOEA, MCTS-DMOEA$_1$, and MCTS-DMOEA$_2$ under test problems DF1-DF14.

Fig. S-4 and Fig. S-5 plot the convergence traces obtained by MCTS-DMOEA, MCTS-DMOEA-SBX, MCTS-DMOEA-DE, and MCTS-DMOEA-Rand under test problems DF1-DF14.

Fig. S-6 displays the percentage allocation of computing resources, i.e., evaluations, to the SBX and DE operators by MCTS-DMOEA.

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Zhenzhong Wang and Kay Chen Tan are with the Department of Computing, The Hong Kong Polytechnic University, Hong Kong SAR, China (e-mail: zhenzhong16.wang@connect.polyu.hk; kctan@polyu.edu.hk).

Min Jiang and Hongkai Hong are with the Department of Artificial Intelligence, Key Laboratory of Digital Protection and Intelligent Processing of Intangible Cultural Heritage of Fujian and Taiwan, Ministry of Culture and Tourism, School of Informatics, Xiamen University, Xiamen 361005, Fujian, China (e-mail: minjiang@xmu.edu.cn; haokaihong@stu.xmu.edu.cn).

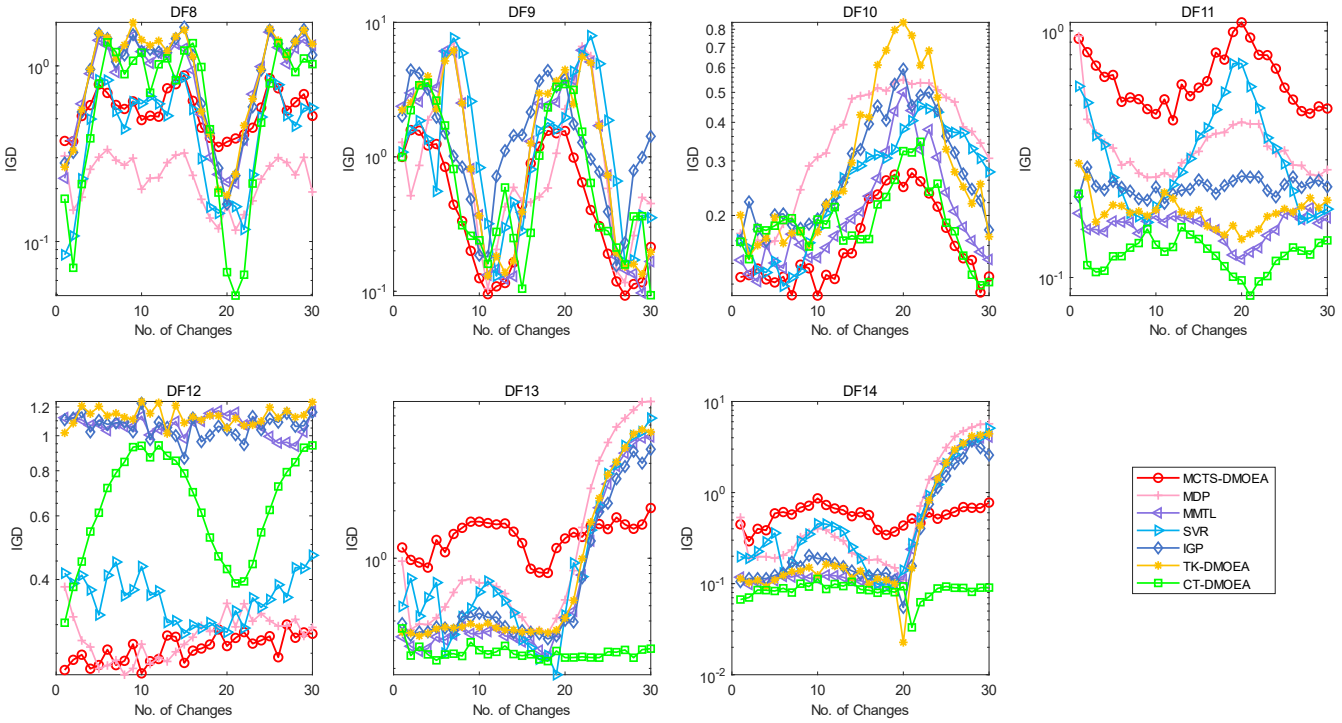

Fig. S-1. Convergence traces of average MIGD values obtained by competing algorithms under test problems DF8-DF14 with dynamic test setting ($n_t = 10, \tau_t = 10 \cdot S$).

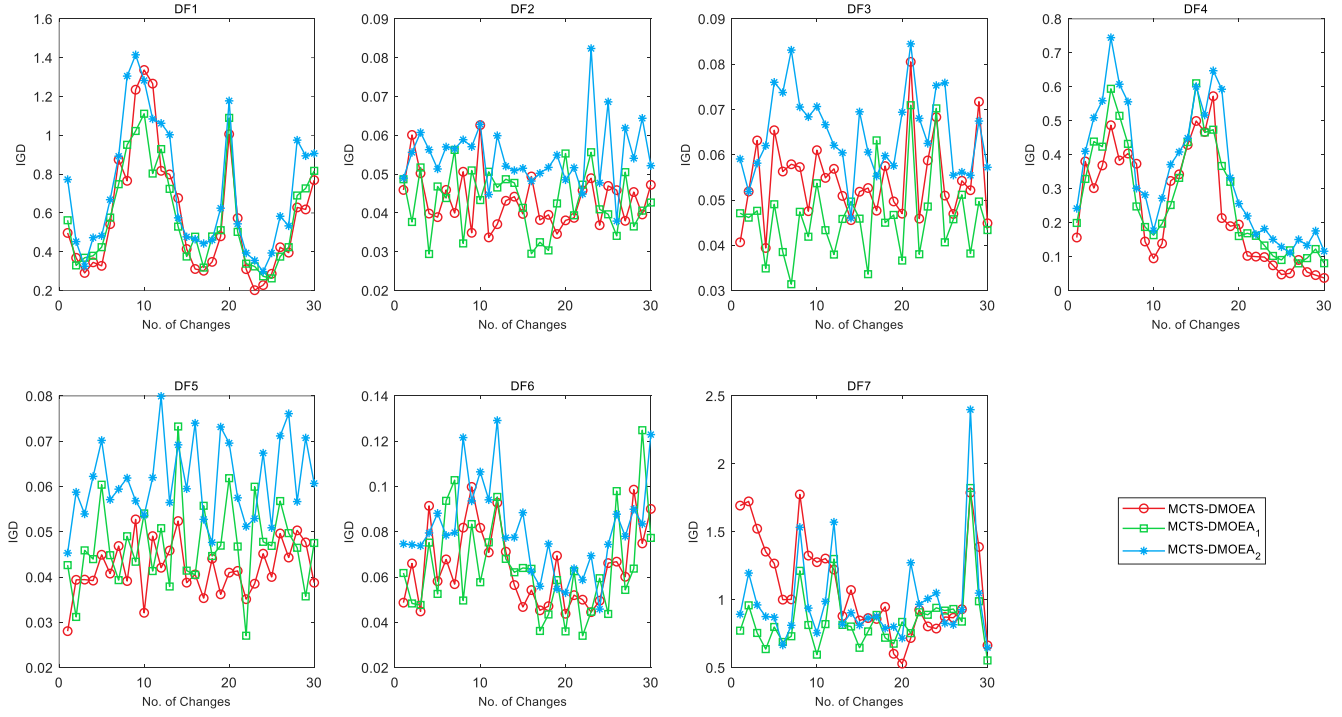

Fig. S-2. Convergence traces of average MIGD values obtained by MCTS-DMOEA, MCTS-DMOEA$_1$ and MCTS-DMOEA$_2$ under test problems DF1-DF7 with dynamic test setting ($n_t = 10, \tau_t = 10 \cdot S$).

