

## Supplementary Materials

**Table S1.** Unimodal benchmark functions.

Function	Dim	Range	Fmin
$f_1(x) = \sum_{i=1}^n x_i^2$	30/50/100	[-100,100]	0
$f_2(x) = \sum_{i=1}^n  x_i  + \prod_{i=1}^n  x_i $	30/50/100	[-10,10]	0
$f_3(x) = \sum_{i=1}^n (\sum_{j=1}^i x_j)^2$	30/50/100	[-100,100]	0
$f_4(x) = \max\{ x_i , 1 \leq i \leq n\}$	30/50/100	[-100,100]	0
$f_5(x) = \sum_{i=1}^{n-1} [100(x_{i+1} - x_i^2)^2 + (x_i - 1)^2]$	30/50/100	[-30,30]	0
$f_6(x) = \sum_{i=1}^n ( x_i + 0.5 )^2$	30/50/100	[-100,100]	0
$f_7(x) = \sum_{i=1}^n i x_i^4 + \text{random}[0,1)$	30/50/100	[1.28,1.28]	0

**Table S2.** Multimodal benchmark functions.

Function	Dim	Range	Fmin
$f_8(x) = \sum_{i=1}^n -x_i \sin(\sqrt{ x_i })$	30/50/100	[-500, 500]	-418.98*Dim
$f_9(x) = \sum_{i=1}^n [x_i^2 - 10 \cos(2\pi x_i) + 10]$	30/50/100	[-5.12, 5.12]	0
$f_{10}(x) = -20 \exp\left(-0.2 \sqrt{\frac{1}{n} \sum_{i=1}^n x_i^2}\right) - \exp\left(\frac{1}{n} \sum_{i=1}^n \cos(2\pi x_i)\right) + 20 + e$	30/50/100	[-32, 32]	0
$f_{11}(x) = \frac{1}{4000} \sum_{i=1}^n x_i^2 - \prod_{i=1}^n \cos\left(\frac{x_i}{\sqrt{i}}\right) + 1$	30/50/100	[-600, 600]	0
$f_{12}(x) = \frac{\pi}{n} \left\{ 10 \sin^2(\pi y_1) + \sum_{i=1}^{n-1} (y_i - 1)^2 [1 + 10 \sin^2(\pi y_{i+1})] + (y_n - 1)^2 \right\}$ $+ \sum_{i=1}^n u(x_i, 10, 100, 4)$	30/50/100	[-50, 50]	0
$y_i = 1 + \frac{x_i+1}{4}; u(x_i, a, k, m) = \begin{cases} k(x_i - a)^m, & x_i > a \\ 0, & -a \leq x_i \leq a \\ k(-x_i - a)^m, & x_i < -a \end{cases}$			
$f_{13}(x) = 0.1 \left\{ \sin^2(3\pi x_1) + \sum_{i=1}^{n-1} (x_i - 1)^2 [1 + \sin^2(3\pi x_{i+1})] + (x_n - 1)^2 [1 + \sin^2(2\pi x_n)] \right\}$ $+ \sum_{i=1}^n u(x_i, 5, 100, 4)$	30/50/100	[-50, 50]	0

