Supplementary Files

I. Basic Concepts in Multi-objective Optimization

Generally, a multi-objective optimization problem (MOP) can be defined as

$$\begin{array}{rl} \text{Minimize} & \mathbf{F}(\mathbf{x}) = (f_1(\mathbf{x}), \cdots, f_m(\mathbf{x}))^T \\ \text{subject to} & \mathbf{x} \in \mathbb{S} \\ & g_i(\mathbf{x}) \le 0,\ i = 1, \cdots, p \\ & h_j(\mathbf{x}) = 0,\ j = p+1, \cdots, q \end{array}, \tag{1}$$

where m denotes the number of objective functions; $\mathbf{x} = (x_1, \ldots, x_n)^T$ is an n-dimensional decision vector; n is the number of decision variables; $\mathbf{x} \in \mathbb{S}$, and $\mathbb{S} \subseteq \mathbb{R}^n$ is the search space. $g_i(\mathbf{x})$ and $h_j(\mathbf{x})$ are the i-th inequality and j-th equality constraints, respectively. q denotes the number of constraints.

For a CMOP, the degree of the j-th constraint violation (denoted as $\varphi_j(\mathbf{x})$) of $\mathbf{x}$ is

$$\varphi_j(\mathbf{x}) = \begin{cases} \max(0, g_j(\mathbf{x})), & j = 1, \cdots, p \\ \max(0, |h_j(\mathbf{x})| - \sigma), & j = p+1, \cdots, q \end{cases}, \tag{2}$$

where σ is a very small positive value to relax the equality constraints into inequality ones. In this paper, $\sigma = 10^{-4}$ is adopted for the tested problems. The overall constraint violation (CV) of $\mathbf{x}$ is calculated by

$$\phi(\mathbf{x}) = \sum_{j=1}^{q} \varphi_j(\mathbf{x}). \tag{3}$$

A solution $\mathbf{x}$ is feasible if $\phi(\mathbf{x}) = 0$; otherwise, it is infeasible.

Since the different objectives conflict with each other, Pareto dominance is used for comparison between two solutions.

- *Pareto dominance*: for two solutions $\mathbf{x}^1$, $\mathbf{x}^2 \in \mathbb{S}$, $\mathbf{x}^1$ is said to Pareto dominate $\mathbf{x}^2$ (denoted as $\mathbf{x}^1 \prec \mathbf{x}^2$), if and only if $f_i(\mathbf{x}^1) \le f_i(\mathbf{x}^2)$ for $\forall\ i \in \{1, \cdots, m\}$ and $f_i(\mathbf{x}^1) < f_i(\mathbf{x}^2)$ for $\exists\ i \in \{1, \cdots, m\}$;
- *Pareto set* (*PS*): the set $PS \subset \mathbb{S}$ that for $\forall\ \mathbf{x}^\diamond \in PS$, $\nexists\ \mathbf{x} \in \mathbb{S}$ such that $\mathbf{x} \prec \mathbf{x}^\diamond$;
- *Constrained PS* (*CPS*): a set that for $\forall\ \mathbf{x}^\star \subset CPS$, $\nexists\ \mathbf{x} \in \mathbb{S}$ such that $\phi(\mathbf{x}) = 0\ \&\&\ \mathbf{x} \prec \mathbf{x}^\star$;
- *Pareto front* (*PF*): $PF = \{\mathbf{F}(\mathbf{x}) | \mathbf{x} \in PS\}$;
- *Constrained PF* (*CPF*): $CPF = \{\mathbf{F}(\mathbf{x}) | \mathbf{x} \in CPS\}$.

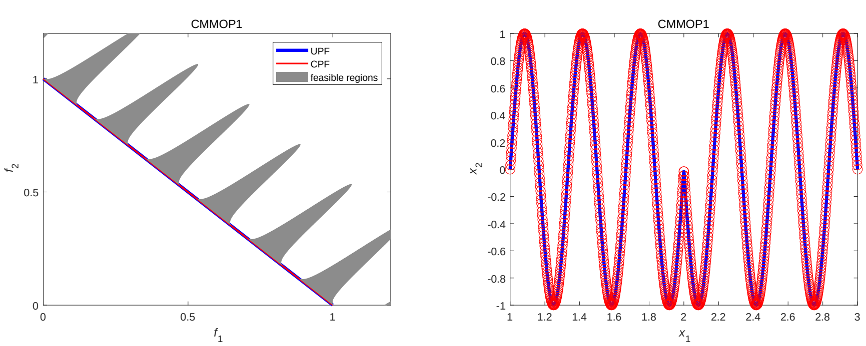
II. Details of the Proposed Test Problem

In this section, the proposed test suite CMMOP is detailed.

CMMOP1:

$$\begin{array}{l} \min \begin{cases} f_1 = |x_1 - 2| \\ f_2 = 1 - \sqrt{|x_1 - 2|} + 2(x_2 - \sin(6\pi|x_1 - 2| + \pi))^2 \end{cases} \\ \text{s.t.}\ c(\mathbf{x}) = 1 - f_1 - f_2 + 0.6\sin(2\pi l)^8 \ge 0, \\ l = \sqrt{2} f_2 - \sqrt{2} f_1 \end{array} \tag{4}$$

where $1 \le x_1 \le 3$, $-1 \le x_2 \le 1$.



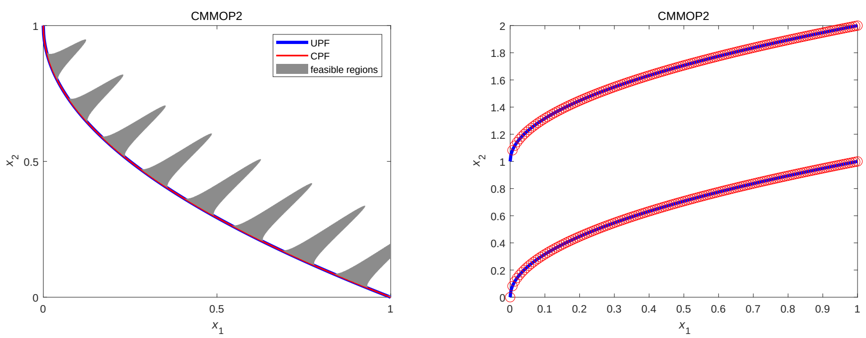
(a) (b)

Fig. S-1. True unconstrained Pareto front and constrained Pareto front of CMMOP1 instance.

CMMOP2:

$$
\begin{aligned}
&\min \begin{cases} f_1 = x_1 \\ f_2 = \begin{cases} 1-\sqrt{x_1}+2(4(x_2-\sqrt{x_1})^2-2\cos(\dfrac{20(x_2-\sqrt{x_1})\pi}{\sqrt{2}}+2), & 0 \le x_2 \le 1 \\ 1-\sqrt{x_1}+2(4(x_2-1-\sqrt{x_1})^2-2\cos(\dfrac{20(x_2-1-\sqrt{x_1})\pi}{\sqrt{2}}+2), & 1 \le x_2 \le 2 \end{cases} \end{cases} \\
&\text{s.t. } c(\mathbf{x}) = 1-\sqrt{f_1}-f_2+0.3\sin(3\pi l)^8 \ge 0, \\
&l = \sqrt{2}f_2-\sqrt{2}f_1
\end{aligned} \tag{5}
$$

where $0 \le x_1 \le 1$, $0 \le x_2 \le 2$.



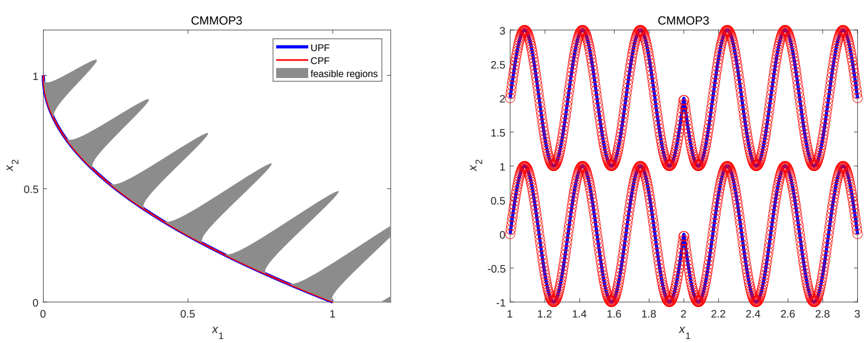
(a) (b)

Fig. S-2. True unconstrained Pareto front and constrained Pareto front of CMMOP2 instance.

CMMOP3:

$$
\begin{aligned}
&\min \begin{cases} f_1 = |x_1-2| \\ f_2 = \begin{cases} 1-\sqrt{|x_1-2|}+2(x_2-\sin(6\pi|x_1-2|+\pi))^2 & -1 \le x_2 \le 1 \\ 1-\sqrt{|x_1-2|}+2(x_2-2-\sin(6\pi|x_1-2|+\pi))^2 & 1 \le x_2 \le 3 \end{cases} \end{cases} \\
&\text{s.t. } c(\mathbf{x}) = 1-\sqrt{f_1}-f_2+0.5\sin(2\pi l)^8 \ge 0, \\
&l = \sqrt{2}f_2-\sqrt{2}f_1
\end{aligned} \tag{6}
$$

where $-1 \le x_1 \le 3$, $1 \le x_2 \le 3$.



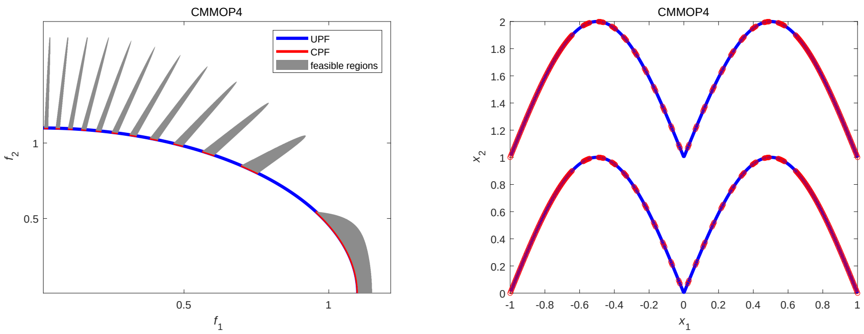
(a) (b)

Fig. S-3. True unconstrained Pareto front and constrained Pareto front of CMMOP3 instance.

CMMOP4:

$$
\begin{aligned}
&\min \begin{cases} f_1 = |x_1| \\ f_2 = \begin{cases} 1.21-x_1^2+2(x_2-\sin(\pi|x_1|))^2 & 0 \le x_2 \le 1 \\ 1.21-x_1^2+2(x_2-1-\sin(\pi|x_1|))^2 & 1 \le x_2 \le 2 \end{cases} \end{cases} \\
&\text{s.t. } c(\mathbf{x}) = 1-(f_1/(1+0.15l))^2-(f_2/(1+0.75l)) \ge 0, \\
&l = \cos(6\arctan(f_2/f_1)^4)^{10}
\end{aligned} \tag{7}
$$

where $-1 \le x_1 \le 1$, $0 \le x_2 \le 2$.



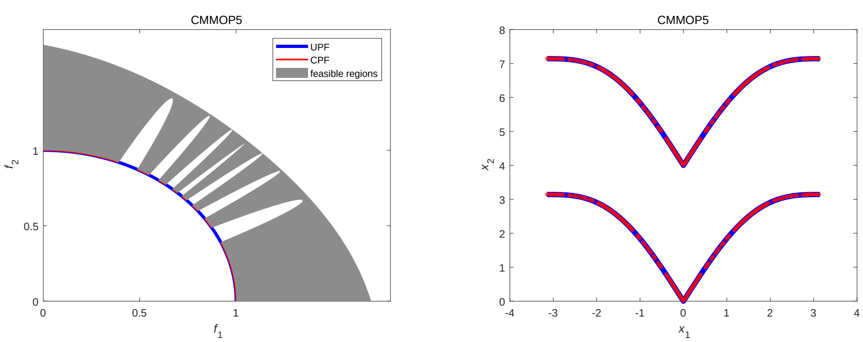
(a) (b)

Fig. S-4. True unconstrained Pareto front and constrained Pareto front of CMMOP4 instance.