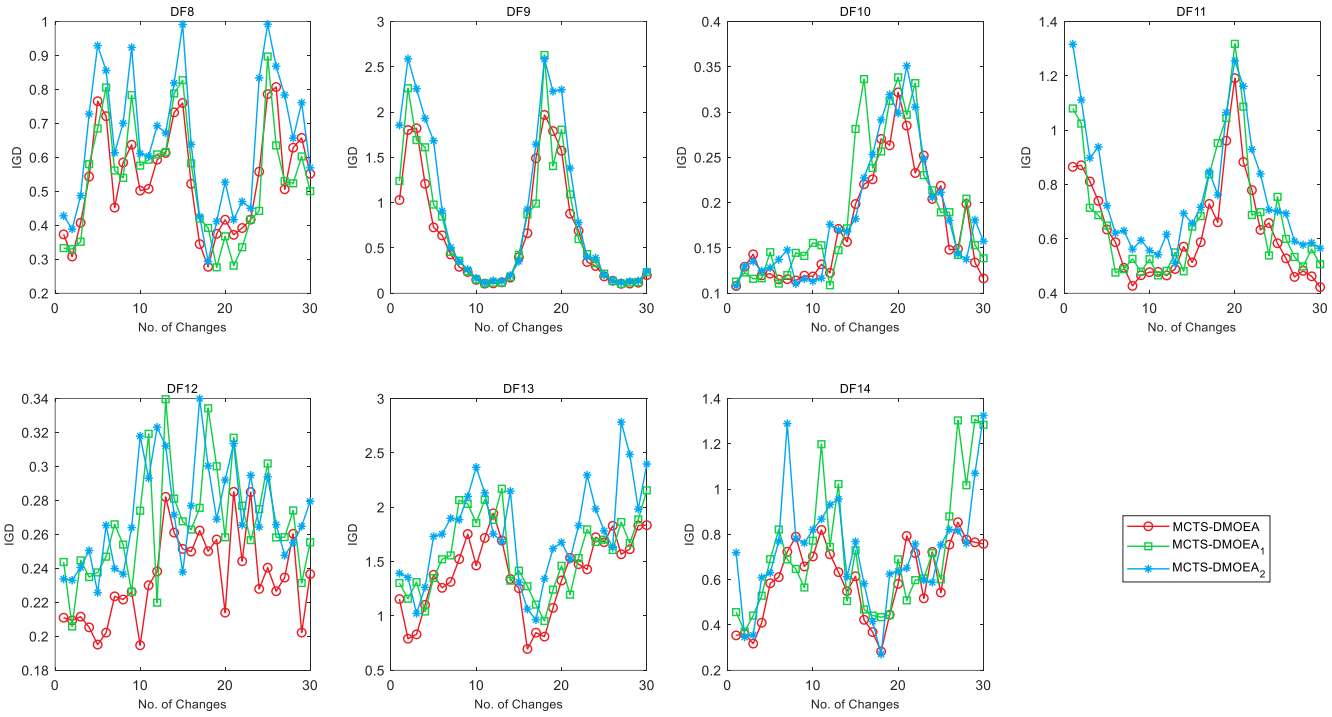

Fig. S-3. Convergence traces of average MIGD values obtained by MCTS-DMOEA, MCTS-DMOEA$_1$ and MCTS-DMOEA$_2$ under test problems DF8-DF14 with dynamic test setting ($n_t = 10, \tau_t = 10 \cdot S$).

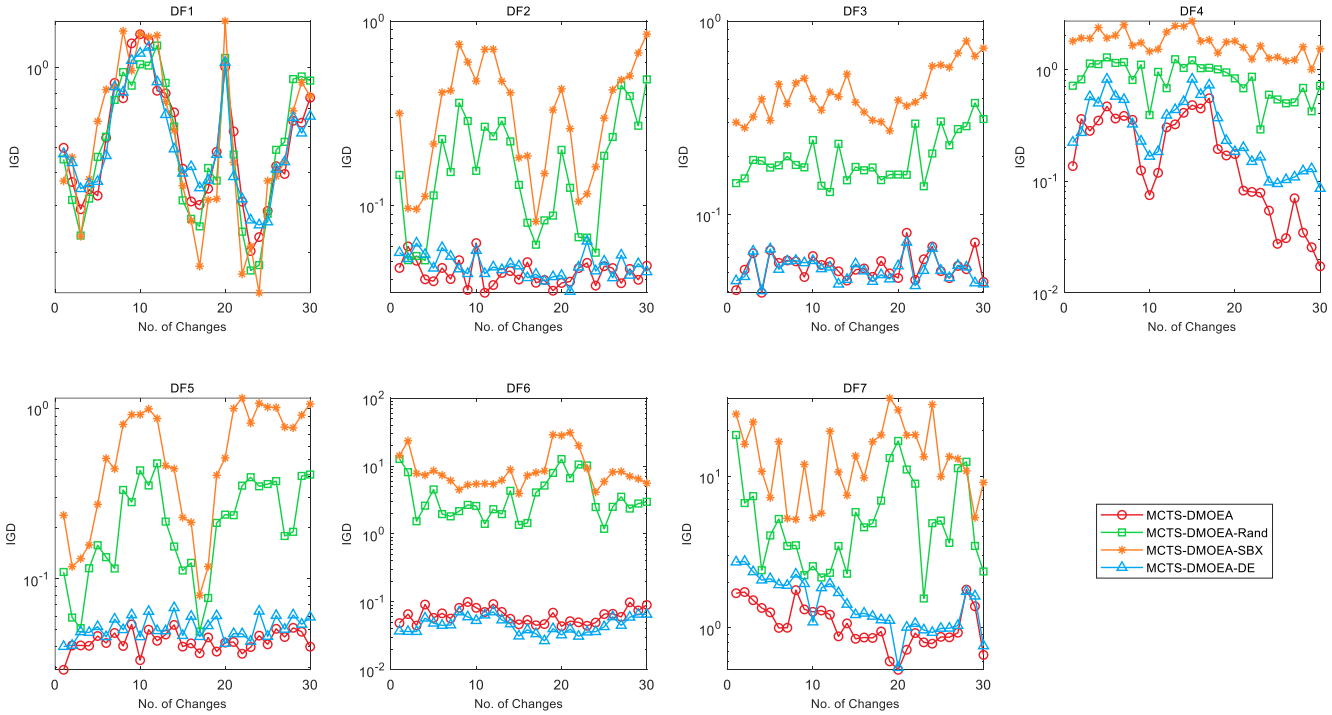

Fig. S-4. Convergence traces of average MIGD values obtained by MCTS-DMOEA, MCTS-DMOEA-SBX, MCTS-DMOEA-DE, and MCTS-DMOEA-Rand under test problems DF1-DF7 with dynamic test setting ($n_t = 10, \tau_t = 10 \cdot S$).