**Table S3.** Summary of IEEE CEC'15 functions.

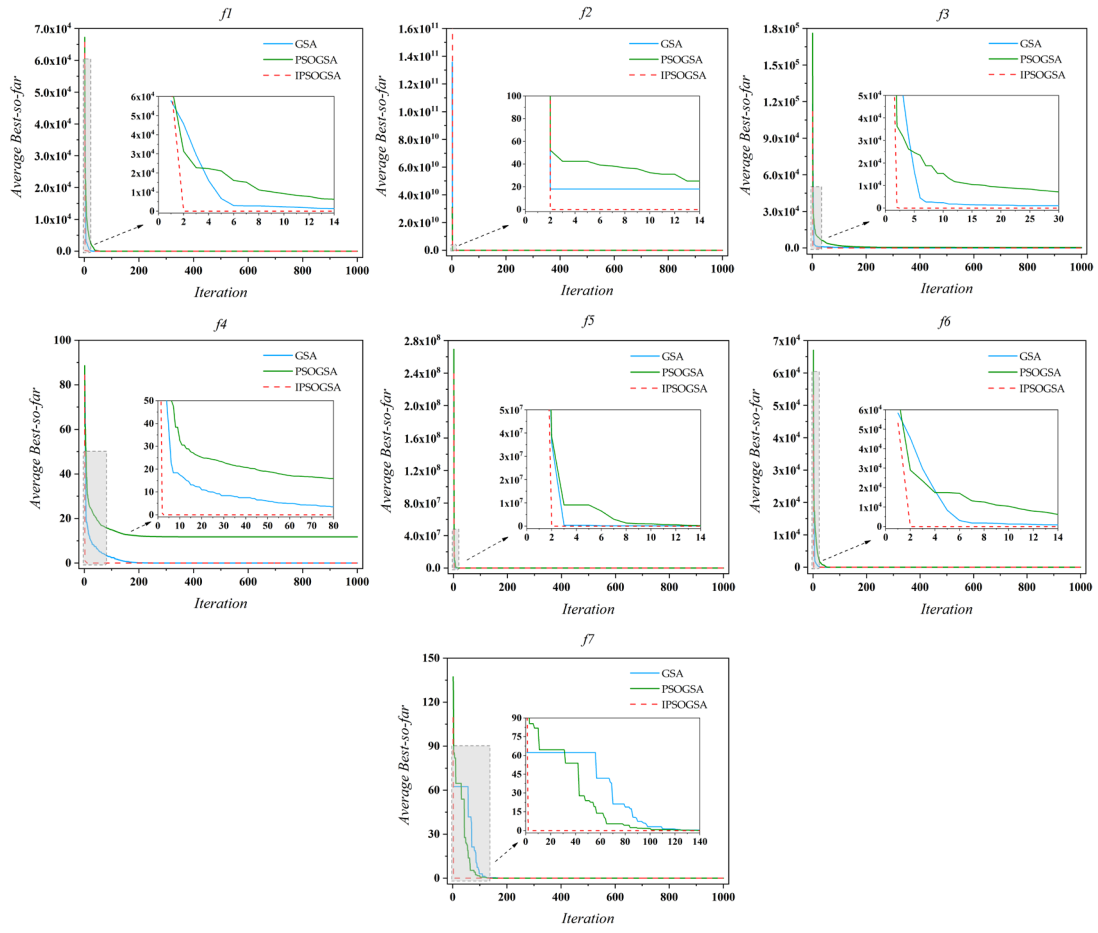
	No.	Functions	$F_i^*=F_i(x^*)$
Unimodal Functions	1	Rotated High Conditioned Elliptic Function	100
	2	Rotated Cigar Function	200
Simple	3	Shifted and Rotated Ackley's Function	300
Multimodal Functions	4	Shifted and Rotated Rastrigin's Function	400
	5	Shifted and Rotated Schwefel's Function	500
Hybrid Functions	6	Hybrid Function 1 (N=3)	600
	7	Hybrid Function 2 (N=4)	700
	8	Hybrid Function 3(N=5)	800
Composition Functions	9	Composition Function 1 (N=3)	900
	10	Composition Function 2 (N=3)	1000
	11	Composition Function 3 (N=5)	1100
	12	Composition Function 4 (N=5)	1200
	13	Composition Function 5 (N=5)	1300
	14	Composition Function 6 (N=7)	1400
	15	Composition Function 7 (N=10)	1500
Search Range: [-100,100] <sup>p</sup>			

