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Supplementary materials for

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Table S1 Description of the CEC2014 test functions

		Functions	f_{min}
Unimodal Functions	F1	Rotated High Conditioned Elliptic Function	100
	F2	Rotated Bent Cigar Function	200
	F3	Rotated Discus Function	300
Simple Multimodal Functions	F4	Shifted and Rotated Rosenbrock's Function	400
	F5	Shifted and Rotated Ackley's Function	500
	F6	Shifted and Rotated Weierstrass Function	600
	F7	Shifted and Rotated Griewank's Function	700
	F8	Shifted Rastrigin's Function	800
	F9	Shifted and Rotated Rastrigin's Function	900
	F10	Shifted Schwefel's Function	1000
	F11	Shifted and Rotated Schwefel's Function	1100
	F12	Shifted and Rotated Katsuura Function	1200
	F13	Shifted and Rotated HappyCat Function	1300
	F14	Shifted and Rotated HGBat Function	1400
	F15	Shifted and Rotated Expanded Griewank's plus Rosenbrock's Function	1500
	F16	Shifted and Rotated Expanded Scaffer's F6 Function	1600
Hybrid Functions	F17	Hybrid Function 1 (N=3)	1700
	F18	Hybrid Function 1 (N=3)	1800
	F19	Hybrid Function 3 (N=4)	1900
	F20	Hybrid Function 4 (N=4)	2000
	F21	Hybrid Function 5 (N=5)	2100
	F22	Hybrid Function 6 (N=5)	2200
Composition Functions	F23	Composition Function 1 (N=5)	2300
	F24	Composition Function 2 (N=3)	2400
	F25	Composition Function 3 (N=3)	2500
	F26	Composition Function 4 (N=5)	2600
	F27	Composition Function 5 (N=5)	2700
	F28	Composition Function 6 (N=5)	2800
	F29	Composition Function 7 (N=3)	2900
	F30	Composition Function 8 (N=3)	3000

Table S2 Description of the CEC2019 test functions

	Function	f_{min}	Dim	Search range
F31	Storn's Chebyshev Polynomial Fitting Problem	1	9	[-8192, 8192]
F32	Inverse Hilbert Matrix Problem	1	16	$[-16384, 16384]$
F33	Lennard-Jones Minimum Energy Cluster	1	18	$[-4, 4]$
F34	Rastrigin's Function	1	10	$[-100, 100]$
F35	Griewangk's Function	1	10	$[-100, 100]$
F36	Weierstrass Function	1	10	$[-100, 100]$
F37	Modified Schwefel's Function	1	10	$[-100, 100]$
F38	Expanded Schaffer's F6 Function	1	10	$[-100, 100]$
F39	Happy Cat Function	1	10	$[-100, 100]$
F40	Ackley Function	1	10	$[-100, 100]$