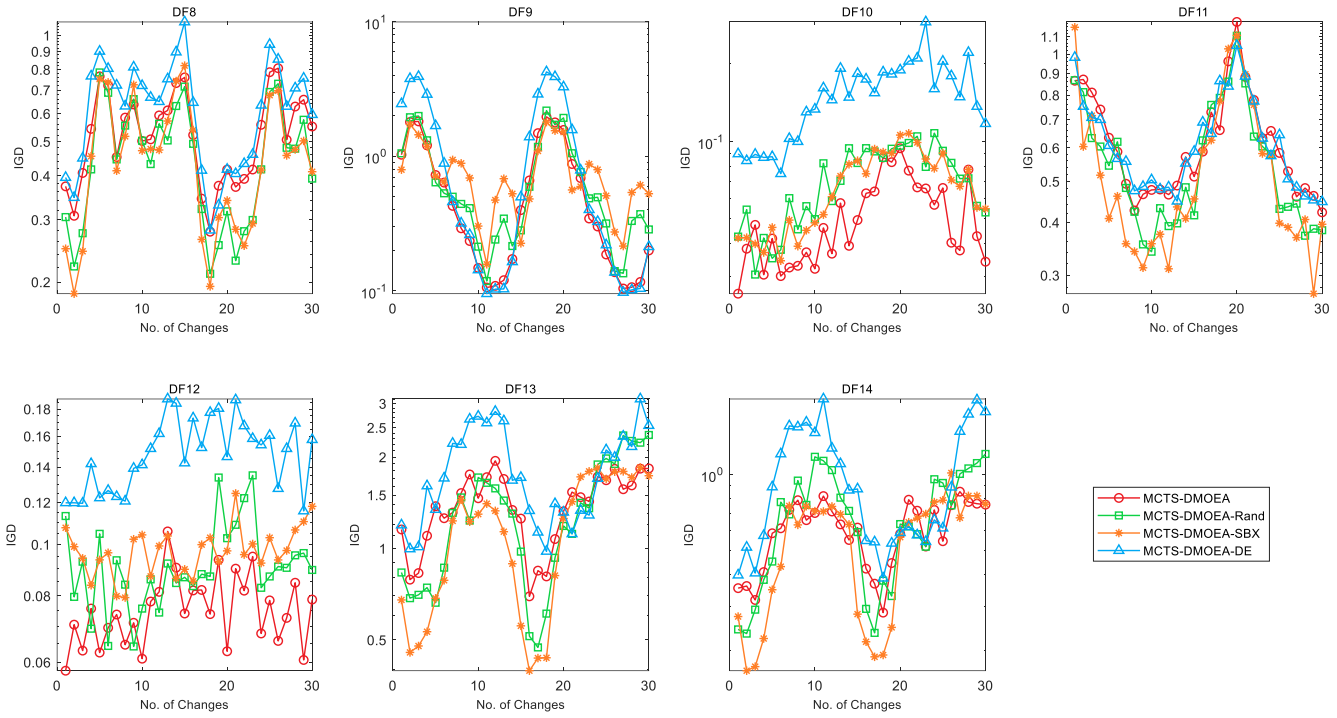

Fig. S-5. Convergence traces of average MIGD values obtained by MCTS-DMOEA, MCTS-DMOEA-SBX, MCTS-DMOEA-DE, and MCTS-DMOEA-Rand under test problems DF8-DF14 with dynamic test setting ($n_t = 10, \tau_t = 10 \cdot S$).

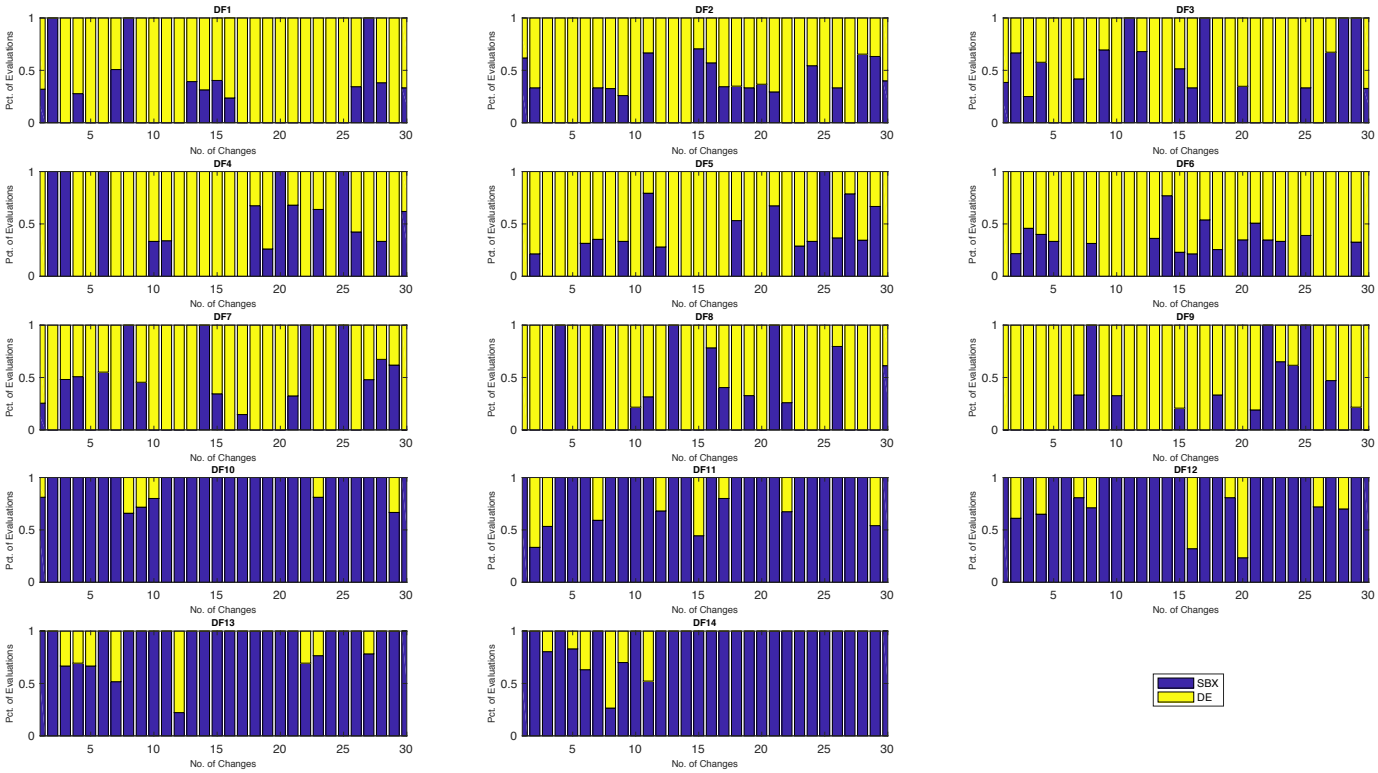

Fig. S-6. The proportion of allocation of computing resources to SBX and DE operators.