**Table S4.** Summary of IEEE CEC'17 functions.

	No.	Functions	$F_i^*=F_i(x^*)$
Unimodal Functions	1	Shifted and Rotated Bent Cigar Function	100
	2	Shifted and Rotated Sum of Different Power Function*	200
	3	Shifted and Rotated Zakharov Function	300
Simple Multimodal Functions	4	Shifted and Rotated Rosenbrock's Function	400
	5	Shifted and Rotated Rastrigin's Function	500
	6	Shifted and Rotated Expanded Scaffer's F6 Function	600
	7	Shifted and Rotated Lunacek Bi_Rastrigin Function	700
	8	Shifted and Rotated Non-Continuous Rastrigin's Function	800
	9	Shifted and Rotated Levy Function	900
	10	Shifted and Rotated Schwefel's Function	1000
Hybrid Functions	11	Hybrid Function 1 (N=3)	1100
	12	Hybrid Function 2 (N=3)	1200
	13	Hybrid Function 2 (N=3)	1300
	14	Hybrid Function 4 (N=4)	1400
	15	Hybrid Function 5 (N=4)	1500
	16	Hybrid Function 6 (N=4)	1600
	17	Hybrid Function 7 (N=5)	1700
	18	Hybrid Function 8 (N=5)	1800
	19	Hybrid Function 9 (N=5)	1900
	20	Hybrid Function 10 (N=6)	2000
Composition Functions	21	Composition Function 1 (N=3)	2100
	22	Composition Function 2 (N=3)	2200
	23	Composition Function 3 (N=4)	2300
	24	Composition Function 4 (N=4)	2400
	25	Composition Function 5 (N=5)	2500
	26	Composition Function 6 (N=5)	2600
	27	Composition Function 7 (N=6)	2700
	28	Composition Function 8 (N=6)	2800
	29	Composition Function 9 (N=3)	2900
	30	Composition Function 10 (N=3)	3000
Search Range: [-100,100] <sup>p</sup>			

**Table S5.** Results of three algorithms for unimodal benchmark functions (Dim=30/50/100).

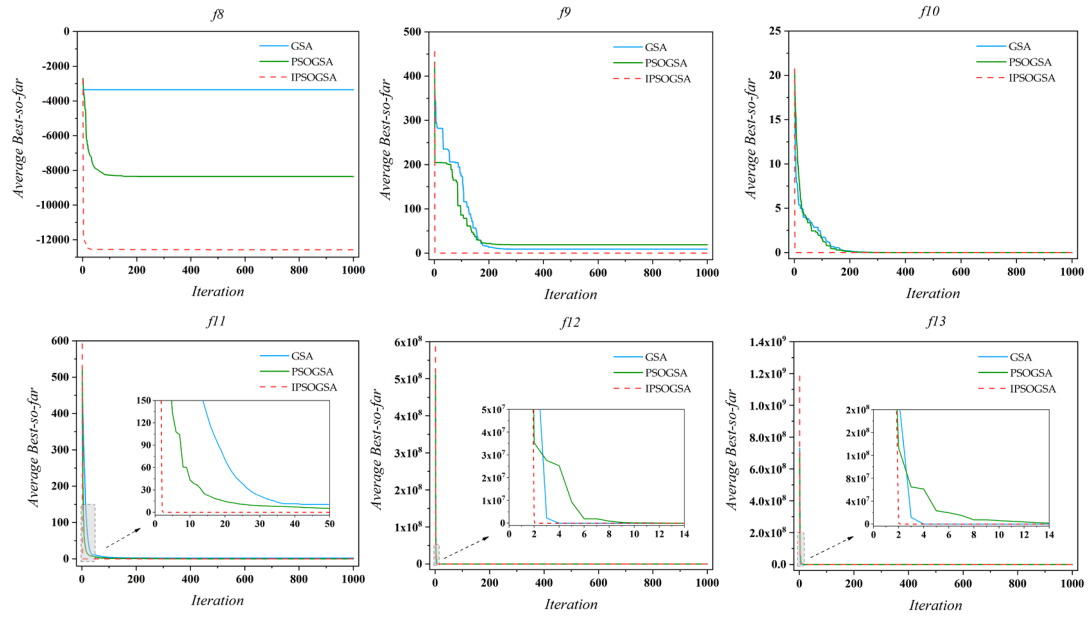
Func		Dim=30			Dim=50			Dim=100		
		GSA	PSOGS	IPSOGSA	GSA	PSOGS	IPSOGSA	GSA	PSOGS	IPSOGSA