Table S3 Description of the classical benchmark functions

Function	Dim	Search range	f_{min}
$F41\,(x) = \sum_{i=1}^{n} x_i^2$	30/50/100/200/500/1000	$[-100, 100]$	0
$F42\,(x) = \sum_{i=1}^{n} \left\|x_i^2\right\| + \prod_{i=1}^{n} \left\|x_i\right\|$	30/50/100/200/500/1000	$[-10, 10]$	0
$F43\,(x) = \sum_{i=1}^{n} \left(\sum_{j-1}^{i} x_j\right)$	30/50/100/200/500/1000	$[-100, 100]$	0
$F44\,(x) = max_i \left\{\left\|x_i\right\|, 1 \le i \le n\right\}$	30/50/100/200/500/1000	$[-100, 100]$	0
$F45\,(x) = \sum_{i=1}^{n-1} \left[100\left(x_{i+1} - x_i^2\right)^2 + (x_i - 1)^2\right]$	30/50/100/200/500/1000	$[-30, 30]$	0
$F46\,(x) = \sum_{i=1}^{n} \left([x_i + 0.5]\right)^2$	30/50/100/200/500/1000	$[-100, 100]$	0
$F47\,(x) = \sum_{i=1}^{n} i x_i^4 + random\,[0, 1)$	30/50/100/200/500/1000	$[-1.28, 1.28]$	0
$F48\,(x) = \sum_{i=1}^{n} -x_i \sin\left(\sqrt{\left\|x_i\right\|}\right)$	30/50/100/200/500/1000	$[-500, 500]$	$-418.9829 \times Dim$
$F49(x) = \frac{\pi}{n}\left\{10\sin(\pi y_1) + \sum_{i=1}^{n-1}(y_i - 1)^2 \left[1 + 10\sin^2(\pi y_{i+1})\right] + (y_n - 1)^2\right\} + \sum_{i=1}^{n} u(x_i, 10, 100, 4)$ $y_i = 1 + \frac{x_i + 1}{4}$ $u\left(x_i, a, k, m\right) = \begin{cases} k(x_i - a)^m & x_i > a \\ 0 & -a < x_i < a \\ k(-x_i - a)^m & x_i < -a \end{cases}$	30/50/100/200/500/1000	$[-50, 50]$	0
$F50(x) = 0.1\left\{10\sin^2(3\pi x_1) + \sum_{i=1}^{n}(x_i - 1)^2\left[1 + \sin^2\left(3\pi x_i + 1\right)\right] + (x_n - 1)^2\left[1 + \sin^2\left(2\pi x_n\right)\right]\right\} + \sum_{i=1}^{n} u(x_i, 5, 100, 4)$	30/50/100/200/500/1000	$[-50, 50]$	0

Table S4 Parameter settings

Algorithm	Year	Parameter	Value
SSA	2020	The number of producers	6
		The number of scouters	6
		Alarm value q	0.8
HFPSO	2018	Randomization parameter α	0.2
		Light absorption coefficient γ	1
		Attractiveness B_0	2
		Acceleration coefficients c_1, c_2	1.49445
		Inertia weight w_i	0.9
		Inertia weight w_f	0.5
ALCPSO	2013	Acceleration coefficients c_1, c_2	2
		Inertia weight w	0.4
		Lifespan	60
		Step T	2
CLPSO	2006	Acceleration coefficient c	1.49445
		Refreshing gap m	5
		Inertia weight w	[0.2,0.9]
SADE	2009	The median value of CR	0.5
		Learning period LP	50
RDWOA	2020	Parameter $a1$	[2,0]
		Parameter $a2$	[-2,-1]
		Constant b	1
		Variable s	0
I-GWO	2021	Vector a	$[2, 0]$
SOGWO	2020	Vector d	$[2, 0]$
AOSMA	2021	δ	0.03
CKGSA	2018	Gconstant G_0	100
		Alpha α	20
		$Final\_per$	2
MSBSO	2020	P_{global}	0.6
		P_{local}	0.8
		Scaling parameter S	0.9
		The slope of transfer function k	20

Table S5 Results generated by Wilcoxon signed ranks test on the CEC2014 test functions

	MSSSAwt	MSSSAwa	MSSSAwh	SSA
F1	+	+	+	+
F2	−	+	+	+
F3	+	+	+	+
F4	+	+	+	+
F5	=	=	+	+
F6	−	+	+	+
F7	=	=	+	+
F8	+	+	+	+
F9	−	−	+	+
F10	+	+	+	+
F11	−	+	+	+
F12	+	+	+	+
F13	=	+	+	+
F14	=	=	+	+
F15	+	+	+	+
F16	+	+	+	+
F17	−	−	+	+
F18	+	+	+	+
F19	−	−	+	+
F20	+	+	+	+
F21	−	+	+	+
F22	−	+	−	+
F23	=	=	=	=
F24	+	=	=	+
F25	=	=	=	=
F26	+	+	+	+
F27	=	=	=	=
F28	=	=	=	=
F29	=	=	=	=
F30	=	=	+	+
+/ = /−	12/10/8	17/10/3	23/6/1	25/5/0