CMMOP5:

$$
\begin{aligned}
&\min \begin{cases} f_1 = \sin|x_1| \\ f_2 = \begin{cases} \sqrt{1-(\sin|x_1|)^2} + 2(x_2 - \sin|x_1| - |x_1|)^2 & 0 \le x_2 \le 4 \\ \sqrt{1-(\sin|x_1|)^2} + 2(x_2 - 4 - \sin|x_1| - |x_1|)^2 & 4 \le x_2 \le 9 \end{cases} \end{cases} \\
&\text{s.t. } c_1(\mathbf{x}) = (1.7 - 0.2\sin(2l_1))^2 - f_1^2 - f_2^2 \ge 0, \\
&\qquad c_2(\mathbf{x}) = (1 - 0.5\sin(6l_2^3))^2 - f_1^2 - f_2^2 \le 0, \\
&\qquad l_1 = \arctan(f_2/f_1), \\
&\qquad l_2 = 0.5\pi - 2|\arctan(f_2/f_1) - 0.25\pi|
\end{aligned} \tag{8}
$$

where $-\pi \le x_1 \le \pi$, $0 \le x_2 \le 9$.

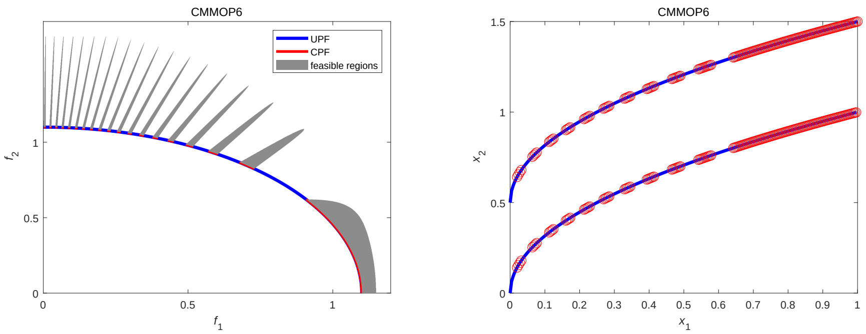


(a) (b)

Fig. S-5. True unconstrained Pareto front and constrained Pareto front of CMMOP5 instance.

CMMOP6:

$$
\begin{aligned}
&\min \begin{cases} f_1 = x_1 \\ f_2 = \begin{cases} 1.21 - \sqrt{x_1} + 2(4(x_2 - \sqrt{x_1})^2) - 2\cos(\dfrac{20(x_2 - \sqrt{x_1})\pi}{\sqrt{2}} + 2) 0 \le x_2 \le 0.5, 0.5 \le x_2 \le 1 \& 0.25 \le < x_1 \le 1 \\ 1.21 - \sqrt{x_1} + 2(4(x_2 - 0.5 - \sqrt{x_1})^2) - 2\cos(\dfrac{20(x_2 - 0.5 - \sqrt{x_1})\pi}{sqrt2} + 2) 1 \le x_2 \le 1.5, 0 \le x_1 \le 0.25 \& 0.5 \le < x_2 \le 1 \end{cases} \end{cases} \\
&\text{s.t. } c(\mathbf{x}) = 1 - (f_1/(1+0.15l))^2 - (f_2/(1+0.75l)) \ge 0, \\
&l = \cos(6\arctan(f_2/f_1)^4)^{10} \\
&\text{where } 0 \le x_1 \le 1,\ 0 \le x_2 \le 1.5.
\end{aligned} \tag{9}
$$



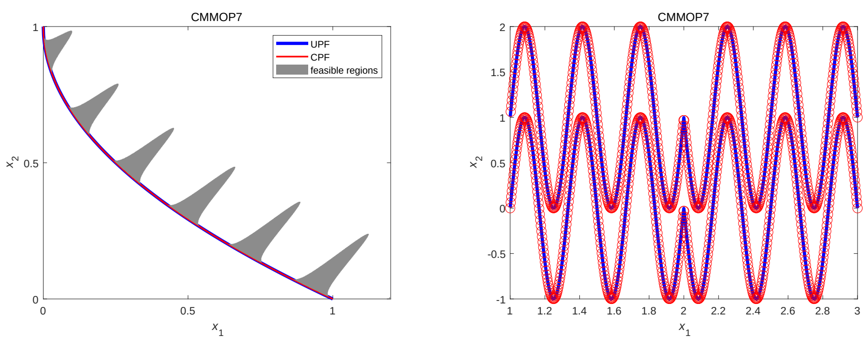
(a) (b)

Fig. S-6. True unconstrained Pareto front and constrained Pareto front of CMMOP6 instance.

CMMOP7:

$$
\begin{aligned}
&\min \begin{cases} f_1 = |x_1 - 2| \\ f_2 = \begin{cases} 1 - \sqrt{|x_1 - 2|} + 2(x_2 - \sin(6\pi|x_1 - 2| + \pi))^2 & -1 \le x_2 \le 1 \\ 1 - \sqrt{|x_1 - 2|} + 2(x_2 - 1 - \sin(6\pi|x_1 - 2| + \pi))^2 & 1 \le x_2 \le 3 \end{cases} \end{cases} \\
&\text{s.t.}\ c(\mathbf{x}) = 1 - \sqrt{f_1} - f_2 + 0.3\sin(2\pi l)^1 2 \ge 0, \\
&l = \sqrt{2} f_2 - \sqrt{2} f_1
\end{aligned} \tag{10}
$$

where $-1 \le x_1 \le 3$, $1 \le x_2 \le 3$.



(a) (b)

Fig. S-7. True unconstrained Pareto front and constrained Pareto front of CMMOP7 instance.

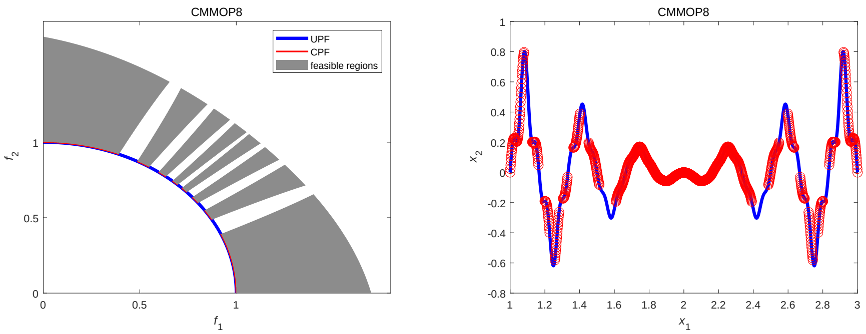
CMMOP8:

$$
\begin{aligned}
&\min \begin{cases} f_1 = |x_1 - 2| \\ f_2 = 1 - \sqrt{|x_1 - 2|} + \left\{x_2 - \left[0.3|x_2 - 2|^2 \cos(24\pi|x_1 - 2| + 4\pi) + 0.6|x_1 - 2|\right] \sin(6\pi|x_1 - 2| + \pi)\right\} \end{cases} \\
&\text{s.t.}\ c_1(\mathbf{x}) = (1.7 - 0.2\sin(2l_1))^2 - f_1^2 - f_2^2 \ge 0, \\
&\quad c_2(\mathbf{x}) = (1 - 0.5\sin(6l_2^3))^2 - f_1^2 - f_2^2 \le 0, \\
&\quad l_1 = \arctan(f_2/f_1), \\
&\quad l_2 = 0.5\pi - 2|\arctan(f_2/f_1) - 0.25\pi|
\end{aligned} \tag{11}
$$

where $1 \le x_1 \le 3$, $-1 \le x_2 \le 1$.

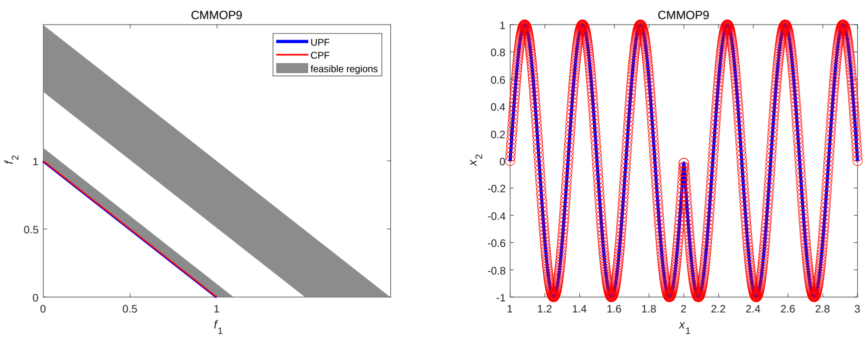
CMMOP9:

$$
\begin{aligned}
&\min \begin{cases} f_1 = |x_1 - 2| \\ f_2 = 1 - \sqrt{|x_1 - 2|} + 2(x_2 - \sin(6\pi|x_1 - 2| + \pi))^2 \end{cases} \\
&\text{s.t.}\ c_1(\mathbf{x}) = f_1 + f_2 \ge 1, \\
&\quad c_2(\mathbf{x}) = f_1 + f_2 \le 1.1, \\
&\quad c_3(\mathbf{x}) = f_1 + f_2 \ge 1.5, \\
&\quad c_4(\mathbf{x}) = f_1 + f_2 \le 2
\end{aligned} \tag{12}
$$



(a) (b)

Fig. S-8. True unconstrained Pareto front and constrained Pareto front of CMMOP8 instance.



(a) (b)

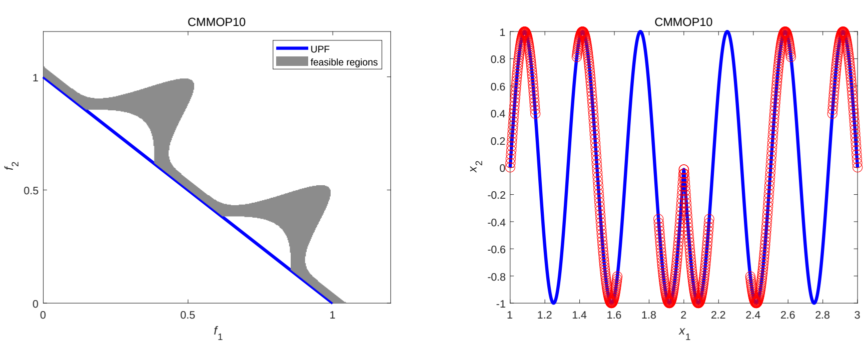
Fig. S-9. True unconstrained Pareto front and constrained Pareto front of CMMOP9 instance.

where $1 \leq x_1 \leq 3$, $-1 \leq x_2 \leq 1$.

CMMOP10:

$$
\begin{aligned}
&\min \begin{cases} f_1 = |x_1 - 2| \\ f_2 = 1 - \sqrt{|x_1 - 2|} + 2(x_2 - \sin(6\pi|x_1 - 2| + \pi))^2 \end{cases} \\
&\text{s.t.}\, c_1(\mathbf{x}) = 1.05 - f_1 - f_2 + 0.45\sin(0.75\pi l))^6 \geq 0, \\
&\quad\;\; c_2(\mathbf{x}) = 0.85 - f_1 - f_2 + 0.3\sin(0.75\pi l))^2 \leq 0, \\
&\quad\;\; l = \sqrt{2} f_2 - \sqrt{2} f_1
\end{aligned} \tag{13}
$$

where $1 \leq x_1 \leq 3$, $-1 \leq x_2 \leq 1$.



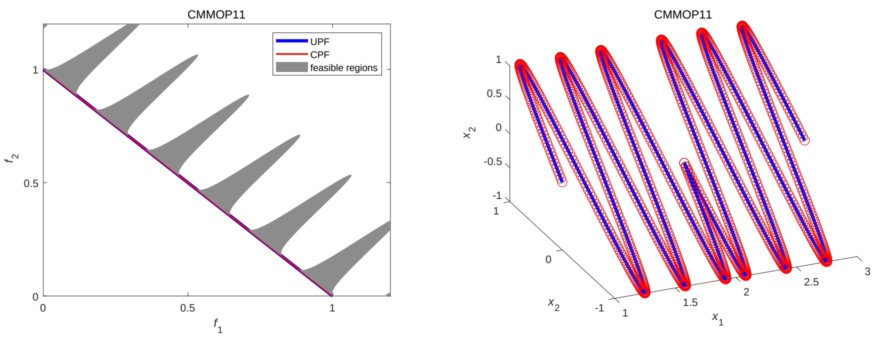
(a) (b)

Fig. S-10. True unconstrained Pareto front and constrained Pareto front of CMMOP10 instance.