$f1$	Mea	2.05E-17	9.22E-18	0.00E+00	7.32E-17	2.81E-17	0.00E+00	7.42E+01	1.14E+03	0.00E+00
	Std	5.34E-18	2.02E-18	0.00E+00	2.37E-17	1.05E-17	0.00E+00	5.44E+01	6.30E+02	0.00E+00
	Ran	3	2	<b>1</b>	3	2	<b>1</b>	2	3	<b>1</b>
$f2$	Mea	2.32E-08	1.47E-08	0.00E+00	5.43E-08	3.12E-08	0.00E+00	1.10E+00	2.04E-03	0.00E+00
	Std	4.30E-09	1.66E-09	0.00E+00	7.24E-09	3.50E-09	0.00E+00	8.67E-01	5.49E-03	0.00E+00
	Ran	3	2	<b>1</b>	3	2	<b>1</b>	3	2	<b>1</b>
$f3$	Mea	2.51E+02	6.21E+02	0.00E+00	1.03E+03	6.17E+03	0.00E+00	5.03E+03	3.98E+04	0.00E+00
	Std	1.04E+02	3.63E+02	0.00E+00	2.36E+02	1.60E+03	0.00E+00	1.02E+03	8.46E+03	0.00E+00
	Ran	2	3	<b>1</b>	2	3	<b>1</b>	2	3	<b>1</b>
$f4$	Mea	3.44E-09	1.09E+00	0.00E+00	4.14E+00	1.52E+01	0.00E+00	1.08E+01	3.11E+01	0.00E+00
	Std	6.97E-10	1.39E+00	0.00E+00	1.19E+00	3.01E+00	0.00E+00	1.06E+00	2.34E+00	0.00E+00
	Ran	2	3	<b>1</b>	2	3	<b>1</b>	2	3	<b>1</b>
$f5$	Mea	3.36E+01	3.93E+01	1.30E+01	6.17E+01	5.02E+01	3.83E+01	1.83E+03	2.11E+02	9.19E+01
	Std	2.30E+01	2.98E+01	1.91E+00	3.40E+01	2.01E+01	1.58E+00	1.20E+03	6.49E+01	1.43E+00
	Ran	2	3	<b>1</b>	3	2	<b>1</b>	3	2	<b>1</b>
$f6$	Mea	2.26E-17	9.01E-18	9.07E-18	7.08E-17	2.67E-17	1.04E-16	6.86E+01	1.34E+03	2.39E-03
	Std	5.94E-18	2.64E-18	2.35E-18	2.10E-17	7.69E-18	6.72E-17	4.98E+01	6.44E+02	2.19E-03
	Ran	3	<b>1</b>	2	2	<b>1</b>	3	2	3	<b>1</b>
$f7$	Mea	1.93E-02	6.42E-03	1.16E-04	6.33E-02	2.20E-02	8.25E-05	6.10E-01	1.85E-01	1.10E-04
	Std	7.78E-03	3.17E-03	9.94E-05	2.37E-02	7.69E-03	1.11E-04	2.69E-01	4.57E-02	9.90E-05
	Ran	3	2	<b>1</b>	3	2	<b>1</b>	3	2	<b>1</b>
Avg.Rank		2.57	2.29	1.14	2.57	2.14	1.29	2.43	2.57	1.00
Fin.Rank		3	2	<b>1</b>	3	2	<b>1</b>	2	3	<b>1</b>