Table S6 Statistical results of the MSSSA and other algorithms on 30 CEC2014 benchmark functions

	F1		F2		F3	
	Mean	SD	Mean	SD	Mean	SD
MSSSA	**2.0946E+05**	**1.0116E+05**	1.5368E+03	**1.2357E+03**	**3.5698E+02**	**3.0817E+01**
SSA	1.8559E+06	1.2502E+06	2.8166E+03	2.9066E+03	6.0559E+03	4.9595E+03
HFPSO	1.1588E+06	5.5363E+05	7.1586E+03	8.3623E+03	1.4851E+04	8.5657E+03
ALCPSO	5.1940E+06	6.6700E+06	5.7223E+03	8.5080E+03	4.7605E+02	8.0112E+02
CLPSO	1.0472E+08	3.5733E+07	3.5745E+07	1.4979E+07	8.1576E+03	3.1231E+03
SADE	1.8621E+06	1.4673E+06	**8.2010E+02**	1.6991E+03	6.6802E+02	6.7639E+02
RDWOA	8.4330E+06	6.7052E+06	1.6520E+07	2.2081E+07	5.7508E+03	3.7023E+03
I-GWO	7.9811E+06	4.8785E+06	1.6591E+05	9.6958E+04	1.0115E+04	2.9096E+03
SOGWO	7.7787E+07	4.3492E+07	3.8827E+09	3.5936E+09	4.3269E+04	1.2877E+04
AOSMA	1.6031E+07	1.0068E+07	2.4445E+04	2.1508E+04	1.8808E+04	1.2890E+04
CKGSA	9.3470E+07	6.7233E+07	1.6846E+08	2.5141E+08	3.9878E+04	1.1172E+04
MSBSO	7.1732E+05	3.2394E+05	8.8205E+03	9.2731E+03	3.1035E+03	2.3925E+03
	F4		F5		F6	
	Mean	SD	Mean	SD	Mean	SD
MSSSA	**4.0925E+02**	**1.0216E+01**	5.2001E+02	3.0990E-02	6.0532E+02	**1.3307E+00**
SSA	4.9124E+02	3.3926E+01	5.2011E+02	3.2180E-01	6.2704E+02	3.7183E+00
HFPSO	4.3896E+02	2.7362E+01	5.2008E+02	6.6177E-02	6.1579E+02	4.7455E+00
ALCPSO	5.2953E+02	3.1737E+01	5.2028E+02	8.7000E-02	6.1672E+02	3.7082E+00
CLPSO	6.3426E+02	2.8982E+01	5.2068E+02	4.7900E-02	6.2346E+02	1.7619E+00
SADE	4.9888E+02	3.0905E+01	5.2077E+02	5.7300E-02	6.0727E+02	3.3358E+00
RDWOA	5.4392E+02	3.8205E+01	5.2015E+02	6.6700E-01	6.2153E+02	3.7830E+00
I-GWO	5.0692E+02	3.1543E+01	5.2101E+02	6.9700E-02	**6.0416E+02**	1.4381E+00
SOGWO	7.0102E+02	9.8554E+01	5.2105E+02	5.6600E-02	6.1623E+02	3.1646E+00
AOSMA	5.3717E+02	3.7643E+01	5.2036E+02	2.1596E-01	6.2340E+02	3.1951E+00
CKGSA	1.3940E+03	5.8907E+02	**5.2000E+02**	**3.3669E-04**	6.2810E+02	2.5654E+00
MSBSO	4.3193E+02	1.5527E+01	5.2103E+02	6.1356E+02	6.0481E+02	1.7469E+00
	F7		F8		F9	
	Mean	SD	Mean	SD	Mean	SD
MSSSA	**7.0000E+02**	**1.1300E-02**	**8.0522E+02**	1.1338E+01	9.4963E+02	1.2207E+01
SSA	7.0005E+02	1.5836E-02	9.4670E+02	2.7115E+01	1.0852E+03	1.3873E+01
HFPSO	7.0001E+02	1.4553E-02	8.9127E+02	2.4257E+01	9.9298E+02	2.8167E+01
ALCPSO	7.0002E+02	7.0270E-02	8.7479E+02	2.0598E+01	9.8562E+02	1.9268E+01
CLPSO	7.0123E+02	7.1200E-02	8.1852E+02	**2.9672E+00**	1.0436E+03	1.9486E+01
SADE	7.0001E+02	1.4300E-02	8.0946E+02	5.0938E+00	1.0158E+03	1.7104E+01
RDWOA	7.0083E+02	3.1000E-01	8.4522E+02	1.4072E+01	1.0736E+03	3.0792E+01
I-GWO	7.0027E+02	7.6400E-02	8.4347E+02	1.7249E+01	9.6239E+02	3.0544E+01
SOGWO	7.2365E+02	1.6627E+01	9.0153E+02	3.4748E+01	1.0150E+03	4.2228E+01
AOSMA	7.0095E+02	1.7062E-01	9.2385E+02	2.4637E+01	1.0699E+03	2.9116E+01
CKGSA	7.0793E+02	1.0655E+01	9.2788E+02	1.6477E+01	1.0507E+03	2.5253E+01
MSBSO	7.0001E+02	1.1700E-02	8.2169E+02	5.5514E+00	**9.3636E+02**	**1.0833E+01**
	F10		F11		F12	
	Mean	SD	Mean	SD	Mean	SD
MSSSA	**1.1037E+03**	**1.2638E+02**	**3.3358E+03**	5.3105E+02	**1.2000E+03**	**1.0038E-02**