CMMOP11:

$$\min \begin{cases} f_1 = |x_1 - 2| \\ f_2 = 1 - \sqrt{|x_1 - 2|} + 2(x_2 - \sin(6\pi|x_1 - 2| + \pi))^2 + 2(x_3 - \sin(6\pi|x_1 - 2| + \pi))^2 \end{cases}$$
$$\text{s.t. } c(\mathbf{x}) = 1 - f_1 - f_2 + 0.6\sin(2\pi l)^8 \geq 0, \tag{14}$$
$$l = \sqrt{2}f_2 - \sqrt{2}f_1$$

where $1 \leq x_1 \leq 3$, $-1 \leq x_2 \leq 1$, $-1 \leq x_3 \leq 1$.



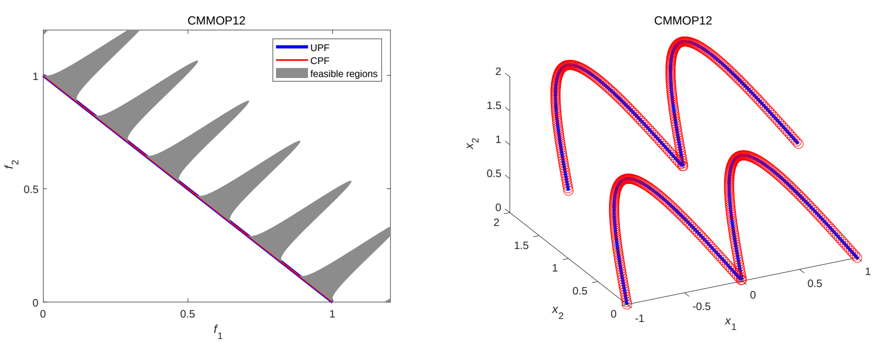
(a) (b)

Fig. S-11. True unconstrained Pareto front and constrained Pareto front of CMMOP11 instance.

CMMOP12:

$$\min \begin{cases} f_1 = |x_1| \\ f_2 = \begin{cases} 1 - |x_1| + 2(x_2 - \sin(\pi|x_1|))^2 + 2(x_2 - \sin(\pi|x_1|))^2 & 0 \leq x_2 \leq 1, 0 \leq x_3 \leq 1 \\ 1 - |x_1| + 2(x_2 - 1 - \sin(\pi|x_1|))^2 + 2(x_3 - 1 - \sin(\pi|x_1|))^2 & 1 \leq x_2 \leq 2, 1 \leq x_3 \leq 2 \end{cases} \end{cases} \tag{15}$$
$$\text{s.t. } c(\mathbf{x}) = 1 - (f_1/(1 + 0.15l))^2 - (f_2/(1 + 0.75l)) \geq 0,$$
$$l = \cos(6\arctan(f_2/f_1)^4)^{10}$$

where $-1 \leq x_1 \leq 1$, $0 \leq x_2 \leq 2$, $0 \leq x_3 \leq 2$.



(a) (b)

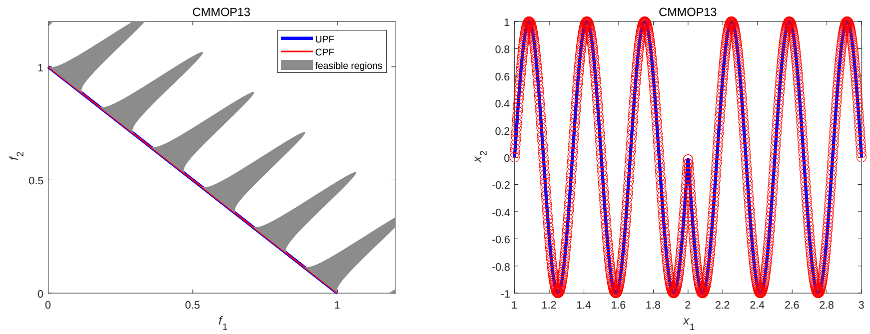
Fig. S-12. True unconstrained Pareto front and constrained Pareto front of CMMOP12 instance.

CMMOP13:

The distance function with variable linkages is formulated as

$$g_3 = 1 + \sum_{i=m}^{n} 2(x_i + (x_{i-1} - 0.5)^2 - 1)^2 \tag{16}$$

$$\min \begin{cases} f_1 = |x_1 - 2| \\ f_2 = g(1 - \sqrt{|x_1 - 2|}/g) + 2(x_2 - \sin(6\pi|x_1 - 2| + \pi))^2 \end{cases}$$
$$\text{s.t. } c(\mathbf{x}) = 1 - f_1 - f_2 + 0.6\sin(2\pi l)^8 \geq 0, \tag{17}$$
$$l = \sqrt{2}f_2 - \sqrt{2}f_1$$



(a) (b)

Fig. S-13. True unconstrained Pareto front and constrained Pareto front of CMMOP13 instance.

where $1 \leq x_1 \leq 3$, $-1 \leq x_2 \leq 1$.

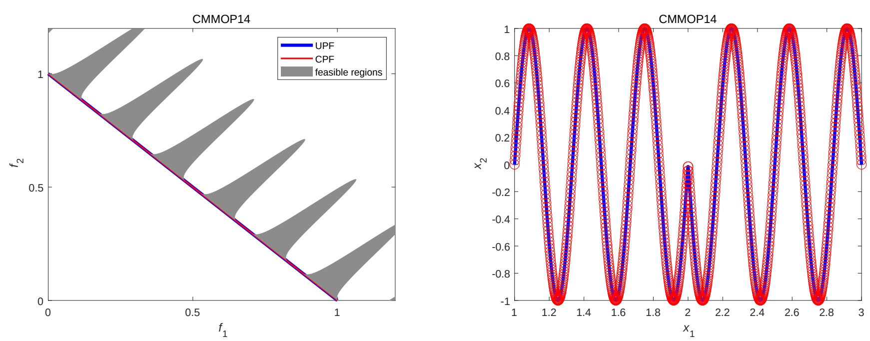
CMMOP14:

The biased distance function is formulated as

$$\begin{aligned} & g_1 = 1 + \sum_{i=m}^{n} (1 - \exp(-10(z_i - 0.5 - \frac{i-1}{2n})^2)) \\ & z_i = x_i^{n-m},\ x_i \in \mathbf{x}_{ii} \end{aligned} \tag{18}$$

$$\begin{aligned} & \min \begin{cases} f_1 = |x_1 - 2| \\ f_2 = g(1 - \sqrt{|x_1 - 2|}/g) + 2(x_2 - \sin(6\pi|x_1 - 2| + \pi))^2 \end{cases} \\ & \text{s.t. } c(\mathbf{x}) = 1 - f_1 - f_2 + 0.6\sin(2\pi l)^8 \geq 0, \\ & l = \sqrt{2} f_2 - \sqrt{2} f_1 \end{aligned} \tag{19}$$

where $1 \leq x_1 \leq 3$, $-1 \leq x_2 \leq 1$.



(a) (b)

Fig. S-14. True unconstrained Pareto front and constrained Pareto front of CMMOP14 instance.

III. Overview of CPF and CPS of the Proposed Test Problem

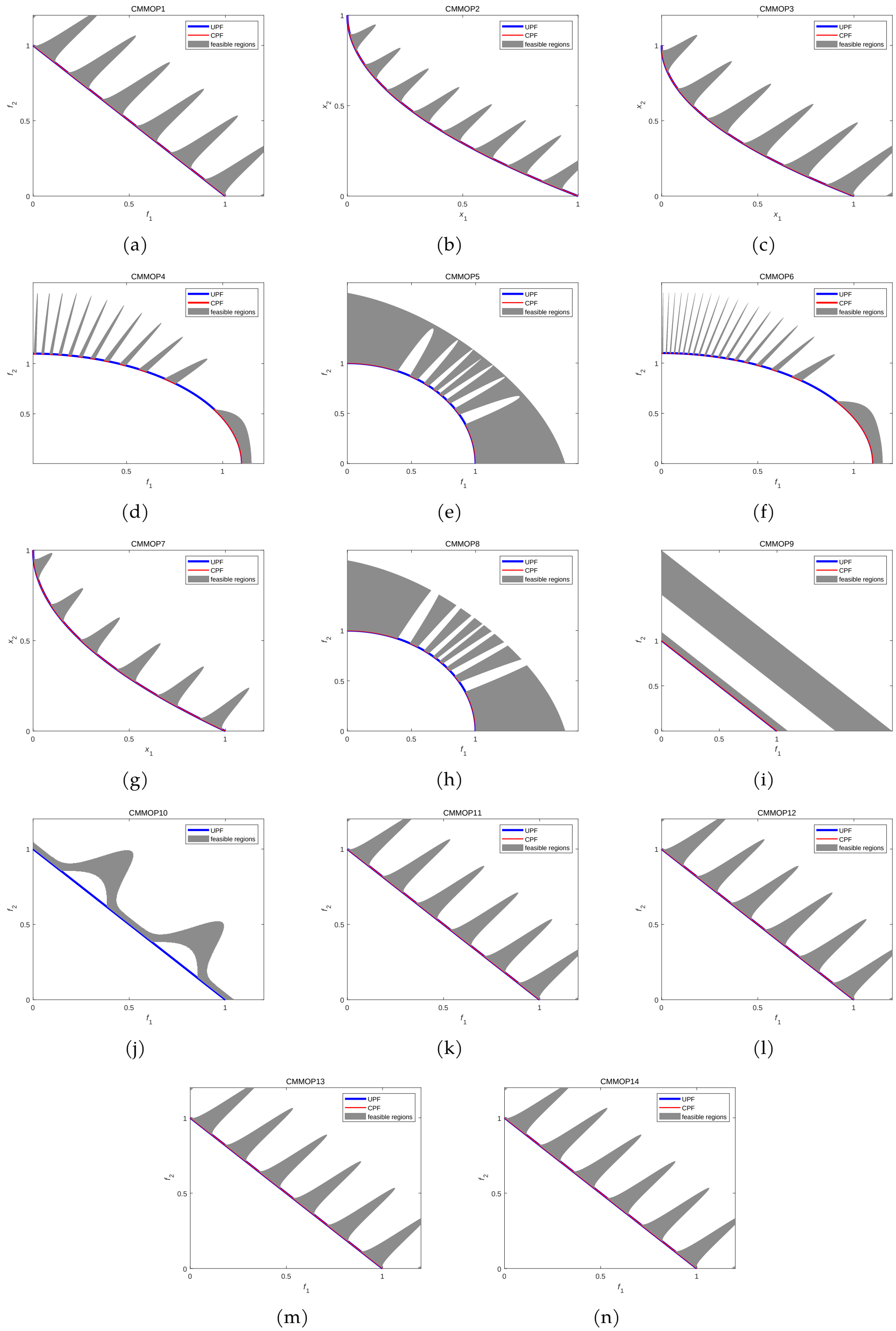


Fig. S-15. True unconstrained Pareto front and constrained Pareto front of CMMOP instances.