**Figure S1.** Convergence curve for unimodal benchmark functions (Dim=30).

**Table S6.** Results of three algorithms for multimodal benchmark functions  
(Dim=30/50/100).

Func		Dim=30			Dim=50			Dim=100		
		GSA	PSOGS	IPSOGSA	GSA	PSOGS	IPSOGSA	GSA	PSOGS	IPSOGSA
$f_8$	Mean	9.88E+03	6.16E+03	1.84E+00	8.99E+03	2.88E+03	2.10E+00	7.44E+03	5.58E+01	2.00E+00
	Std	3.70E+02	9.48E+02	1.23E+00	5.51E+02	1.20E+03	2.10E+00	6.62E+02	2.59E+02	1.78E+00
	Rank	3	2	1	3	2	1	3	2	1
$f_9$	Mean	1.61E+01	2.09E+01	0.00E+00	3.16E+01	3.92E+01	0.00E+00	7.48E+01	8.59E+01	0.00E+00
	Std	3.62E+00	5.88E+00	0.00E+00	6.48E+00	8.66E+00	0.00E+00	7.87E+00	9.26E+00	0.00E+00
	Rank	2	3	1	2	3	1	2	3	1
$f_{10}$	Mean	3.47E-09	2.25E-09	8.88E-16	4.80E-09	3.21E-09	8.88E-16	1.21E+00	9.83E-01	8.88E-16
	Std	5.29E-10	2.69E-10	0.00E+00	5.81E-10	3.20E-10	0.00E+00	5.70E-01	6.62E-01	0.00E+00
	Rank	3	2	1	3	2	1	3	2	1
$f_{11}$	Mean	4.05E+00	1.89E+00	0.00E+00	1.85E+01	4.55E+01	0.00E+00	5.56E+01	3.28E+02	0.00E+00
	Std	1.36E+00	1.29E+00	0.00E+00	4.21E+00	1.14E+01	0.00E+00	7.15E+00	3.93E+01	0.00E+00
	Rank	3	2	1	2	3	1	2	3	1
$f_{12}$	Mean	3.12E-02	1.73E-02	5.49E-20	3.93E-01	1.88E+00	3.39E-19	1.88E+00	8.99E+00	5.58E-05
	Std	8.14E-02	3.86E-02	2.59E-20	3.23E-01	1.08E+00	1.33E-19	3.66E-01	1.74E+00	1.92E-04
	Rank	3	2	1	2	3	1	2	3	1
$f_{13}$	Mean	7.32E-04	8.89E-19	2.39E-01	3.88E+00	1.80E-03	5.82E-01	6.48E+01	1.39E+02	6.68E+00
	Std	2.74E-03	1.93E-19	5.15E-01	4.59E+00	4.85E-03	1.05E+00	1.15E+01	1.87E+01	3.90E+00
	Rank	2	1	3	3	1	2	2	3	1
Avg.Rank		2.67	2.00	1.33	2.50	2.33	1.17	2.33	2.67	1.00
Fin.Rank		3	2	1	3	2	1	2	3	1



**Figure S2.** Convergence curve for multimodal benchmark functions (Dim=30).



**Table S7.** Comparison on classical benchmark functions.

Function	Dim=30			Dim=50		Dim=100		
	IPSOGSA	HGSA	COGSA	IPSOGSA	HGSA	IPSOGSA	HGSA	ChOA
F1	0.00E+00	0.00E+00	5.19E-30	0.00E+00	2.28E-295	0.00E+00	3.85E-292	2.80E-09
F2	0.00E+00	1.32E-202	1.06E-14	0.00E+00	5.00E-192	0.00E+00	2.65E-186	4.42E+01
F3	0.00E+00	0.00E+00	6.59E-29	0.00E+00	3.68E-282	0.00E+00	4.98E-291	1.94E+02
F4	0.00E+00	2.94E-200	1.16E-15	0.00E+00	9.66E-184	0.00E+00	2.34E-184	2.18E+00
F5	1.30E+01	2.81E+01	2.71E+01	3.83E+01	4.82E+01	9.19E+01	9.82E+01	1.39E+01
F6	9.07E-18	7.18E-13	0.00E+00	1.04E-16	1.71E-01	2.39E-03	5.21E+00	1.60E-07
F7	1.16E-04	5.39E-05	4.94E-05	8.25E-05	4.68E-01	1.10E-04	5.64E-01	5.46E-04
F8	1.84E+00	3.67E+02	9.85E+03	2.10E+00	5.13E+03	2.00E+00	1.23E+04	3.19E+04
F9	0.00E+00	0.00E+00	7.58E-15	0.00E+00	4.41E-10	0.00E+00	9.60E-13	1.19E+01
F10	8.88E-16	4.44E-16	4.44E-15	8.88E-16	1.30E-11	8.88E-16	3.39E-13	3.06E-01
F11	0.00E+00	0.00E+00	7.40E-18	0.00E+00	9.30E-13	0.00E+00	5.25E-13	1.40E-03
F12	5.49E-20	3.75E-15	1.38E-02	3.39E-19	9.21E-04	5.58E-05	3.93E-02	3.98E-01
F13	2.39E-01	2.72E+00	1.06E-22	5.82E-01	4.91E+00	6.68E+00	9.92E+00	1.39E-01

Green color indicates that the two algorithms perform equally well; Orange color represents that the algorithm outperforms IPSOGSA algorithm.