TABLE S-I
MEAN AND VARIANCE VALUES OF MHV METRIC OBTAINED BY COMPETING ALGORITHMS FOR DIFFERENT DYNAMIC TEST FUNCTIONS UNDER VARIOUS TEST SETTINGS

Problem	n_t, τ_t	MCTS-DMOEA	MDP	MMTL	SVR	IGP	TK-DMOEA	CT-DMOEA
DF1	10,10	1.34e-01(8.77e-05)	3.02e-01(1.26e-04)-	5.37e-01(6.23e-05)-	4.59e-01(1.54e-05)-	5.32e-01(9.05e-05)-	5.05e-01(1.32e-04)-	**5.95e-01(2.97e-06)-**
	5,10	1.22e-01(9.85e-04)	3.06e-01(2.29e-04)-	4.92e-01(7.18e-05)-	4.53e-01(2.73e-05)-	5.39e-01(4.21e-05)-	4.89e-01(1.92e-04)-	**5.79e-01(3.21e-06)-**
	10,5	1.19e-01(2.71e-04)	2.76e-01(4.26e-04)-	4.70e-01(5.36e-04)-	3.21e-01(6.82e-05)-	4.45e-01(1.46e-04)-	4.40e-01(2.50e-05)-	**5.56e-01(3.15e-05)-**
DF2	10,10	**8.16e-01(1.15e-05)**	5.13e-01(3.61e-04)+	7.63e-01(1.42e-04)+	7.37e-01(9.32e-06)+	7.72e-01(3.24e-05)+	7.46e-01(6.23e-05)+	8.03e-01(1.61e-05)=
	5,10	**8.14e-01(6.94e-05)**	4.88e-01(3.69e-04)+	7.35e-01(1.23e-04)+	7.30e-01(1.81e-05)+	7.75e-01(5.20e-05)+	7.49e-01(5.82e-05)+	8.03e-01(2.92e-05)=
	10,5	**8.08e-01(7.73e-06)**	4.96e-01(9.93e-05)+	7.03e-01(1.31e-04)+	6.00e-01(7.46e-05)+	6.92e-01(1.63e-04)+	6.98e-01(1.02e-04)+	7.81e-01(1.10e-05)+
DF3	10,10	**5.35e-01(1.03e-04)**	1.81e-01(1.88e-04)+	2.79e-01(1.00e-04)+	1.60e-01(3.92e-05)+	1.98e-01(1.20e-04)+	2.46e-01(1.07e-04)+	4.43e-01(6.43e-05)+
	5,10	**5.34e-01(1.33e-04)**	1.65e-01(4.85e-04)+	2.43e-01(1.59e-04)+	1.78e-01(5.49e-05)+	1.89e-01(1.65e-04)+	2.31e-01(9.40e-05)+	4.25e-01(7.58e-05)+
	10,5	**5.35e-01(1.26e-04)**	1.29e-01(1.75e-04)+	2.50e-01(1.36e-04)+	1.01e-01(4.36e-05)+	1.84e-01(4.12e-05)+	2.18e-01(1.05e-04)+	3.93e-01(7.40e-05)+
DF4	10,10	**5.58e+00(4.56e-02)**	1.48e+00(1.42e-01)+	3.20e+00(8.30e-04)+	4.50e+00(3.90e-03)+	2.53e+00(8.07e-02)+	3.10e+00(3.59e-03)+	5.12e+00(6.41e-05)+
	5,10	**5.69e+00(2.77e-02)**	1.60e+00(4.97e-02)+	3.18e+00(2.31e-03)+	4.72e+00(6.76e-03)+	2.65e+00(2.53e-02)+	3.16e+00(5.70e-03)+	4.97e+00(3.18e-05)+
	10,5	**5.56e+00(2.37e-02)**	8.60e-01(6.67e-02)+	3.14e+00(3.19e-03)+	2.90e+00(1.94e-02)+	2.54e+00(4.51e-02)+	2.99e+00(2.69e-03)+	5.01e+00(8.04e-04)+
DF5	10,10	**6.36e-01(5.40e-05)**	2.35e-01(7.56e-05)+	4.13e-01(8.69e-05)+	3.22e-01(2.75e-05)+	1.97e-01(1.04e-04)+	4.06e-01(1.90e-05)+	5.70e-01(8.61e-07)+
	5,10	**6.35e-01(6.41e-05)**	2.53e-01(6.96e-05)+	4.03e-01(1.74e-04)+	2.98e-01(3.00e-05)+	2.06e-01(7.76e-05)+	4.14e-01(8.50e-05)+	5.64e-01(7.44e-06)+
	10,5	**6.35e-01(2.16e-05)**	2.18e-01(2.83e-04)+	3.73e-01(7.28e-05)+	1.98e-01(4.46e-05)+	1.46e-01(1.77e-04)+	3.59e-01(1.48e-04)+	5.41e-01(1.54e-06)+
DF6	10,10	**9.13e-01(6.77e-06)**	3.59e-02(9.46e-04)+	1.24e-01(1.35e-03)+	00(00)+	2.21e-01(1.57e-03)+	2.26e-01(2.13e-03)+	5.65e-01(1.79e-04)+
	5,10	**8.91e-01(4.32e-06)**	1.56e-02(1.71e-04)+	1.21e-01(1.13e-03)+	1.13e-04(1.01e-07)+	2.12e-01(1.11e-03)+	1.59e-01(4.43e-04)+	5.64e-01(3.17e-03)+
	10,5	**9.11e-01(2.44e-06)**	2.00e-02(2.69e-04)+	1.26e-01(1.02e-03)+	00(00)+	1.12e-01(1.16e-03)+	1.27e-01(7.63e-04)+	4.88e-01(1.79e-04)+
DF7	10,10	**2.90e+00(3.58e+00)**	1.92e+00(4.63e-03)+	2.02e+00(3.19e-03)+	2.47e+00(5.77e-04)+	2.21e+00(2.31e-04)+	2.04e+00(1.92e-03)+	4.86e-03(7.38e-06)+
	5,10	**5.98e+00(3.25e+01)**	2.65e+00(7.53e-03)+	2.60e+00(6.34e-03)+	3.23e+00(3.83e-04)+	2.89e+00(9.91e-04)+	2.48e+00(8.14e-02)+	2.95e-01(2.51e-02)+
	10,5	**2.90e+00(3.21e+00)**	1.52e+00(4.48e-03)+	1.97e+00(3.45e-03)+	2.15e+00(5.02e-03)+	2.23e+00(1.60e-03)+	1.95e+00(7.76e-03)+	3.21e-03(1.03e-05)+