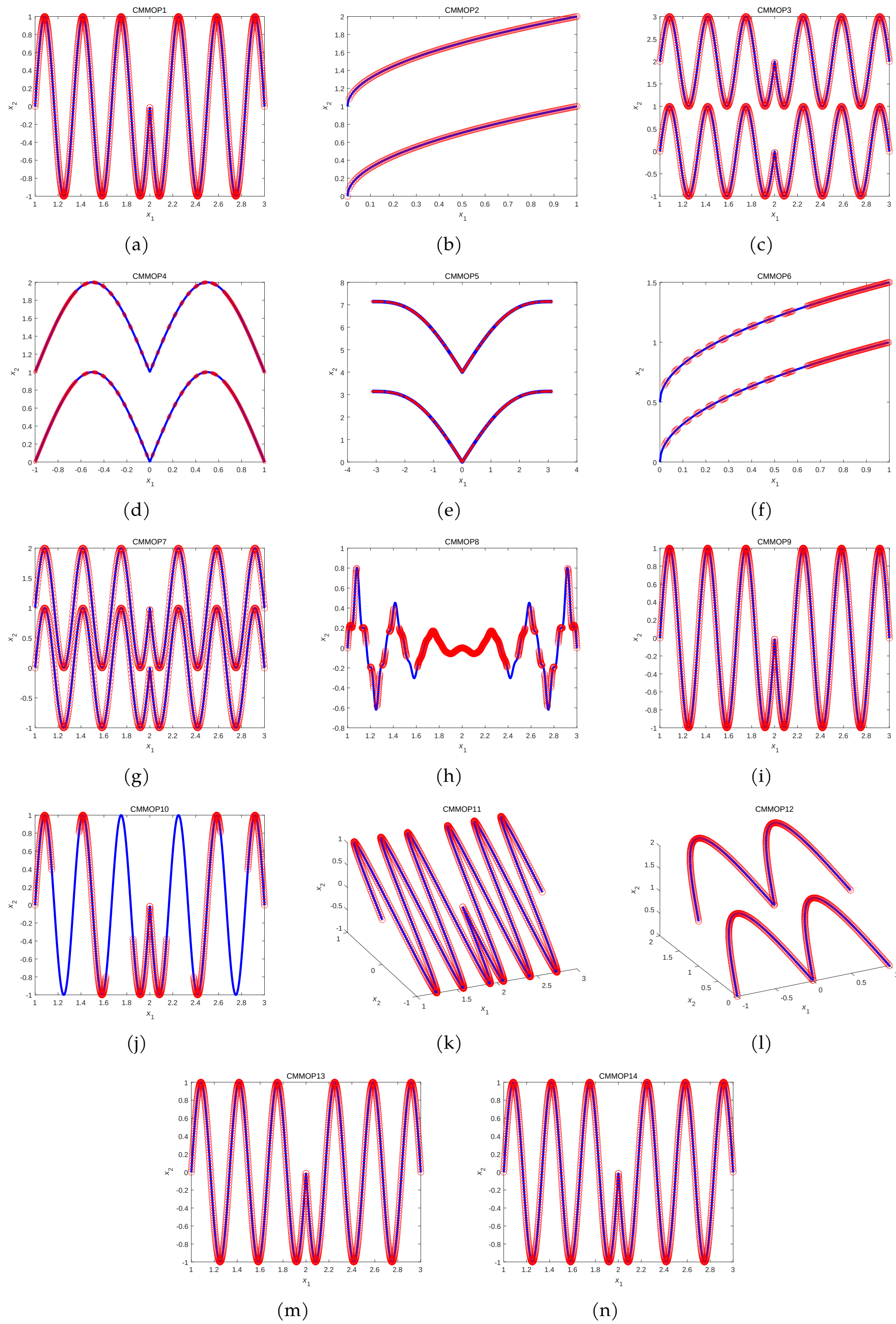


Fig. S-16. True unconstrained Pareto set and constrained Pareto set of CMMOP instances.

IV. Details of Varians for Comparison

TABLE S-I
Details of variants of CMMOCEA.

name	feature	function
CMMOCEAESDec	use only decision space diversity for turncation	test the effectiveness of using both decision and objective space diversity
CMMOCEAMSBoth	use both decision and objective space diversity for mating selection	test the influence of diversity indicator used in mating selection
CMMOCEAMSRand	randomly mating selection	test the effectiveness of using both decision and objective space diversity
CMMOCEAPop1	use only the constraint considered population	test the effectiveness of the constraint ignoring population
CMMOCEANormCo	use normal coevolution that generates offspring by mixed mating pool	test the effectiveness of generating offspring seperately

V. Details of Algorithms for Comparison

TABLE S-II
MMOEAs and CHTs used to create CMMOEAs for comparison.

Name	MMOEA		CHT		
DNNSGA-II-CDP	DNNSGAII	CEC2016	CDP	NSGAII	TEVC2007
DNNSGA-II-epsilon	DNNSGAII	CEC2016	ε-constrained	PPS	SWEC2019
DNNSGA-II-penalty	DNNSGAII	CEC2016	penalty	c-DPEA	TEVC2021
MO-Ring-PSO-SCD-CDP	MO-Ring-PSO-SCD	TEVC2018	CDP	NSGAII	TEVC2007
MO-Ring-PSO-SCD-epsilon	MO-Ring-PSO-SCD	TEVC2018	ε-constrained	PPS	SWEC2019
MO-Ring-PSO-SCD-penalty	MO-Ring-PSO-SCD	TEVC2018	penalty	c-DPEA	TEVC2021
TriMOEATAR-CDP	TriMOEATAR	TEVC2019	CDP	NSGAII	TEVC2007
TriMOEATAR-epsilon	TriMOEATAR	TEVC2019	ε-constrained	PPS	SWEC2019
TriMOEATAR-penalty	TriMOEATAR	TEVC2019	penalty	c-DPEA	TEVC2021
MMEAWI-CDP	MMEAWI	TEVC2021	CDP	NSGA-II	TEVC2007
MMEAWI-epsilon	MMEAWI	TEVC2021	ε-constrained	PPS	SWEC2019
MMEAWI-penalty	MMEAWI	TEVC2021	penalty	c-DPEA	TEVC2021

VI. Experimental Results

TABLE S-III
Statistical results of IGDX obtained by CMMOCEA and its variants on the proposed CMMOP benchmark. Best result in each row is highlighted.

Problem	CMMOCEAESDec	CMMOCEAMSBoth	CMMOCEAMSRand	CMMOCEAPop1	CMMOCEANormCo	CMMOCEA
CMMOP1	3.3467e-2 (1.11e-3) ≈	3.2777e-2 (7.95e-4) ≈	3.4942e-2 (1.44e-3) −	4.1016e-2 (1.97e-3) −	3.2733e-2 (1.15e-3) ≈	3.3013e-2 (1.05e-3)
CMMOP2	1.3334e-2 (1.61e-3) ≈	1.3885e-2 (2.35e-3) ≈	2.3691e-2 (7.76e-3) −	1.8545e-2 (5.23e-3) −	1.4074e-2 (2.26e-3) −	1.3102e-2 (2.09e-3)
CMMOP3	4.6410e-2 (1.42e-3) −	4.6037e-2 (1.18e-3) ≈	4.6812e-2 (1.45e-3) −	4.8253e-2 (2.14e-3) −	4.6209e-2 (1.23e-3) −	4.5591e-2 (1.16e-3)
CMMOP4	1.0293e-2 (1.09e-3) +	1.1376e-2 (8.20e-4) ≈	1.1750e-2 (1.70e-3) ≈	1.2869e-2 (1.82e-3) −	1.0723e-2 (1.35e-3) ≈	1.1032e-2 (1.13e-3)
CMMOP5	3.1101e-2 (6.81e-3) ≈	3.0442e-2 (1.16e-2) ≈	9.9264e-2 (4.52e-2) −	3.7934e-2 (1.43e-2) −	2.8954e-2 (6.23e-3) ≈	2.9677e-2 (4.96e-3)
CMMOP6	2.0578e-2 (7.05e-3) ≈	1.9718e-2 (5.57e-3) ≈	3.2111e-2 (1.41e-2) −	2.4104e-2 (8.05e-3) −	2.0891e-2 (7.55e-3) ≈	1.8664e-2 (4.24e-3)
CMMOP7	4.5888e-2 (1.46e-3) −	4.4852e-2 (1.35e-3) ≈	4.8090e-2 (2.23e-3) −	4.8878e-2 (1.74e-3) −	4.5127e-2 (1.48e-3) ≈	4.4571e-2 (1.09e-3)
CMMOP8	8.6055e-3 (2.14e-4) +	9.4877e-3 (2.17e-4) ≈	9.5680e-3 (2.82e-4) ≈	9.4309e-3 (3.71e-4) ≈	9.4932e-3 (3.26e-4) ≈	9.5265e-3 (2.69e-4)
CMMOP9	2.2550e-2 (7.61e-4) −	2.1409e-2 (4.96e-4) ≈	2.1920e-2 (4.57e-4) −	2.1595e-2 (5.33e-4) ≈	2.1507e-2 (5.09e-4) ≈	2.1506e-2 (4.31e-4)
CMMOP10	1.3848e-2 (3.48e-4) −	1.3759e-2 (4.80e-4) ≈	1.4108e-2 (7.66e-4) −	1.3026e-2 (4.07e-4) +	1.3673e-2 (5.77e-4) ≈	1.3622e-2 (4.38e-4)
CMMOP11	6.6522e-2 (3.75e-3) ≈	6.5831e-2 (5.47e-3) ≈	7.6869e-2 (4.34e-3) −	8.8081e-2 (7.61e-3) −	6.5973e-2 (4.22e-3) ≈	6.6889e-2 (4.27e-3)
CMMOP12	4.9610e-2 (4.51e-3) ≈	4.6886e-2 (4.98e-3) ≈	5.6310e-2 (7.80e-3) −	5.3094e-2 (6.34e-3) −	4.5712e-2 (3.89e-3) ≈	4.7770e-2 (4.81e-3)
CMMOP13	3.4953e-2 (1.30e-3) ≈	3.5347e-2 (1.42e-3) −	3.8214e-2 (2.30e-3) −	4.3683e-2 (2.83e-3) −	3.4879e-2 (9.72e-4) ≈	3.4670e-2 (9.91e-4)
CMMOP14	4.1772e-2 (1.89e-3) ≈	4.0513e-2 (2.17e-3) ≈	4.6731e-2 (3.59e-3) −	5.3847e-2 (3.11e-3) −	4.0819e-2 (2.25e-3) ≈	4.1478e-2 (2.27e-3)
+/ − / ≈	2/4/8	0/1/13	0/12/2	1/11/2	0/2/12	

TABLE S-IV
Statistical results of IGDX obtained by CMMOCEA and other methods with $N = 200$ on the proposed CMMOP benchmark. Best result in each row is highlighted.