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Table S6 (continued)

SSA	4.0592E+03	5.4626E+02	5.2417E+03	6.9806E+02	1.2009E+03	6.1930E-01
HFPSO	3.3303E+03	5.4959E+02	4.2999E+03	5.7898E+02	1.2004E+03	2.8638E-01
ALCPSO	3.1601E+03	5.6567E+02	4.6898E+03	7.0415E+02	1.2008E+03	4.6480E-01
CLPSO	1.3891E+03	1.3386E+02	5.4190E+03	**3.2216E+02**	1.2010E+03	1.4200E-01
SADE	1.5853E+03	1.6040E+02	6.4945E+03	3.3832E+02	1.2015E+03	1.8940E-01
RDWOA	1.6790E+03	3.0966E+02	4.7988E+03	6.3620E+02	1.2003E+03	1.0810E-01
I-GWO	4.5964E+03	2.1994E+03	7.2622E+03	1.7502E+03	1.2028E+03	3.0051E-01
SOGWO	3.9491E+03	1.3412E+03	4.7064E+03	1.1520E+03	1.2022E+03	1.3132E+00
AOSMA	4.4751E+03	5.2602E+03	5.0226E+03	6.0605E+02	1.2006E+03	2.5996E-01
CKGSA	4.8572E+03	7.1769E+02	5.5451E+03	6.5280E+02	1.2000E+03	1.4900E-02
MSBSO	1.5333E+03	3.3189E+02	6.8884E+03	1.4096E+03	1.2028E+03	4.9932E-01
	F13		F14		F15	
	Mean	SD	Mean	SD	Mean	SD
MSSSA	**1.3003E+03**	**1.1028E-02**	1.4002E+03	4.2838E-02	1.5070E+03	**1.3832E+00**
SSA	1.3006E+03	1.3080E-01	1.4004E+03	2.1740E-01	1.5247E+03	8.0577E+00
HFPSO	1.3005E+03	1.4826E-01	1.4005E+03	4.0246E-01	1.5153E+03	5.2924E+01
ALCPSO	1.3005E+03	1.4400E-01	1.4008E+03	2.8270E-01	1.5116E+03	3.5372E+00
CLPSO	1.3004E+03	5.3500E-02	1.4003E+03	4.5900E-02	1.5273E+03	4.4011E+00
SADE	1.3004E+03	5.9700E-02	1.4003E+03	**3.9000E-02**	1.5142E+03	2.4875E+00
RDWOA	1.3005E+03	1.1340E-01	**1.4002E+03**	3.9507E-02	1.5208E+03	4.0398E+00
I-GWO	1.3003E+03	9.3100E-02	1.4003E+03	5.7100E-02	1.5135E+03	3.9155E+00
SOGWO	1.3006E+03	3.7540E-01	1.4071E+03	1.0198E+01	1.7654E+03	5.0074E+02
AOSMA	1.3006E+03	1.3495E-01	1.4005E+03	3.1380E-01	1.5342E+03	1.6296E+01