DF8	10,10	4.33e+01(3.23e+00)	**4.61e+01(6.56e-03)=**	4.55e+01(3.72e-02)=	4.60e+01(4.28e-04)=	4.59e+01(4.28e-02)=	4.56e+01(4.86e-01)=	4.36e+01(1.38e-03)=
	5,10	4.04e+01(2.25e+00)	4.31e+01(9.69e-04)-	4.24e+01(7.89e-02)=	4.31e+01(1.83e-03)=	4.28e+01(4.70e-02)=	4.20e+01(2.48e+00)=	**4.33e+01(4.55e-02)=**
	10,5	4.30e+01(3.39e+00)	**4.58e+01(3.02e-03)=**	4.55e+01(3.35e-02)=	4.56e+01(1.04e-03)=	4.57e+01(7.10e-02)=	4.56e+01(6.15e-01)=	4.37e+01(3.13e-04)=
DF9	10,10	**2.58e+01(1.00e-02)**	1.69e+01(3.11e-01)+	1.63e+01(3.38e-01)+	1.88e+01(2.67e-02)+	1.85e+01(7.14e-02)+	1.80e+01(4.66e-02)+	2.14e+01(4.86e-02)+
	5,10	**2.45e+01(1.90e-02)**	1.52e+01(2.86e-01)+	1.52e+01(2.66e-01)+	1.82e+01(1.52e-02)+	1.71e+01(7.77e-02)+	1.65e+01(8.49e-02)+	2.00e+01(3.36e-02)+
	10,5	**2.58e+01(1.63e-02)**	1.61e+01(6.81e-01)+	1.61e+01(4.24e-01)+	1.75e+01(3.64e-02)+	1.82e+01(1.22e-01)+	1.78e+01(4.65e-02)+	2.13e+01(5.12e-02)+
DF10	10,10	**7.50e-01(3.39e-03)**	4.60e-01(8.24e-05)+	7.11e-01(7.97e-05)+	5.42e-01(2.49e-05)+	6.04e-01(8.64e-05)+	6.46e-01(5.90e-04)+	7.13e-01(5.25e-04)=
	5,10	7.83e-01(1.24e-03)	5.88e-01(7.04e-05)+	**8.05e-01(4.82e-05)=**	7.02e-01(2.60e-05)+	7.17e-01(7.19e-05)+	7.62e-01(5.15e-04)=	7.35e-01(4.09e-05)=
	10,5	**7.81e-01(3.42e-03)**	4.07e-01(2.84e-04)+	6.71e-01(7.36e-05)+	4.79e-01(1.64e-05)+	5.31e-01(1.67e-04)+	5.93e-01(4.18e-04)+	7.32e-01(3.25e-04)=
DF11	10,10	2.54e-01(1.55e-02)	6.64e-01(2.16e-03)-	7.62e-01(8.47e-05)-	5.97e-01(2.53e-04)-	6.12e-01(6.58e-04)-	7.16e-01(1.02e-04)-	**8.10e-01(1.66e-05)-**
	5,10	3.25e-01(3.86e-02)	6.32e-01(2.26e-03)-	7.59e-01(2.41e-05)-	5.96e-01(2.69e-04)-	6.19e-01(8.00e-04)-	7.15e-01(3.76e-04)-	**7.94e-01(2.01e-05)-**
	10,5	2.32e-01(2.82e-02)	4.04e-01(4.95e-04)-	7.22e-01(1.29e-04)-	3.36e-01(1.49e-04)-	4.97e-01(2.86e-04)-	6.54e-01(5.39e-04)-	**7.74e-01(2.10e-05)-**
DF12	10,10	**9.80e+00(3.43e-01)**	9.25e+00(6.91e-04)+	9.38e+00(00)+	9.33e+00(9.72e-05)+	9.28e+00(3.89e-03)+	9.38e+00(1.85e-04)+	4.19e+00(8.94e-05)+
	5,10	**9.27e+00(3.28e-01)**	8.55e+00(2.04e-02)+	8.95e+00(00)+	8.51e+00(3.71e-03)+	8.52e+00(1.33e-02)+	8.54e+00(1.44e-02)+	3.88e+00(3.99e-04)+
	10,5	**9.89e+00(7.81e-02)**	8.97e+00(1.37e-02)+	9.38e+00(6.63e-08)+	9.11e+00(7.10e-04)+	9.24e+00(6.65e-03)+	9.38e+00(4.74e-05)+	4.10e+00(3.43e-04)+
DF13	10,10	1.99e-01(1.71e-02)	9.87e-02(1.37e-05)+	1.26e-01(9.39e-06)+	1.18e-01(9.12e-06)+	1.21e-01(5.73e-06)+	1.23e-01(1.16e-05)+	**2.66e+00(1.87e-03)-**
	5,10	2.92e-01(5.52e-03)	1.01e-01(1.04e-05)+	1.31e-01(1.68e-05)+	1.13e-01(1.70e-05)+	1.25e-01(1.82e-05)+	1.27e-01(1.25e-05)+	**2.67e+00(6.16e-04)-**
	10,5	2.75e-01(9.30e-03)	9.05e-02(1.07e-05)+	1.14e-01(2.79e-05)+	8.88e-02(3.18e-06)+	1.03e-01(1.96e-05)+	1.05e-01(1.19e-05)+	**2.60e+00(6.58e-04)-**
DF14	10,10	2.86e-02(1.87e-04)	9.42e-02(2.89e-05)-	2.24e-01(4.80e-06)-	1.53e-01(7.90e-05)-	2.05e-01(5.50e-05)-	2.19e-01(1.21e-05)-	**3.59e-01(2.36e-06)-**
	5,10	2.89e-02(1.08e-04)	1.14e-01(8.66e-05)-	2.16e-01(1.12e-05)-	1.29e-01(3.94e-05)-	2.07e-01(1.98e-05)-	2.11e-01(1.98e-05)-	**3.72e-01(1.01e-05)-**
	10,5	3.30e-02(3.57e-04)	1.18e-01(1.28e-05)-	2.11e-01(1.80e-05)-	9.55e-02(4.05e-05)-	1.79e-01(1.10e-04)-	2.00e-01(3.39e-05)-	**3.53e-01(1.59e-06)-**
+/=/-			30/2/10	29/4/9	30/3/9	29/4/9	29/4/9	22/8/12