**Table S8.** Results of three algorithms on CEC 2015 (D=30).

Function	GSA			PSOGSA			IPSOGSA	
	Mean	Std	p-value	Mean	Std	p-value	Mean	Std
F1	6.86E+05	1.29E+05	5.15E-10(+)	9.76E+05	1.04E+06	5.15E-10(+)	<b>1.38E+02</b>	<b>9.77E+01</b>
F2	<b>5.67E+02</b>	<b>3.59E+02</b>	1.04E-04(-)	2.15E+03	2.38E+03	1.57E-01(=)	1.33E+03	1.30E+03
F3	<b>3.20E+02</b>	<b>5.71E-05</b>	5.15E-10(-)	3.20E+02	1.74E-01	7.35E-10(-)	3.21E+02	4.84E-02
F4	6.27E+02	1.43E+01	5.15E-10(+)	5.28E+02	2.33E+01	5.15E-10(+)	<b>4.14E+02</b>	<b>4.42E+00</b>
F5	4.49E+03	<b>3.85E+02</b>	5.15E-10(+)	3.85E+03	5.78E+02	5.15E-10(+)	<b>2.28E+03</b>	4.28E+02
F6	1.32E+05	4.04E+04	5.15E-10(+)	5.29E+04	5.73E+04	5.15E-10(+)	<b>1.97E+03</b>	<b>3.20E+02</b>
F7	7.16E+02	3.73E+00	5.15E-10(+)	7.15E+02	9.90E+00	5.15E-10(+)	<b>7.05E+02</b>	<b>1.01E+00</b>
F8	2.01E+04	4.05E+03	5.15E-10(+)	3.34E+04	1.87E+04	5.15E-10(+)	<b>1.41E+03</b>	<b>3.21E+02</b>
F9	1.00E+03	2.19E-01	5.15E-10(+)	1.01E+03	4.66E+01	1.11E-09(+)	<b>1.00E+03</b>	<b>1.36E-01</b>
F10	5.34E+05	1.22E+05	5.15E-10(+)	2.12E+05	5.42E+05	5.15E-10(+)	<b>4.77E+03</b>	<b>3.51E+03</b>
F11	<b>1.41E+03</b>	<b>1.25E+00</b>	6.15E-10(-)	1.82E+03	3.60E+02	1.21E-04(+)	1.62E+03	8.37E+01
F12	1.30E+03	<b>4.79E-01</b>	9.37E-04(+)	1.31E+03	1.54E+00	5.15E-10(+)	<b>1.30E+03</b>	5.66E-01
F13	2.20E+03	4.84E+02	5.15E-10(+)	1.45E+03	1.67E+01	5.15E-10(+)	<b>1.42E+03</b>	<b>7.50E+00</b>
F14	<b>1.50E+03</b>	<b>2.54E-08</b>	5.15E-10(-)	4.35E+04	8.08E+03	9.66E-09(+)	3.27E+04	1.80E+03
F15	1.60E+03	4.91E-11	1.00E+00(=)	<b>1.60E+03</b>	<b>3.34E-11</b>	1.00E+00(=)	1.60E+03	8.60E-11
<i>w/t/l</i>		10/1/4			12/2/1			