Problem	DNNSGAII-CDP	DNNSGAII-epsilon	DNNSGAII-penalty	MO-Ring-PSO-SCD-CDP	MO-Ring-PSO-SCD-epsilon	MO-Ring-PSO-SCD-penalty	TriMOEATAR-CDP	TriMOEATAR-epsilon	TriMOEATAR-penalty	MMEAWI-CDP	MMEAWI-epsilon	MMEAWI-penalty	CMMOCEA
CMMOP1	5.2757e-2 (2.54e-3) −	5.3452e-2 (2.11e-3) −	5.2810e-2 (2.22e-3) −	6.1400e-2 (3.12e-3) −	6.8872e-2 (7.16e-3) −	6.1726e-2 (3.42e-3) −	7.0032e-2 (5.88e-3) −	6.3179e-2 (5.65e-3) −	8.0848e-1 (3.10e-1) −	4.7699e-2 (2.13e-3) −	4.8301e-2 (1.47e-3) −	4.8436e-2 (1.84e-3) −	3.9956e-2 (1.15e-3)
CMMOP2	4.6654e-2 (2.51e-2) −	4.8071e-2 (4.15e-2) −	4.6116e-2 (2.38e-2) −	1.4598e-2 (1.84e-3) ≈	2.9532e-2 (6.82e-3) −	1.4180e-2 (2.70e-3) +	7.4683e-2 (4.33e-2) −	5.8325e-2 (2.41e-2) −	4.5801e-1 (8.16e-2) −	1.8699e-2 (6.89e-3) ≈	1.7379e-2 (6.77e-3) ≈	1.8522e-2 (7.10e-3) ≈	1.7085e-2 (5.65e-3)
CMMOP3	8.6570e-2 (4.32e-3) −	8.6506e-2 (4.66e-3) −	8.5843e-2 (4.37e-3) −	9.8882e-2 (7.62e-3) −	1.1537e-1 (1.42e-2) −	1.0042e-1 (8.97e-3) −	8.7734e-2 (1.10e-2) −	8.7347e-2 (8.00e-3) −	1.3177e+0 (4.24e-1) −	6.9357e-2 (2.33e-3) −	6.9715e-2 (2.85e-3) −	6.9373e-2 (2.34e-3) −	5.9732e-2 (2.10e-3)
CMMOP4	2.9078e-2 (5.29e-3) −	2.8353e-2 (4.04e-3) −	2.8603e-2 (4.50e-3) −	4.1189e-2 (6.80e-3) −	5.3054e-2 (1.21e-2) −	4.5246e-2 (1.12e-2) −	7.2869e-2 (1.14e-1) −	8.3935e-2 (1.25e-1) −	1.0714e+0 (3.11e-1) −	1.7903e-2 (1.78e-3) −	1.7884e-2 (1.85e-3) −	1.7612e-2 (1.50e-3) −	1.4314e-2 (1.20e-3)
CMMOP5	9.6988e-2 (5.52e-2) −	9.1630e-2 (5.56e-2) −	7.8930e-2 (4.01e-2) −	1.1600e-1 (5.07e-2) −	1.5098e-1 (3.61e-2) −	9.7459e-2 (2.79e-2) −	4.5375e-1 (9.51e-2) −	4.7271e-1 (8.74e-2) −	2.8061e+0 (8.61e-1) −	4.9652e-2 (6.61e-3) −	5.0108e-2 (6.17e-3) −	4.9397e-2 (5.97e-3) −	4.0033e-2 (1.32e-2)
CMMOP6	4.6793e-2 (1.74e-2) −	5.3881e-2 (3.38e-2) −	4.9727e-2 (1.82e-2) −	9.2603e-3 (1.66e-3) +	1.5660e-2 (3.15e-3) +	8.8960e-3 (1.44e-3) +	7.1882e-2 (2.85e-2) −	6.9242e-2 (3.99e-2) −	4.4418e-1 (8.45e-2) −	1.4177e-2 (3.37e-3) +	1.4388e-2 (4.14e-3) +	1.5197e-2 (5.30e-3) +	2.1110e-2 (6.57e-3)
CMMOP7	8.1168e-2 (5.22e-3) −	8.2637e-2 (3.97e-3) −	8.0982e-2 (4.20e-3) −	9.1547e-2 (8.70e-3) −	1.0314e-1 (9.74e-3) −	8.8024e-2 (6.36e-3) −	7.9410e-2 (1.13e-2) −	8.3081e-2 (1.14e-2) −	1.0408e+0 (2.55e-1) −	6.5452e-2 (3.04e-3) −	6.4672e-2 (2.27e-3) −	6.4374e-2 (2.63e-3) −	5.6979e-2 (1.44e-3)
CMMOP8	1.5113e-2 (1.04e-3) −	1.4738e-2 (1.15e-3) −	1.4967e-2 (7.49e-4) −	2.7779e-2 (8.35e-3) −	3.0766e-2 (8.54e-3) −	2.7476e-2 (6.81e-3) −	2.0256e-2 (2.29e-2) −	2.4768e-2 (3.16e-2) −	5.3992e-1 (1.22e-1) −	1.6894e-2 (8.97e-4) −	1.6797e-2 (7.83e-4) −	1.6854e-2 (9.25e-4) −	1.2387e-2 (4.14e-4)
CMMOP9	4.0667e-2 (9.27e-4) −	4.0453e-2 (8.02e-4) −	4.0222e-2 (1.05e-3) −	5.3156e-2 (4.31e-3) −	5.6243e-2 (7.51e-3) −	5.4362e-2 (5.54e-3) −	4.3353e-2 (8.43e-3) −	3.9080e-2 (2.29e-3) −	8.7943e-1 (1.95e-1) −	3.7978e-2 (1.91e-3) −	3.8349e-2 (2.47e-3) −	3.8884e-2 (2.16e-3) −	3.2301e-2 (1.29e-3)
CMMOP10	2.6486e-2 (1.11e-3) −	2.6815e-2 (1.48e-3) −	2.6727e-2 (1.10e-3) −	4.0659e-2 (5.98e-3) −	4.8205e-2 (9.04e-3) −	4.2359e-2 (5.77e-3) −	3.6692e-2 (6.91e-3) −	3.8415e-2 (9.17e-3) −	9.5443e-1 (1.12e-1) −	2.8205e-2 (1.69e-3) −	2.7976e-2 (1.19e-3) −	2.7897e-2 (1.55e-3) −	2.1319e-2 (1.03e-3)
CMMOP11	1.0039e-1 (9.80e-3) −	1.0487e-1 (1.08e-2) −	9.8561e-2 (7.90e-3) −	1.3576e-1 (1.27e-2) −	1.5043e-1 (1.94e-2) −	1.2998e-1 (1.36e-2) −	1.3376e-1 (3.24e-2) −	1.1854e-1 (2.75e-2) −	7.3825e-1 (5.76e-1) −	9.0653e-2 (6.73e-3) −	8.8292e-2 (7.45e-3) −	9.0057e-2 (6.73e-3) −	6.8819e-2 (3.45e-3)
CMMOP12	9.8445e-2 (2.21e-2) −	1.0341e-1 (1.48e-2) −	1.0422e-1 (2.68e-2) −	1.4287e-1 (3.31e-2) −	1.6690e-1 (4.05e-2) −	1.4276e-1 (2.82e-2) −	1.0218e-1 (2.71e-2) −	1.2659e-1 (4.38e-2) −	4.3802e-1 (4.62e-1) −	7.1503e-2 (6.66e-3) −	6.8788e-2 (6.74e-3) −	7.1261e-2 (7.74e-3) −	6.0540e-2 (6.07e-3)
CMMOP13	5.7069e-2 (3.19e-3) −	5.6219e-2 (2.26e-3) −	5.6887e-2 (3.74e-3) −	6.3206e-2 (5.66e-3) −	6.9289e-2 (6.04e-3) −	6.3084e-2 (3.88e-3) −	7.8884e-2 (8.04e-3) −	7.2624e-2 (6.45e-3) −	8.3068e-1 (3.19e-1) −	4.7995e-2 (1.13e-3) −	4.8204e-2 (1.81e-3) −	4.8423e-2 (1.60e-3) −	4.0841e-2 (1.21e-3)
CMMOP14	6.5032e-2 (4.73e-3) −	6.2835e-2 (3.53e-3) −	6.5259e-2 (4.80e-3) −	6.3152e-2 (3.98e-3) −	7.3959e-2 (9.26e-3) −	6.3441e-2 (2.48e-3) −	8.6825e-2 (1.67e-2) −	8.5543e-2 (9.99e-3) −	9.6195e-1 (1.27e-1) −	5.1715e-2 (2.65e-3) −	5.1750e-2 (2.49e-3) −	5.1348e-2 (2.18e-3) −	4.5950e-2 (3.42e-3)
+/ − / ≈	0/14/0	0/14/0	0/14/0	1/12/1	1/13/0	2/12/0	0/14/0	0/14/0	0/14/0	1/12/1	1/12/1	1/12/1	

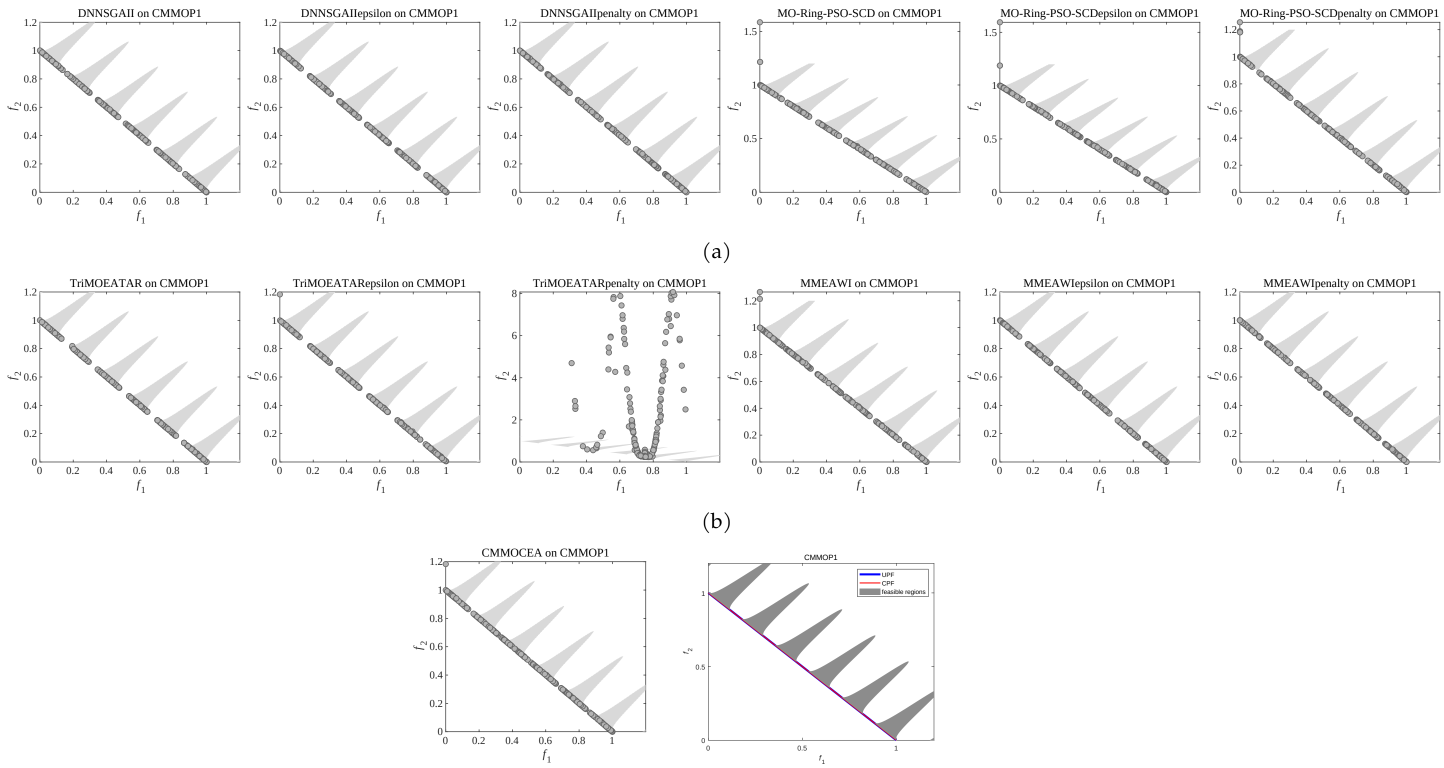
TABLE S-V
Statistical results of feasble ratio obtained by CMMOCEA and other methods on the proposed CMMOP benchmark. Best result in each row is highlighted.