TABLE S-II
MEAN AND VARIANCE VALUES OF MIGD METRIC OBTAINED BY MCTS-DMOEA, MCTS-DMOEA-SBX, MCTS-DMOEA-DE, AND MCTS-DMOEA-RAND FOR DIFFERENT DYNAMIC TEST FUNCTIONS UNDER VARIOUS TEST SETTINGS

Problem	n_t, τ_t	MCTS-DMOEA	MCTS-DMOEA-SBX	MCTS-DMOEA-DE	MCTS-DMOEA-Rand
DF1	10,10	5.78e-01(1.65e-03)	6.27e-01(3.08e-04)=	**5.60e-01(4.38e-04)=**	5.80e-01(2.61e-03)=
	5,10	5.92e-01(3.72e-03)	6.52e-01(3.81e-03)=	**5.77e-01(7.91e-04)=**	6.08e-01(4.84e-03)=
	10,5	**5.79e-01(2.65e-03)**	6.69e-01(1.04e-04)+	5.98e-01(2.28e-03)=	6.08e-01(3.95e-03)=
DF2	10,10	4.20e-02(6.68e-06)	3.67e-01(2.52e-02)+	**3.33e-02(2.05e-04)=**	1.86e-01(5.26e-02)+
	5,10	4.36e-02(2.77e-05)	3.83e-01(2.85e-02)+	**3.37e-02(1.91e-04)=**	1.59e-01(3.36e-02)+
	10,5	4.69e-02(7.07e-06)	3.45e-01(2.22e-02)+	**3.69e-02(1.75e-04)=**	1.73e-01(4.27e-02)+
DF3	10,10	5.29e-02(5.88e-05)	4.43e-01(3.50e-02)+	**3.64e-02(4.21e-04)=**	2.02e-01(5.97e-02)+
	5,10	5.17e-02(7.09e-05)	4.22e-01(3.20e-02)+	**3.51e-02(3.33e-04)=**	1.89e-01(5.00e-02)+
	10,5	5.43e-02(5.40e-05)	4.41e-01(3.51e-02)+	**3.73e-02(3.58e-04)=**	1.93e-01(5.27e-02)+
DF4	10,10	**2.30e-01(3.28e-03)**	1.75e+00(4.88e-01)+	2.31e-01(6.36e-03)=	8.46e-01(8.54e-01)+
	5,10	2.27e-01(2.98e-03)	1.82e+00(5.56e-01)+	**2.13e-01(5.59e-03)=**	8.51e-01(8.75e-01)+
	10,5	2.42e-01(2.40e-03)	1.87e+00(5.89e-01)+	**2.41e-01(5.51e-03)=**	8.65e-01(9.61e-01)+
DF5	10,10	**4.10e-02(2.36e-05)**	6.15e-01(7.81e-02)+	3.68e-02(3.61e-04)=	2.35e-01(8.96e-02)+
	5,10	**4.27e-02(2.82e-05)**	6.06e-01(7.28e-02)+	3.58e-02(3.11e-04)=	2.66e-01(1.20e-01)+
	10,5	**4.15e-02(1.16e-05)**	6.47e-01(8.42e-02)+	3.80e-02(3.74e-04)=	2.67e-01(1.18e-01)+
DF6	10,10	6.54e-02(1.98e-05)	1.02e+01(2.54e+01)+	**4.71e-02(1.90e-04)=**	4.28e+00(4.29e+01)+
	5,10	6.45e-02(3.45e-05)	1.01e+01(2.71e+01)+	**4.53e-02(1.35e-04)-**	4.31e+00(4.35e+01)+
	10,5	7.28e-02(2.21e-05)	1.14e+01(3.13e+01)+	**5.04e-02(2.53e-04)=**	4.84e+00(5.49e+01)+
DF7	10,10	**1.02e+00(2.65e-01)**	1.44e+01(4.99e+01)+	1.52e+00(1.84e-01)=	6.12e+00(5.17e+01)+
	5,10	**1.09e+00(9.27e-03)**	1.51e+01(5.17e+01)+	1.24e+00(1.29e-02)=	5.92e+00(5.32e+01)+
	10,5	**1.01e+00(2.70e-01)**	1.78e+01(6.84e+01)+	1.54e+00(1.82e-01)=	7.96e+00(9.75e+01)+
DF8	10,10	5.47e-01(4.54e-03)	4.65e-01(3.59e-04)=	6.37e-01(6.86e-03)+	**4.62e-01(4.30e-04)**-
	5,10	5.18e-01(3.97e-03)	**4.52e-01(2.87e-04)=**	6.29e-01(7.43e-03)+	4.57e-01(3.62e-04)-
	10,5	5.58e-01(5.10e-03)	**4.57e-01(3.02e-04)-**	6.35e-01(6.50e-03)=	4.80e-01(3.40e-04)-
DF9	10,10	**6.50e-01(2.88e-03)**	7.79e-01(2.07e-03)+	1.25e+00(2.07e-01)+	7.42e-01(3.91e-04)+
	5,10	**6.42e-01(2.39e-03)**	7.96e-01(2.24e-03)+	1.25e+00(1.94e-01)+	7.05e-01(3.27e-03)=
	10,5	**6.61e-01(5.39e-03)**	8.24e-01(2.12e-03)+	1.26e+00(2.09e-01)=	7.17e-01(7.44e-03)=
DF10	10,10	**1.75e-01(3.26e-05)**	1.84e-01(7.25e-04)=	4.36e-01(2.20e-02)+	2.23e-01(1.98e-03)=
	5,10	**1.64e-01(6.48e-06)**	1.71e-01(4.07e-04)=	4.24e-01(2.45e-02)+	2.13e-01(2.69e-03)=
	10,5	**1.64e-01(4.52e-05)**	1.88e-01(6.89e-04)+	4.54e-01(2.79e-02)+	2.28e-01(2.14e-03)+
DF11	10,10	6.33e-01(2.42e-03)	**5.46e-01(1.22e-03)-**	6.28e-01(9.66e-04)=	5.69e-01(1.41e-03)-
	5,10	6.41e-01(5.63e-04)	**5.63e-01(1.89e-03)-**	6.68e-01(1.11e-03)=	5.84e-01(2.71e-03)-
	10,5	6.60e-01(3.59e-04)	**5.83e-01(6.35e-04)-**	6.49e-01(4.97e-04)=	5.89e-01(6.26e-04)-
DF12	10,10	**2.44e-01(2.20e-03)**	2.53e-01(1.19e-04)=	3.80e-01(3.27e-03)+	2.57e-01(4.86e-04)=
	5,10	2.50e-01(1.94e-03)	**2.47e-01(1.48e-04)=**	3.74e-01(2.55e-03)+	2.56e-01(4.43e-04)=
	10,5	**2.47e-01(2.89e-03)**	2.53e-01(3.72e-04)=	3.91e-01(2.83e-03)+	2.73e-01(1.39e-03)=
DF13	10,10	1.41e+00(4.47e-03)	**1.16e+00(4.99e-03)-**	1.83e+00(1.22e-01)=	1.33e+00(2.08e-02)=
	5,10	1.35e+00(2.47e-03)	**1.19e+00(9.32e-03)-**	1.70e+00(8.08e-02)=	1.33e+00(1.78e-02)=
	10,5	1.41e+00(7.67e-03)	**1.18e+00(1.29e-02)-**	1.96e+00(1.72e-01)+	1.30e+00(4.23e-02)=
DF14	10,10	5.94e-01(2.68e-03)	**5.53e-01(2.81e-03)=**	9.90e-01(8.01e-02)+	6.94e-01(1.79e-02)=
	5,10	5.96e-01(5.65e-03)	**5.84e-01(2.87e-03)=**	9.56e-01(8.40e-02)=	6.73e-01(8.21e-03)+
	10,5	5.81e-01(5.09e-03)	**5.78e-01(9.36e-04)=**	9.71e-01(1.05e-01)=	7.53e-01(3.89e-02)+
+/=/-			23/12/7	12/29/1	22/14/6