**Table S9.** Results of three algorithms on CEC 2017 (D=30).

Function	GSA			PSOGSA			IPSOGSA	
	Mean	Std	p-value	Mean	Std	p-value	Mean	Std
F1	1.99E+03	8.84E+02	5.15E-10(+)	2.89E+03	2.83E+03	1.12E-07(+)	<b>3.95E+02</b>	<b>2.33E+02</b>
F2	2.60E+10	4.49E+10	5.15E-10(+)	1.61E+08	1.10E+09	1.74E-02(+)	<b>2.00E+02</b>	<b>4.96E-06</b>
F3	7.49E+04	4.97E+03	5.15E-10(+)	9.19E+03	6.12E+03	5.15E-10(+)	<b>3.00E+02</b>	<b>0.00E+00</b>
F4	5.33E+02	<b>1.31E+01</b>	5.15E-10(+)	5.27E+02	4.48E+01	2.42E-06(+)	<b>4.81E+02</b>	3.38E+01
F5	7.15E+02	1.68E+01	5.15E-10(+)	6.28E+02	2.22E+01	5.15E-10(+)	<b>5.14E+02</b>	<b>4.98E+00</b>
F6	6.46E+02	3.96E+00	5.15E-10(+)	6.22E+02	9.18E+00	5.15E-10(+)	<b>6.00E+02</b>	<b>1.34E-02</b>
F7	7.51E+02	<b>4.56E+00</b>	2.31E-06(+)	8.11E+02	1.91E+01	5.15E-10(+)	<b>7.44E+02</b>	6.12E+00
F8	9.48E+02	1.02E+01	5.15E-10(+)	9.07E+02	2.14E+01	5.15E-10(+)	<b>8.14E+02</b>	<b>3.48E+00</b>
F9	1.78E+03	2.80E+02	5.15E-10(+)	3.25E+03	1.02E+03	5.15E-10(+)	<b>9.00E+02</b>	<b>1.07E-01</b>
F10	4.73E+03	<b>3.15E+02</b>	5.15E-10(+)	4.83E+03	6.29E+02	7.80E-10(+)	<b>3.26E+03</b>	4.67E+02
F11	<b>1.19E+03</b>	<b>2.27E+01</b>	2.45E-02(-)	1.24E+03	4.45E+01	3.89E-03(+)	1.21E+03	3.47E+01
F12	5.08E+05	1.65E+05	5.15E-10(+)	6.91E+05	3.02E+06	5.15E-10(+)	<b>9.16E+03</b>	<b>4.63E+03</b>
F13	2.83E+04	<b>4.92E+03</b>	5.15E-10(+)	1.76E+04	1.20E+04	1.10E-05(+)	<b>7.80E+03</b>	5.09E+03
F14	9.05E+04	2.75E+04	5.15E-10(+)	1.51E+04	3.69E+04	5.15E-10(+)	<b>1.51E+03</b>	<b>2.43E+01</b>
F15	9.25E+03	1.36E+03	5.15E-10(+)	5.29E+03	3.76E+03	7.32E-09(+)	<b>1.95E+03</b>	<b>4.17E+02</b>
F16	3.05E+03	2.60E+02	5.15E-10(+)	2.77E+03	2.83E+02	5.46E-10(+)	<b>2.16E+03</b>	<b>1.48E+02</b>
F17	2.86E+03	1.70E+02	5.15E-10(+)	2.25E+03	2.64E+02	1.25E-09(+)	<b>1.86E+03</b>	<b>6.75E+01</b>
F18	1.67E+05	4.83E+04	5.15E-10(+)	1.17E+05	7.03E+04	5.15E-10(+)	<b>2.19E+03</b>	<b>5.22E+02</b>
F19	6.20E+03	1.02E+03	1.05E-09(+)	9.52E+03	7.63E+03	8.13E-06(+)	<b>3.73E+03</b>	<b>1.00E+03</b>
F20	3.01E+03	1.83E+02	5.15E-10(+)	2.67E+03	1.92E+02	5.80E-10(+)	<b>2.22E+03</b>	<b>1.08E+02</b>
F21	2.52E+03	1.84E+01	5.15E-10(+)	2.42E+03	2.97E+01	5.15E-10(+)	<b>2.32E+03</b>	<b>6.18E+00</b>
F22	4.30E+03	2.32E+03	4.01E-05(+)	3.63E+03	2.10E+03	6.55E-04(+)	<b>2.30E+03</b>	<b>5.24E-10</b>
F23	3.45E+03	1.05E+02	5.15E-10(+)	3.03E+03	8.65E+01	5.15E-10(+)	<b>2.67E+03</b>	<b>1.12E+01</b>
F24	3.17E+03	4.47E+01	5.15E-10(+)	3.20E+03	9.20E+01	5.15E-10(+)	<b>2.84E+03</b>	<b>1.02E+01</b>
F25	2.93E+03	9.00E+00	5.15E-10(+)	2.91E+03	2.08E+01	1.40E-09(+)	<b>2.88E+03</b>	<b>4.80E+00</b>
F26	4.46E+03	1.80E+03	6.25E-04(+)	5.70E+03	1.56E+03	1.25E-08(+)	<b>3.24E+03</b>	<b>5.01E+02</b>
F27	4.05E+03	2.50E+02	5.15E-10(+)	3.50E+03	9.96E+01	5.15E-10(+)	<b>3.20E+03</b>	<b>4.72E-05</b>
F28	3.22E+03	2.68E+01	5.46E-10(-)	<b>3.14E+03</b>	5.85E+01	5.14E-10(-)	3.30E+03	<b>9.88E-03</b>
F29	4.51E+03	1.96E+02	5.15E-10(+)	4.08E+03	2.07E+02	5.15E-10(+)	<b>3.47E+03</b>	<b>1.23E+02</b>
F30	4.58E+04	5.24E+03	5.15E-10(+)	2.53E+04	1.03E+04	5.15E-10(+)	<b>7.92E+03</b>	<b>2.14E+03</b>
w/t/l		28/0/2			29/0/1			