Problem	DNNSGAII-CDP	DNNSGAII-epsilon	DNNSGAII-penalty	MO-Ring-PSO-SCD-CDP	MO-Ring-PSO-SCD-epsilon	MO-Ring-PSO-SCD-penalty	TriMOEATAR-CDP	TriMOEATAR-epsilon	TriMOEATAR-penalty	MMEAWI-CDP	MMEAWI-epsilon	MMEAWI-penalty	CMMOCEA
CMMOP1	1.0000e+0 (0.00e+0) ≈	1.0000e+0 (0.00e+0) ≈	1.0000e+0 (0.00e+0) ≈	1.0000e+0 (0.00e+0) ≈	1.0000e+0 (0.00e+0) ≈	1.0000e+0 (0.00e+0) ≈	9.1877e-1 (2.48e-1) ≈	9.1797e-1 (2.50e-1) ≈	6.0310e-1 (8.42e-2) −	1.0000e+0 (0.00e+0) ≈	1.0000e+0 (0.00e+0) ≈	1.0000e+0 (0.00e+0) ≈	1.0000e+0 (0.00e+0)
CMMOP2	1.0000e+0 (0.00e+0) ≈	1.0000e+0 (0.00e+0) ≈	1.0000e+0 (0.00e+0) ≈	1.0000e+0 (0.00e+0) ≈	1.0000e+0 (0.00e+0) ≈	1.0000e+0 (0.00e+0) ≈	1.0000e+0 (0.00e+0) ≈	9.6706e-1 (1.80e-1) ≈	1.3278e-1 (3.51e-2) −	1.0000e+0 (0.00e+0) ≈	1.0000e+0 (0.00e+0) ≈	1.0000e+0 (0.00e+0) ≈	1.0000e+0 (0.00e+0)
CMMOP3	1.0000e+0 (0.00e+0) ≈	1.0000e+0 (0.00e+0) ≈	1.0000e+0 (0.00e+0) ≈	1.0000e+0 (0.00e+0) ≈	1.0000e+0 (0.00e+0) ≈	1.0000e+0 (0.00e+0) ≈	8.6394e-1 (3.09e-1) −	9.7383e-1 (1.43e-1) ≈	4.7549e-1 (5.55e-2) −	1.0000e+0 (0.00e+0) ≈	1.0000e+0 (0.00e+0) ≈	1.0000e+0 (0.00e+0) ≈	1.0000e+0 (0.00e+0)
CMMOP4	1.0000e+0 (0.00e+0) ≈	1.0000e+0 (0.00e+0) ≈	1.0000e+0 (0.00e+0) ≈	1.0000e+0 (0.00e+0) ≈	1.0000e+0 (0.00e+0) ≈	1.0000e+0 (0.00e+0) ≈	9.0956e-1 (2.35e-1) −	9.7767e-1 (1.22e-1) ≈	7.8478e-1 (2.05e-1) −	1.0000e+0 (0.00e+0) ≈	1.0000e+0 (0.00e+0) ≈	1.0000e+0 (0.00e+0) ≈	1.0000e+0 (0.00e+0)
CMMOP5	1.0000e+0 (0.00e+0) ≈	1.0000e+0 (0.00e+0) ≈	1.0000e+0 (0.00e+0) ≈	1.0000e+0 (0.00e+0) ≈	1.0000e+0 (0.00e+0) ≈	1.0000e+0 (0.00e+0) ≈	9.7750e-1 (1.23e-1) ≈	1.0000e+0 (0.00e+0) ≈	8.2933e-1 (1.86e-2) −	1.0000e+0 (0.00e+0) ≈	1.0000e+0 (0.00e+0) ≈	1.0000e+0 (0.00e+0) ≈	1.0000e+0 (0.00e+0)
CMMOP6	1.0000e+0 (0.00e+0) ≈	1.0000e+0 (0.00e+0) ≈	1.0000e+0 (0.00e+0) ≈	1.0000e+0 (0.00e+0) ≈	1.0000e+0 (0.00e+0) ≈	1.0000e+0 (0.00e+0) ≈	1.0000e+0 (0.00e+0) ≈	1.0000e+0 (0.00e+0) ≈	5.5411e-1 (1.74e-1) −	1.0000e+0 (0.00e+0) ≈	1.0000e+0 (0.00e+0) ≈	1.0000e+0 (0.00e+0) ≈	1.0000e+0 (0.00e+0)
CMMOP7	1.0000e+0 (0.00e+0) ≈	1.0000e+0 (0.00e+0) ≈	1.0000e+0 (0.00e+0) ≈	1.0000e+0 (0.00e+0) ≈	1.0000e+0 (0.00e+0) ≈	1.0000e+0 (0.00e+0) ≈	9.4496e-1 (2.09e-1) ≈	9.4481e-1 (2.10e-1) ≈	4.2844e-1 (9.72e-2) −	1.0000e+0 (0.00e+0) ≈	1.0000e+0 (0.00e+0) ≈	1.0000e+0 (0.00e+0) ≈	1.0000e+0 (0.00e+0)
CMMOP8	1.0000e+0 (0.00e+0) ≈	1.0000e+0 (0.00e+0) ≈	1.0000e+0 (0.00e+0) ≈	1.0000e+0 (0.00e+0) ≈	1.0000e+0 (0.00e+0) ≈	1.0000e+0 (0.00e+0) ≈	9.9411e-1 (2.25e-2) ≈	9.8367e-1 (3.34e-2) −	9.0778e-1 (2.50e-2) −	1.0000e+0 (0.00e+0) ≈	1.0000e+0 (0.00e+0) ≈	1.0000e+0 (0.00e+0) ≈	1.0000e+0 (0.00e+0)
CMMOP9	1.0000e+0 (0.00e+0) ≈	1.0000e+0 (0.00e+0) ≈	1.0000e+0 (0.00e+0) ≈	1.0000e+0 (0.00e+0) ≈	1.0000e+0 (0.00e+0) ≈	1.0000e+0 (0.00e+0) ≈	9.5391e-1 (1.75e-1) ≈	9.7669e-1 (1.28e-1) ≈	6.3310e-1 (1.53e-1) −	1.0000e+0 (0.00e+0) ≈	1.0000e+0 (0.00e+0) ≈	1.0000e+0 (0.00e+0) ≈	1.0000e+0 (0.00e+0)
CMMOP10	1.0000e+0 (0.00e+0) ≈	1.0000e+0 (0.00e+0) ≈	1.0000e+0 (0.00e+0) ≈	1.0000e+0 (0.00e+0) ≈	1.0000e+0 (0.00e+0) ≈	1.0000e+0 (0.00e+0) ≈	8.9145e-1 (2.81e-1) −	1.0000e+0 (0.00e+0) ≈	5.4414e-1 (2.06e-1) −	1.0000e+0 (0.00e+0) ≈	1.0000e+0 (0.00e+0) ≈	1.0000e+0 (0.00e+0) ≈	1.0000e+0 (0.00e+0)
CMMOP11	1.0000e+0 (0.00e+0) ≈	1.0000e+0 (0.00e+0) ≈	1.0000e+0 (0.00e+0) ≈	1.0000e+0 (0.00e+0) ≈	1.0000e+0 (0.00e+0) ≈	1.0000e+0 (0.00e+0) ≈	7.0020e-1 (3.73e-1) −	6.2118e-1 (3.86e-1) −	4.8692e-1 (3.07e-1) −	1.0000e+0 (0.00e+0) ≈	1.0000e+0 (0.00e+0) ≈	1.0000e+0 (0.00e+0) ≈	1.0000e+0 (0.00e+0)
CMMOP12	1.0000e+0 (0.00e+0) ≈	1.0000e+0 (0.00e+0) ≈	1.0000e+0 (0.00e+0) ≈	1.0000e+0 (0.00e+0) ≈	1.0000e+0 (0.00e+0) ≈	1.0000e+0 (0.00e+0) ≈	7.3060e-1 (3.36e-1) −	7.8204e-1 (3.14e-1) −	4.2746e-1 (2.32e-1) −	1.0000e+0 (0.00e+0) ≈	1.0000e+0 (0.00e+0) ≈	1.0000e+0 (0.00e+0) ≈	1.0000e+0 (0.00e+0)
CMMOP13	1.0000e+0 (0.00e+0) ≈	1.0000e+0 (0.00e+0) ≈	1.0000e+0 (0.00e+0) ≈	1.0000e+0 (0.00e+0) ≈	1.0000e+0 (0.00e+0) ≈	1.0000e+0 (0.00e+0) ≈	1.0000e+0 (0.00e+0) ≈	9.7100e-1 (1.59e-1) ≈	5.6343e-1 (8.43e-2) −	1.0000e+0 (0.00e+0) ≈	1.0000e+0 (0.00e+0) ≈	1.0000e+0 (0.00e+0) ≈	1.0000e+0 (0.00e+0)
CMMOP14	1.0000e+0 (0.00e+0) ≈	1.0000e+0 (0.00e+0) ≈	1.0000e+0 (0.00e+0) ≈	1.0000e+0 (0.00e+0) ≈	1.0000e+0 (0.00e+0) ≈	1.0000e+0 (0.00e+0) ≈	1.0000e+0 (0.00e+0) ≈	8.4910e-1 (3.43e-1) −	4.8951e-1 (1.14e-1) −	1.0000e+0 (0.00e+0) ≈	1.0000e+0 (0.00e+0) ≈	1.0000e+0 (0.00e+0) ≈	1.0000e+0 (0.00e+0)
+/ − / ≈	0/0/14	0/0/14	0/0/14	0/0/14	0/0/14	0/0/14	0/5/9	0/4/10	0/14/0	0/0/14	0/0/14	0/0/14	

TABLE S-VI

STATISTICAL RESULTS OF IGDX OBTAINED BY CMMOCEA AND OTHER METHODS WITH $E_{max} = 900,000$ ON THE PROPOSED CMMOP BENCHMARK. BEST RESULT IN EACH ROW IS HIGHLIGHTED.

Problem	DNNSGAII-CDP	DNNSGAII-epsilon	DNNSGAII-penalty	MO-Ring-PSO-SCD-CDP	MO-Ring-PSO-SCD-epsilon	MO-Ring-PSO-SCD-penalty	TriMOEATAR-CDP	TriMOEATAR-epsilon	TriMOEATAR-penalty	MMEAWI-CDP	MMEAWI-epsilon	MMEAWI-penalty	CMMOCEA
CMMOP1	4.3729e-2 (2.06e-3) −	4.3399e-2 (1.68e-3) −	4.2962e-2 (1.59e-3) −	4.9863e-2 (3.06e-3) −	5.3811e-2 (4.12e-3) −	5.0043e-2 (2.96e-3) −	6.0872e-2 (3.81e-3) −	5.7738e-2 (4.28e-3) −	8.2442e-1 (2.36e-1) −	3.9610e-2 (1.22e-3) −	3.9093e-2 (1.19e-3) −	3.9198e-2 (1.54e-3) −	3.0979e-2 (9.23e-4)
CMMOP2	2.9576e-2 (1.36e-2) −	2.7850e-2 (1.53e-2) −	2.8479e-2 (1.45e-2) −	1.2072e-2 (1.77e-3) −	2.2801e-2 (4.38e-3) −	1.1238e-2 (1.49e-3) −	4.6996e-2 (2.93e-2) −	5.1993e-2 (5.19e-2) −	4.3309e-1 (8.70e-2) −	1.2424e-2 (3.94e-3) −	1.2703e-2 (6.95e-3) −	1.2333e-2 (2.76e-3) −	1.0695e-2 (2.56e-3)
CMMOP3	6.6226e-2 (4.28e-3) −	6.6846e-2 (2.88e-3) −	6.4957e-2 (3.22e-3) −	7.8646e-2 (5.86e-3) −	9.3970e-2 (7.52e-3) −	7.9506e-2 (5.41e-3) −	7.0228e-2 (1.62e-2) −	7.1494e-2 (1.96e-2) −	1.2264e+0 (4.33e-1) −	5.4801e-2 (2.04e-3) −	5.4059e-2 (1.90e-3) −	5.4295e-2 (1.87e-3) −	4.4582e-2 (1.15e-3)
CMMOP4	2.0353e-2 (3.58e-3) −	2.0394e-2 (4.16e-3) −	1.9796e-2 (3.33e-3) −	3.4127e-2 (8.37e-3) −	4.1202e-2 (1.36e-2) −	2.9837e-2 (6.10e-3) −	1.0775e-1 (1.54e-1) −	5.2254e-2 (1.04e-1) −	1.0902e+0 (2.63e-1) −	1.3240e-2 (1.42e-3) −	1.3070e-2 (1.37e-3) −	1.3360e-2 (1.53e-3) −	9.8252e-3 (6.30e-4)
CMMOP5	5.5838e-2 (2.58e-2) −	5.1612e-2 (2.80e-2) −	5.4727e-2 (2.31e-2) −	7.7340e-2 (2.14e-2) −	1.1753e-1 (3.39e-2) −	7.6727e-2 (2.43e-2) −	3.3724e-1 (1.05e-1) −	3.7184e-1 (8.64e-2) −	2.9634e+0 (7.26e-1) −	3.6319e-2 (6.57e-3) −	3.7892e-2 (7.85e-3) −	3.5201e-2 (4.64e-3) −	2.6706e-2 (5.02e-3)
CMMOP6	3.7915e-2 (1.62e-2) −	3.7744e-2 (1.49e-2) −	3.9661e-2 (1.44e-2) −	6.5364e-3 (1.08e-3) +	1.2396e-2 (3.11e-3) +	7.4428e-3 (1.43e-3) +	5.1940e-2 (2.35e-2) −	4.8544e-2 (1.55e-2) −	4.7694e-1 (1.28e-1) −	9.1812e-3 (2.82e-3) +	8.9027e-3 (2.11e-3) +	9.4893e-3 (3.89e-3) +	1.6328e-2 (6.41e-3)
CMMOP7	6.4210e-2 (4.24e-3) −	6.3782e-2 (2.95e-3) −	6.5632e-2 (2.96e-3) −	7.2879e-2 (5.65e-3) −	8.5098e-2 (7.34e-3) −	7.3534e-2 (5.19e-3) −	6.6426e-2 (5.52e-3) −	6.4684e-2 (5.11e-3) −	1.0672e+0 (1.33e-1) −	5.2778e-2 (2.34e-3) −	5.2884e-2 (2.32e-3) −	5.2201e-2 (1.83e-3) −	4.4664e-2 (1.28e-3)
CMMOP8	1.0523e-2 (3.74e-4) −	1.0706e-2 (5.00e-4) −	1.0506e-2 (3.81e-4) −	1.9421e-2 (2.73e-3) −	2.1698e-2 (5.56e-3) −	2.0324e-2 (7.12e-3) −	1.8354e-2 (2.32e-2) −	1.4176e-2 (1.12e-3) −	4.7013e-1 (1.53e-1) −	1.1843e-2 (4.89e-4) −	1.1877e-2 (5.76e-4) −	1.1878e-2 (4.39e-4) −	8.6548e-3 (2.79e-4)
CMMOP9	2.8500e-2 (8.10e-4) −	2.8521e-2 (7.00e-4) −	2.8500e-2 (7.28e-4) −	4.2256e-2 (4.09e-3) −	4.2773e-2 (5.51e-3) −	4.0935e-2 (4.48e-3) −	3.8922e-2 (9.53e-3) −	3.5975e-2 (1.46e-3) −	9.2102e-1 (1.92e-1) −	2.9202e-2 (1.57e-3) −	2.8951e-2 (1.43e-3) −	2.8906e-2 (1.59e-3) −	2.2149e-2 (4.97e-4)
CMMOP10	1.8153e-2 (8.31e-4) −	1.8202e-2 (6.70e-4) −	1.8037e-2 (6.85e-4) −	2.9106e-2 (3.38e-3) −	3.5806e-2 (9.76e-3) −	2.9887e-2 (3.81e-3) −	3.3378e-2 (8.26e-3) −	3.5395e-2 (1.03e-2) −	8.5704e-1 (2.57e-1) −	1.9734e-2 (8.18e-4) −	1.9542e-2 (1.11e-3) −	1.9876e-2 (1.20e-3) −	1.4270e-2 (5.83e-4)
CMMOP11	8.6947e-2 (8.34e-3) −	8.5473e-2 (7.03e-3) −	8.8347e-2 (7.76e-3) −	1.1890e-1 (1.03e-2) −	1.3316e-1 (1.30e-2) −	1.1557e-1 (1.22e-2) −	1.1515e-1 (2.51e-2) −	1.0547e-1 (1.98e-2) −	7.5328e-1 (6.00e-1) −	7.7454e-2 (5.41e-3) −	7.5824e-2 (6.49e-3) −	7.5596e-2 (5.88e-3) −	5.7634e-2 (2.57e-3)
CMMOP12	7.3212e-2 (1.56e-2) −	7.3070e-2 (1.17e-2) −	7.0982e-2 (1.29e-2) −	1.1945e-1 (3.35e-2) −	1.2993e-1 (2.35e-2) −	1.1726e-1 (2.85e-2) −	9.0810e-2 (2.00e-2) −	9.4589e-2 (3.72e-2) −	5.7329e-1 (4.68e-1) −	5.3460e-2 (5.85e-3) −	5.3134e-2 (5.96e-3) −	5.4306e-2 (8.53e-3) −	4.1916e-2 (3.23e-3)
CMMOP13	4.6135e-2 (1.94e-3) −	4.6620e-2 (2.57e-3) −	4.6797e-2 (2.66e-3) −	5.0498e-2 (3.23e-3) −	5.6254e-2 (6.71e-3) −	5.0370e-2 (2.65e-3) −	6.7356e-2 (4.70e-3) −	5.9996e-2 (3.85e-3) −	8.3150e-1 (2.91e-1) −	4.0294e-2 (1.68e-3) −	4.0373e-2 (1.45e-3) −	4.0230e-2 (1.65e-3) −	3.2113e-2 (8.33e-4)
CMMOP14	5.5048e-2 (3.26e-3) −	5.2398e-2 (3.25e-3) −	5.3130e-2 (3.29e-3) −	5.2200e-2 (3.95e-3) −	5.8509e-2 (6.54e-3) −	5.0943e-2 (2.67e-3) −	7.9088e-2 (9.01e-3) −	7.1810e-2 (8.28e-3) −	8.4632e-1 (2.36e-1) −	4.2081e-2 (2.34e-3) −	4.2414e-2 (2.15e-3) −	4.2546e-2 (2.01e-3) −	3.5459e-2 (1.49e-3)
+/ − / ≈	0/14/0	0/14/0	0/14/0	1/13/0	1/13/0	1/13/0	0/14/0	0/14/0	0/14/0	1/13/0	1/13/0	1/13/0	