TABLE S-III
MEAN AND VARIANCE VALUES OF MHV METRIC OBTAINED BY MCTS-DMOEA, MCTS-DMOEA-SBX, MCTS-DMOEA-DE, AND MCTS-DMOEA-RAND FOR DIFFERENT DYNAMIC TEST FUNCTIONS UNDER VARIOUS TEST SETTINGS

Problem	n_t, τ_t	MCTS-DMOEA	MCTS-DMOEA-SBX	MCTS-DMOEA-DE	MCTS-DMOEA-Rand
DF1	10,10	1.34e-01(8.77e-05)	**1.66e-01(5.18e-04)-**	1.24e-01(1.53e-04)+	1.46e-01(7.40e-04)=
	5,10	1.22e-01(9.85e-04)	**1.54e-01(4.22e-04)-**	1.26e-01(2.04e-05)=	1.48e-01(6.39e-04)-
	10,5	1.19e-01(2.71e-04)	**1.28e-01(7.12e-04)-**	1.10e-01(6.34e-04)=	1.28e-01(8.49e-04)-
DF2	10,10	8.16e-01(1.15e-05)	4.51e-01(3.06e-02)+	**8.34e-01(3.31e-04)-**	6.69e-01(5.57e-02)+
	5,10	8.14e-01(6.94e-05)	4.41e-01(3.30e-02)+	**8.34e-01(2.98e-04)-**	6.77e-01(4.85e-02)+
	10,5	8.08e-01(7.73e-06)	4.53e-01(3.18e-02)+	**8.31e-01(2.73e-04)-**	6.68e-01(5.48e-02)+
DF3	10,10	5.35e-01(1.03e-04)	1.57e-01(3.26e-02)+	**5.66e-01(6.88e-04)-**	3.92e-01(5.75e-02)+
	5,10	5.34e-01(1.33e-04)	1.64e-01(3.08e-02)+	**5.63e-01(5.78e-04)-**	3.94e-01(5.32e-02)+
	10,5	5.35e-01(1.26e-04)	1.49e-01(3.42e-02)+	**5.64e-01(5.29e-04)-**	3.96e-01(5.52e-02)+
DF4	10,10	5.58e+00(4.56e-02)	1.49e+00(3.62e+00)+	**5.80e+00(5.21e-02)-**	3.96e+00(6.92e+00)+
	5,10	5.69e+00(2.77e-02)	1.38e+00(4.16e+00)+	**5.92e+00(4.06e-02)-**	4.03e+00(7.05e+00)+
	10,5	5.56e+00(2.37e-02)	1.41e+00(4.09e+00)+	**5.80e+00(3.03e-02)-**	4.09e+00(6.37e+00)+
DF5	10,10	6.36e-01(5.40e-05)	2.17e-01(4.02e-02)+	**6.61e-01(6.05e-04)-**	4.80e-01(6.73e-02)+
	5,10	6.35e-01(6.41e-05)	2.16e-01(4.11e-02)+	**6.64e-01(5.22e-04)-**	4.82e-01(6.65e-02)+
	10,5	6.35e-01(2.16e-05)	2.11e-01(4.07e-02)+	**6.60e-01(5.89e-04)-**	4.76e-01(6.71e-02)+
DF6	10,10	9.13e-01(6.77e-06)	1.53e-01(1.40e-01)+	**9.21e-01(3.38e-05)-**	6.12e-01(2.25e-01)+
	5,10	8.91e-01(4.32e-06)	1.49e-01(1.32e-01)+	**8.98e-01(2.49e-05)-**	5.95e-01(2.13e-01)+
	10,5	9.11e-01(2.44e-06)	1.52e-01(1.39e-01)+	**9.19e-01(3.41e-05)-**	6.11e-01(2.24e-01)+
DF7	10,10	2.90e+00(3.58e+00)	8.36e-01(4.19e+00)+	2.17e+00(1.55e+00)+	**3.31e+00(6.63e+00)=**
	5,10	5.98e+00(3.25e+01)	2.19e+00(2.16e+01)+	3.06e+00(1.96e+01)+	**8.33e+00(4.19e+01)-**
	10,5	2.90e+00(3.21e+00)	8.77e-01(4.53e+00)+	2.15e+00(1.67e+00)+	**3.37e+00(6.84e+00)=**
DF8	10,10	4.33e+01(3.23e+00)	**4.57e+01(7.75e-02)-**	4.31e+01(1.03e+00)=	4.52e+01(3.23e-01)=
	5,10	4.04e+01(2.25e+00)	**4.26e+01(9.56e-02)-**	4.02e+01(9.04e-01)=	4.21e+01(2.44e-01)=
	10,5	4.30e+01(3.39e+00)	**4.56e+01(1.67e-01)-**	4.28e+01(1.04e+00)=	4.49e+01(2.56e-01)=
DF9	10,10	**2.58e+01(1.00e-02)**	1.85e+01(1.36e+00)+	2.10e+01(2.12e-02)+	2.00e+01(2.28e+00)=
	5,10	**2.45e+01(1.90e-02)**	1.72e+01(1.64e+00)+	1.97e+01(1.71e-02)+	1.87e+01(2.43e+00)=
	10,5	**2.58e+01(1.63e-02)**	1.83e+01(1.64e+00)+	2.10e+01(2.36e-02)+	1.99e+01(2.62e+00)=
DF10	10,10	7.50e-01(3.39e-03)	**8.19e-01(3.11e-03)-**	3.35e-01(9.30e-02)+	6.83e-01(2.25e-02)=
	5,10	7.83e-01(1.24e-03)	**8.71e-01(2.42e-03)-**	3.95e-01(8.26e-02)+	7.33e-01(1.46e-02)=
	10,5	7.81e-01(3.42e-03)	**8.17e-01(8.37e-04)=**	3.61e-01(1.14e-01)+	6.67e-01(2.53e-02)+
DF11	10,10	**2.54e-01(1.55e-02)**	2.06e-01(1.29e-03)=	1.38e-01(1.94e-02)+	1.78e-01(4.45e-04)=
	5,10	**3.25e-01(3.86e-02)**	1.75e-01(2.14e-03)=	1.43e-01(3.97e-02)+	1.87e-01(3.09e-03)=
	10,5	**2.32e-01(2.82e-02)**	1.80e-01(2.33e-03)=	1.15e-01(1.20e-02)+	1.60e-01(1.93e-03)+
DF12	10,10	**9.80e+00(3.43e-01)**	8.56e+00(4.37e-02)=	7.41e+00(1.03e+00)+	8.09e+00(2.70e-01)+
	5,10	**9.27e+00(3.28e-01)**	7.81e+00(2.16e-02)=	6.98e+00(1.03e+00)+	7.52e+00(7.66e-02)+
	10,5	**9.89e+00(7.81e-02)**	8.43e+00(6.03e-02)+	7.15e+00(1.13e+00)+	7.79e+00(4.61e-01)+
DF13	10,10	1.99e-01(1.71e-02)	**6.37e-01(3.60e-02)-**	1.29e-01(4.36e-03)+	5.39e-01(4.20e-02)-
	5,10	2.92e-01(5.52e-03)	**7.30e-01(4.76e-02)-**	1.64e-01(1.14e-02)+	5.37e-01(7.31e-02)-
	10,5	2.75e-01(9.30e-03)	**6.58e-01(2.01e-02)-**	1.71e-01(1.53e-02)+	5.67e-01(4.48e-02)-
DF14	10,10	2.86e-02(1.87e-04)	**4.15e-02(2.29e-04)-**	7.08e-03(8.56e-05)+	2.50e-02(1.50e-04)=
	5,10	2.89e-02(1.08e-04)	**4.10e-02(1.11e-04)-**	9.48e-03(1.43e-04)+	2.70e-02(2.40e-04)=
	10,5	**3.30e-02(3.57e-04)**	3.26e-02(1.08e-04)=	9.67e-03(2.63e-04)+	2.38e-02(3.27e-04)+
+/=/-			22/7/13	22/5/15	21/15/6