**Table S10.** Comparison on CEC 2017 (D=30)

Function	IPSOGSA	GPSG (2022)	SSC (2021)	ESA (2021)	HFPSO (2018)
F1	3.95E+02	5.36E+02	6.09E+03	1.61E+04	1.49E+09
F2	2.00E+02		8.53E+03	6.80E+05	4.29E+30
F3	3.00E+02	2.20E+04	9.13E+03	6.30E+02	1.32E+05
F4	4.81E+02	4.02E+02	8.43E+03	4.35E+02	6.81E+02
F5	5.14E+02	5.55E+02	1.65E+04	5.14E+02	7.44E+02
F6	6.00E+02	6.03E+02	8.73E+03	2.75E+03	6.55E+02
F7	7.44E+02	7.41E+02	8.78E+04	1.41E+03	1.06E+03
F8	8.14E+02	8.46E+02	1.88E+05	8.16E+02	1.02E+03
F9	9.00E+02	9.00E+02	1.41E+05	2.00E+03	9.04E+03
F10	3.26E+03	3.19E+03	2.18E+05	2.33E+03	7.50E+03
F11	1.21E+03	1.16E+03	1.84E+05	1.11E+03	2.29E+03
F12	9.16E+03	1.13E+05	1.18E+06	2.60E+03	5.95E+07
F13	7.80E+03	2.01E+04	1.42E+06	1.31E+03	5.07E+06
F14	1.51E+03	2.07E+03	1.32E+06	4.72E+03	6.63E+05
F15	1.95E+03	1.03E+04	1.03E+04	3.20E+03	7.35E+04
F16	2.16E+03	2.06E+03	2.20E+03	2.52E+05	3.20E+03
F17	1.86E+03	1.76E+03	2.53E+03	7.70E+06	2.30E+03
F18	2.19E+03	4.39E+04	2.68E+03	2.22E+03	2.60E+06
F19	3.73E+03	1.90E+04	2.70E+03	2.41E+03	5.95E+05
F20	2.22E+03	2.21E+03	7.11E+03	2.12E+03	2.77E+03
F21	2.32E+03	2.34E+03	2.61E+03	5.15E+03	2.51E+03
F22	2.30E+03	2.30E+03	1.56E+04	3.00E+03	5.80E+03
F23	2.67E+03	2.72E+03	1.69E+04	4.77E+03	2.96E+03
F24	2.84E+03	2.86E+03	2.12E+05	2.24E+04	3.17E+03
F25	2.88E+03	2.89E+03	1.37E+04	2.72E+03	3.06E+03
F26	3.24E+03	2.80E+03	1.39E+04	3.65E+03	5.66E+03
F27	3.20E+03	3.22E+03	1.05E+05	2.57E+04	3.32E+03
F28	3.30E+03	3.10E+03	1.55E+05	5.58E+04	3.39E+03
F29	3.47E+03	3.60E+03	1.14E+05	3.22E+03	4.42E+03
F30	7.92E+03	3.71E+04	1.03E+04	2.90E+04	4.61E+06

Green color indicates that the two algorithms perform equally well; Orange color represents that the algorithm outperforms IPSOGSA algorithm.

**Table S11.** Environmental quality standards for surface water of China

Standard value	class	I	II	III	IV	V
		Indicators				
COD <sub>Mn</sub>		2	4	6	10	15
≤						
NH <sub>3</sub> -N		0.15	0.5	1.0	1.5	2.0
≤						
TP	≤	0.02	0.1	0.2	0.3	0.4