(a) (b) (c) (d)

Fig. S-17. Feasible non-dominated solution sets in the objective space obtained by CMMOCEA and other methods on CMMOP1.

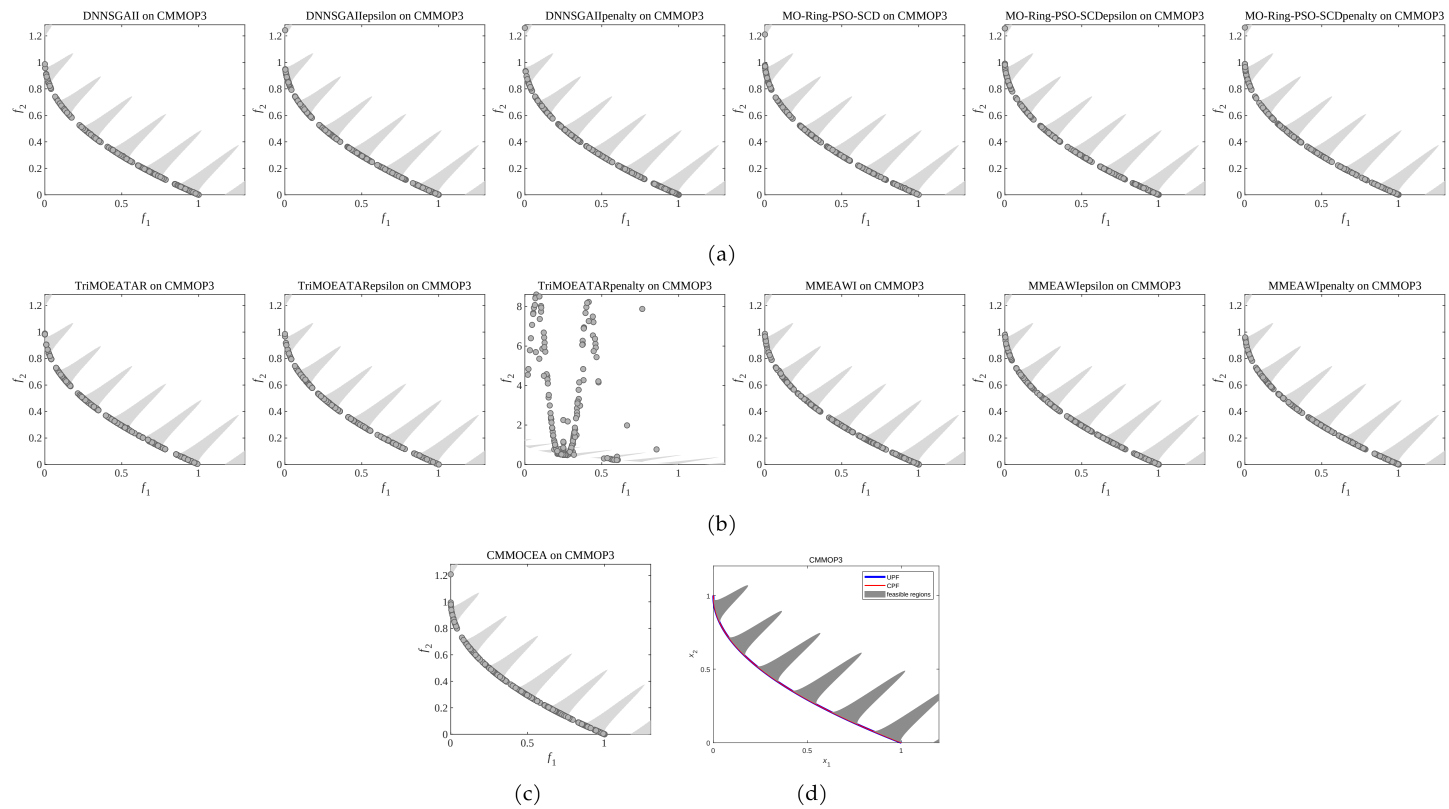


Fig. S-18. Feasible non-dominated solution sets in the objective space obtained by CMMOCEA and other methods on CMMOP3.

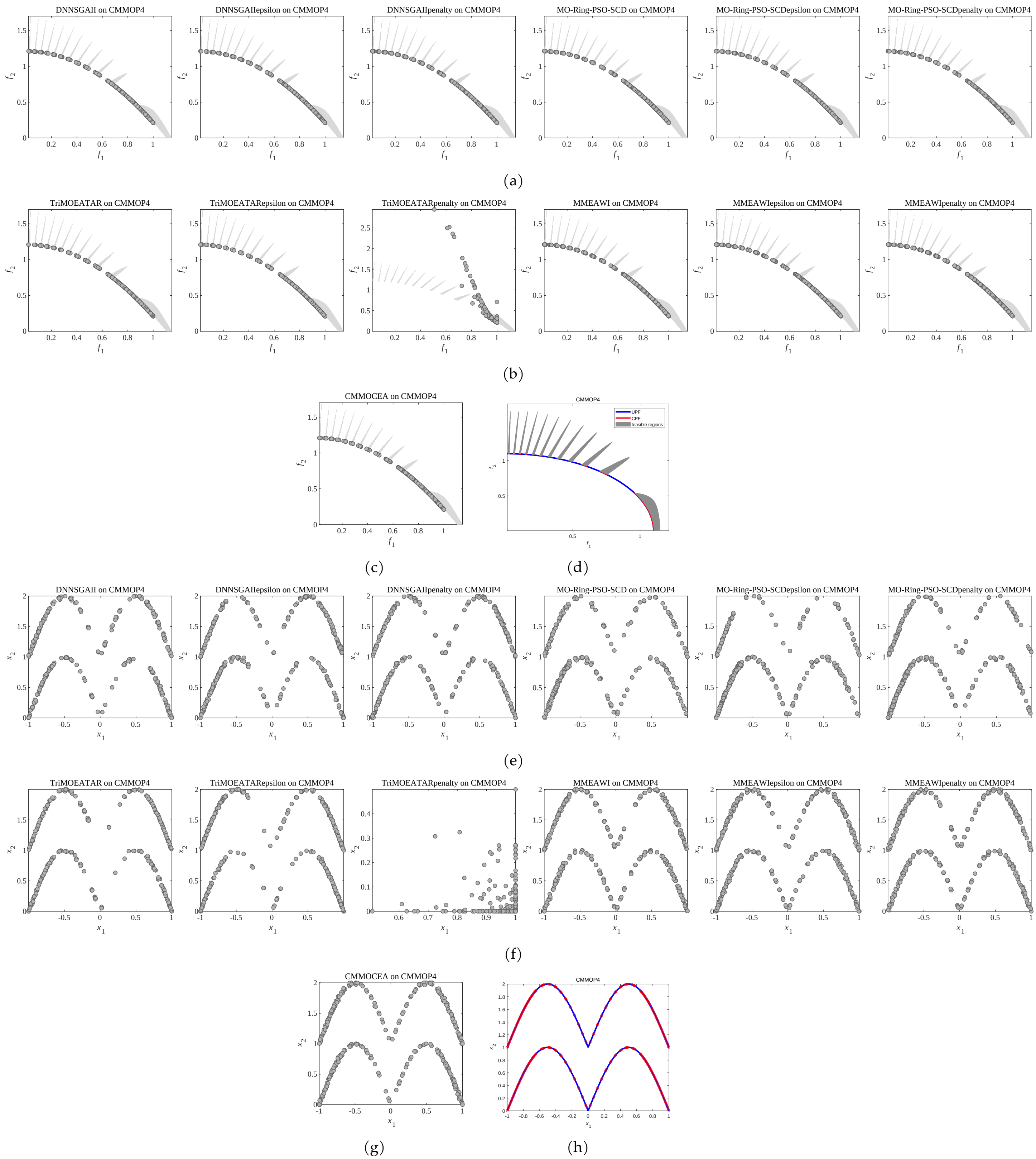
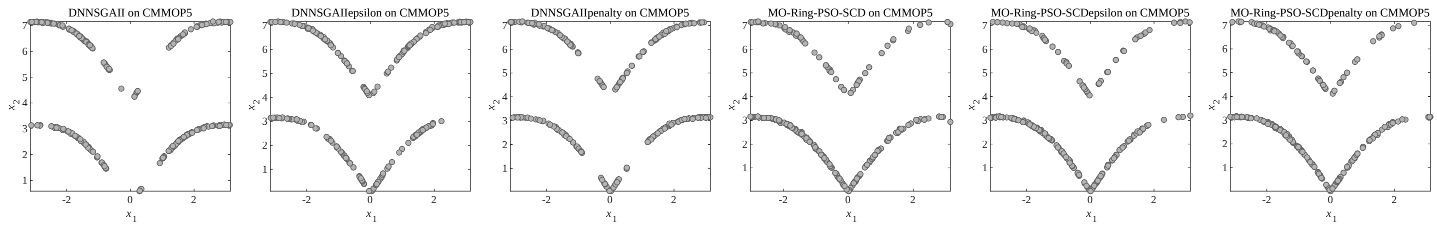
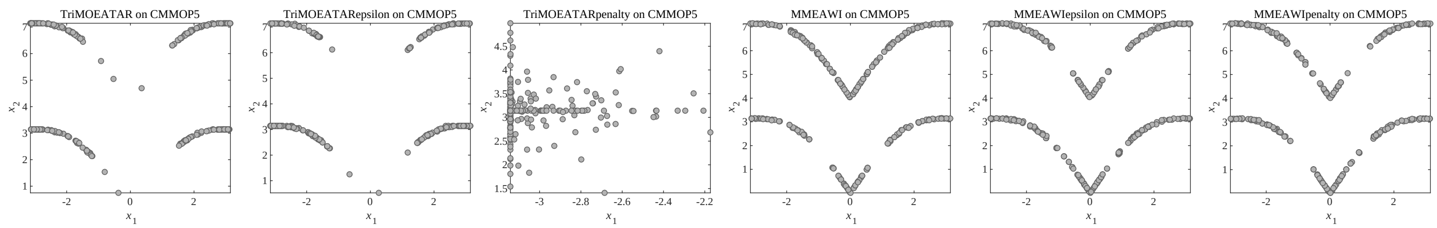