TABLE S-IV
MEAN VALUES OF RUNTIME OBTAINED BY COMPARED ALGORITHMS AT τ_t=10 AND τ_t=5. (IN SECONDS)

Problem	τ_t	MCTS-DMOEA	MDP	MMTL	SVR	IGP	TK-DMOEA	CT-DMOEA
DF1	10	7.33e-01	1.01e-01	2.85e+00	5.78e-02	1.55e+00	1.62e+00	1.97e+01
	5	3.90e-01	4.98e-02	1.58e+00	4.83e-02	7.40e-01	8.77e-01	1.02e+01
DF2	10	6.70e-01	7.91e-02	2.77e+00	5.58e-02	1.56e+00	1.67e+00	1.94e+01
	5	3.54e-01	4.12e-02	1.65e+00	4.85e-02	8.35e-01	9.41e-01	9.40e+00
DF3	10	6.23e-01	1.27e-01	2.52e+00	6.13e-02	1.15e+00	1.33e+00	1.36e+01
	5	3.22e-01	7.03e-02	1.48e+00	5.35e-02	5.49e-01	8.30e-01	6.67e+00
DF4	10	6.14e-01	1.53e-01	2.30e+00	7.13e-02	1.20e+00	1.30e+00	2.01e+01
	5	3.24e-01	7.57e-02	1.36e+00	5.78e-02	6.04e-01	7.22e-01	1.19e+01
DF5	10	5.88e-01	6.61e-02	3.31e+00	5.59e-02	1.40e+00	1.71e+00	2.06e+01
	5	3.33e-01	3.10e-02	1.85e+00	4.96e-02	7.10e-01	9.37e-01	1.05e+01
DF6	10	7.84e-01	6.39e-02	2.52e+00	5.52e-02	1.31e+00	1.44e+00	1.45e+01
	5	4.27e-01	3.25e-02	1.51e+00	4.72e-02	6.13e-01	7.75e-01	8.11e+00
DF7	10	7.00e-01	5.30e-02	2.54e+00	6.08e-02	1.09e+00	1.06e+00	1.82e+01
	5	4.13e-01	3.13e-02	1.76e+00	5.33e-02	5.39e-01	6.17e-01	9.95e+00
DF8	10	7.02e-01	9.62e-02	2.60e+00	5.71e-02	1.49e+00	1.59e+00	1.60e+01
	5	3.74e-01	5.15e-02	1.48e+00	5.38e-02	7.41e-01	8.69e-01	6.92e+00
DF9	10	6.90e-01	8.96e-02	2.66e+00	6.66e-02	1.17e+00	1.55e+00	1.42e+01
	5	3.67e-01	4.43e-02	1.72e+00	5.50e-02	5.79e-01	8.43e-01	6.19e+00
DF10	10	6.43e-01	7.21e-02	3.95e+00	6.06e-02	1.38e+00	2.11e+00	1.91e+01
	5	3.69e-01	4.45e-02	2.28e+00	5.79e-02	6.89e-01	1.27e+00	1.04e+01
DF11	10	7.39e-01	4.06e-02	4.31e+00	5.28e-02	1.53e+00	2.19e+00	2.18e+01
	5	3.94e-01	4.24e-02	2.62e+00	4.72e-02	7.54e-01	1.38e+00	1.23e+01
DF12	10	6.93e-01	9.42e-02	1.57e+00	6.06e-02	7.91e-01	1.25e+00	2.27e+01
	5	3.77e-01	4.67e-02	9.23e-01	5.35e-02	4.06e-01	8.61e-01	1.26e+01
DF13	10	6.33e-01	3.47e-02	5.20e+00	6.63e-02	1.48e+00	2.09e+00	2.17e+01
	5	3.37e-01	1.91e-02	3.11e+00	5.42e-02	7.34e-01	1.39e+00	1.23e+01
DF14	10	6.76e-01	3.45e-02	4.98e+00	6.27e-02	1.49e+00	2.14e+00	1.95e+01
	5	3.60e-01	2.35e-02	2.83e+00	5.57e-02	7.22e-01	1.33e+00	9.74e+00
Rank		3	2	6	1	4	5	7

TABLE S-V
FIVE ENVIRONMENTAL STEP FOR RAW ORE ALLOCATION OF MINERAL PROCESSING

Series Number	Parameters	Step 1	Step 2	Step 3	Step 4	Step 5
1	Capacity (N_k)	80.60	58.56	36.52	36.52	36.52
	Running Time (T_k)	2.08	2.08	2.08	2.08	2.08
2	Capacity (N_k)	80.60	80.60	80.60	80.60	80.60
	Running Time (T_k)	2.08	2.08	2.08	2.08	2.08
3	Capacity (N_k)	80.60	80.60	80.60	80.60	80.60
	Running Time (T_k)	2.08	2.08	2.08	2.08	2.08
4	Capacity (N_k)	80.60	80.60	80.60	80.60	80.60
	Running Time (T_k)	27.08	27.08	27.08	25.37	23.66
5	Capacity (N_k)	80.60	80.60	80.60	80.60	80.60
	Running Time (T_k)	27.08	27.08	27.08	27.08	27.08
6	Capacity (N_k)	80.60	80.60	80.60	80.60	80.60
	Running Time (T_k)	27.08	27.08	27.08	27.08	27.08
7	Capacity (N_k)	80.60	80.60	80.60	80.60	80.60
	Running Time (T_k)	27.08	27.08	27.08	27.08	27.08

TABLE S-VI
RAW ORE PROPERTIES

i	α_i (%)	$\beta_{1,i}$ (%)	$\beta_{2,i}$ (%)	u_i (%)	$k_{1,i}$ (times)	$k_{2,i}$ (times)
1	33.3	47.5	56.1	62.0	2.3	2.0
2	34.1	47.5	56.1	54.0	2.0	1.92
3	32.5	47.0	54.0	50.0	2.3	2.2
4	33.1	44.5	52.0	65.0	2.8	2.4
5	55.0	60.0	61.0	55.0	1.45	1.4
6	52.0	60.0	0.0	0.0	1.3	2.0