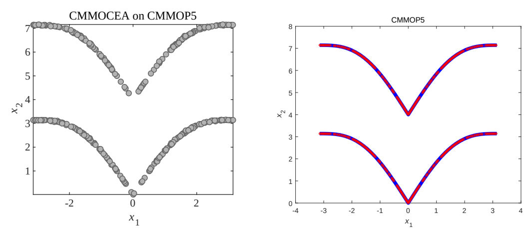
Fig. S-19. Feasible non-dominated solution sets in the objective and decision spaces obtained by CMMOCEA and other methods on CMMOP4.



(a)

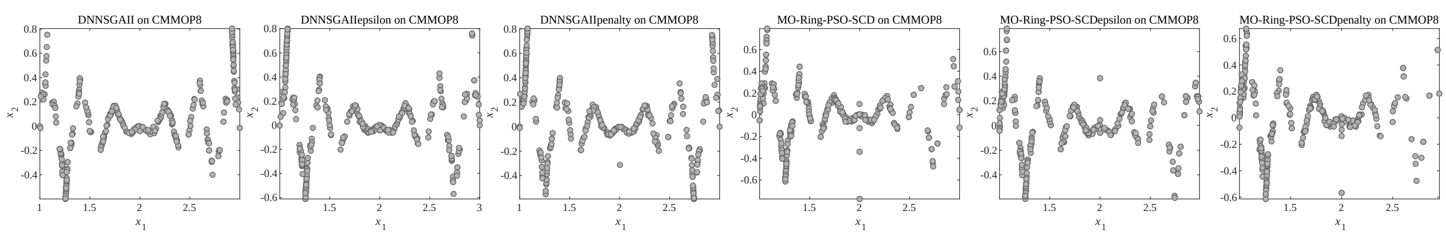


(b)

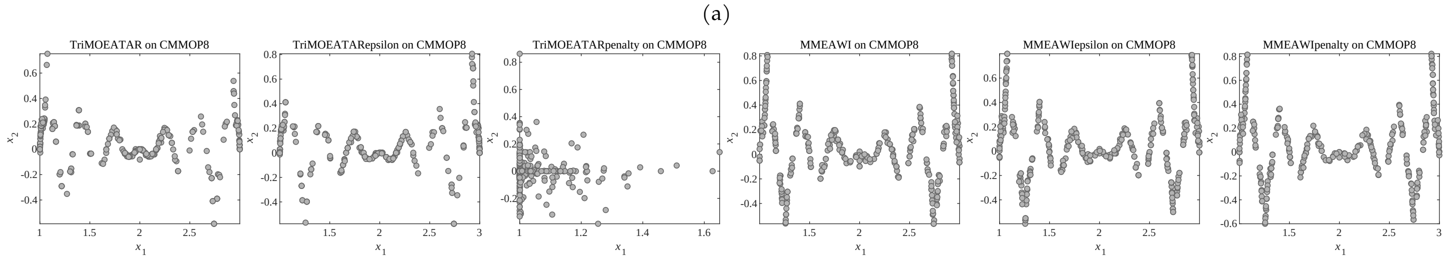


(c) (d)

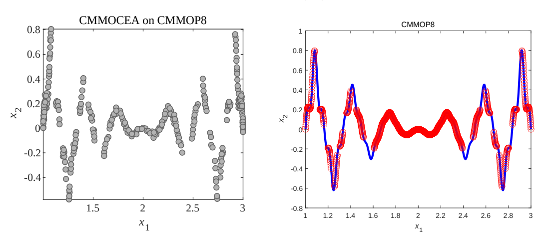
Fig. S-20. Feasible non-dominated solution sets in the objective space obtained by CMMOCEA and other methods on CMMOP5.



(a)

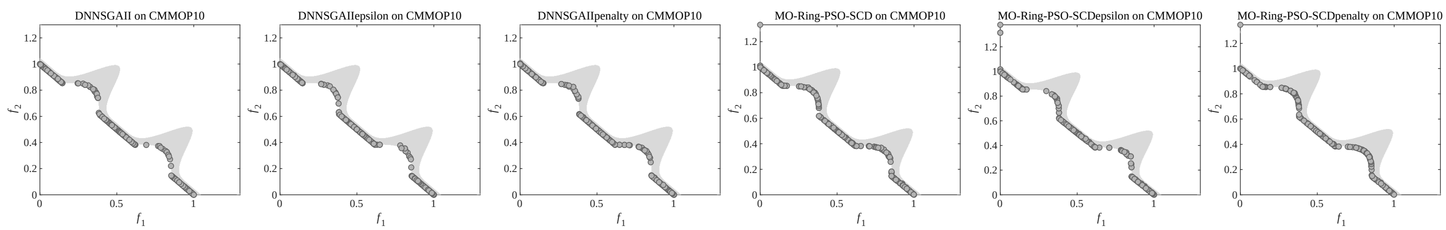


(b)

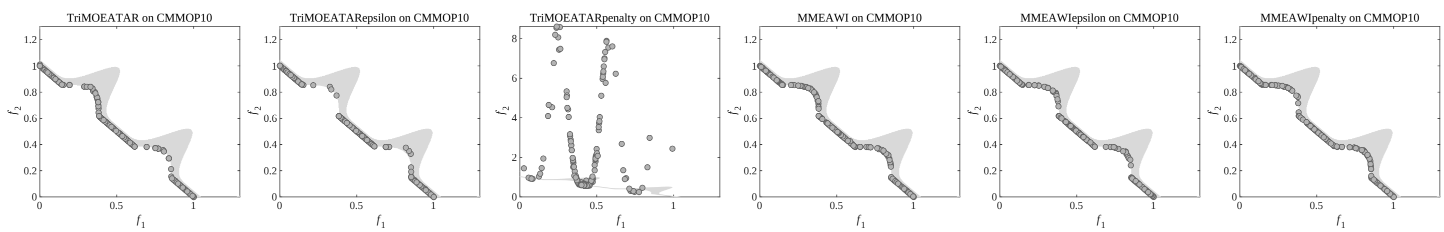


(c) (d)

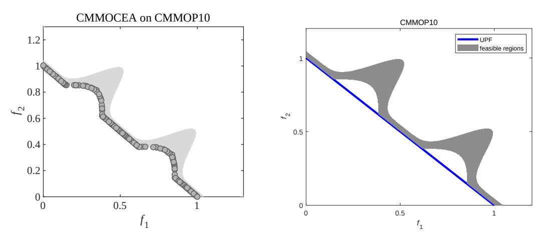
Fig. S-21. Feasible non-dominated solution sets in the objective space obtained by CMMOCEA and other methods on CMMOP8.



(a)



(b)



(c) (d)

Fig. S-22. Feasible non-dominated solution sets in the objective space obtained by CMMOCEA and other methods on CMMOP10.

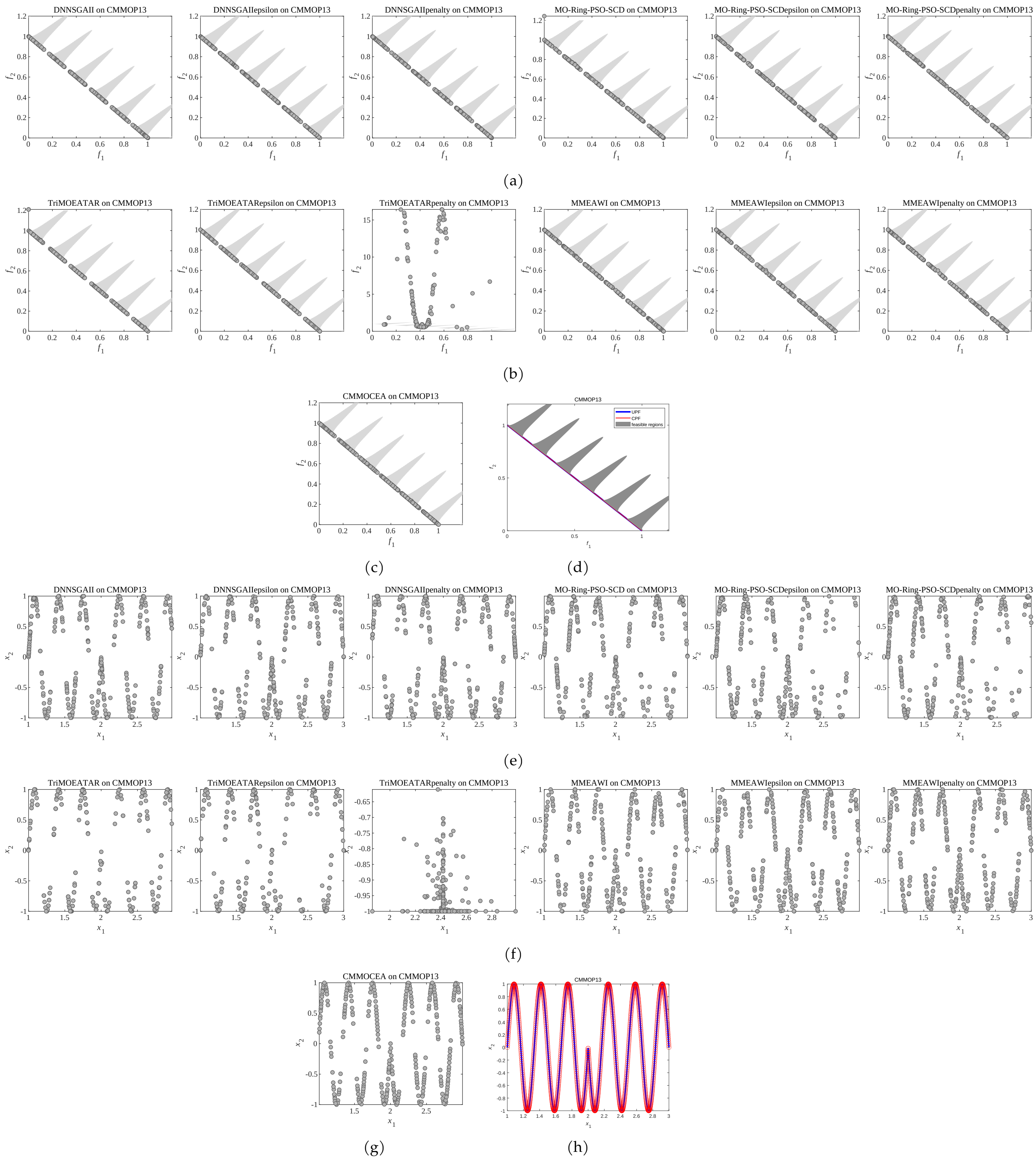


Fig. S-23. Feasible non-dominated solution sets in the objective and decision spaces obtained by CMMOCEA and other methods on CMMOP13.