CKGSA	1.3007E+03	5.9920E-01	1.4115E+03	1.8215E+01	1.5268E+03	1.4147E+01
MSBSO	1.3004E+03	8.3700E-02	1.4004E+03	1.1389E-01	**1.5054E+03**	3.6179E+00
	F16		F17		F18	
	Mean	SD	Mean	SD	Mean	SD
MSSSA	**1.6087E+03**	**1.9285E-01**	2.1687E+04	1.3591E+04	3.3152E+03	1.3484E+03
SSA	1.6127E+03	4.7110E-01	6.7824E+05	4.5978E+05	9.4590E+03	6.8163E+03
HFPSO	1.6122E+03	6.0240E-01	2.3972E+05	1.5798E+05	1.7497E+04	1.9473E+04
ALCPSO	1.6119E+03	5.1020E-01	1.1575E+06	1.1731E+06	1.4344E+04	8.9911E+03
CLPSO	1.6120E+03	3.6060E-01	6.7431E+06	2.9285E+06	6.0736E+05	4.8470E+05
SADE	1.6122E+03	2.6230E-01	6.6540E+04	5.2197E+04	**2.6823E+03**	**1.0361E+03**
RDWOA	1.6115E+03	6.3290E-01	6.5894E+05	8.2681E+05	8.0562E+03	7.3480E+03
I-GWO	1.6117E+03	5.6500E-01	3.0817E+05	1.3938E+05	1.0905E+04	5.4028E+03
SOGWO	1.6119E+03	4.1936E-01	3.2905E+06	3.1138E+06	1.7198E+07	2.8107E+07
AOSMA	1.6120E+03	6.7544E-01	1.6360E+06	9.9233E+05	1.3391E+04	9.2750E+03
CKGSA	1.6133E+03	3.1160E-01	1.0476E+06	1.3172E+06	2.7840E+03	1.4570E+03
MSBSO	1.6126E+03	2.6942E-01	**1.0819E+04**	**9.4321E+03**	1.2542E+04	1.2283E+04
	F19		F20		F21	
	Mean	SD	Mean	SD	Mean	SD
MSSSA	**1.9013E+03**	**8.2007E-01**	**2.3205E+03**	**6.6893E+02**	**3.3152E+03**	**2.0188E+03**
SSA	1.9226E+03	2.0281E+01	1.9882E+04	1.1503E+04	2.9249E+05	2.4753E+05
HFPSO	1.9163E+03	2.8529E+01	8.6512E+03	4.7523E+03	1.4789E+04	1.0324E+04
ALCPSO	1.9143E+03	1.5136E+01	1.9720E+04	1.2999E+04	2.3338E+05	2.5884E+05
CLPSO	1.9357E+03	1.5625E+01	1.3253E+04	5.2046E+03	1.4703E+06	8.6733E+05
SADE	1.9085E+03	1.1933E+01	4.3399E+03	2.3428E+03	1.8085E+04	2.3216E+04

(continued on next page)

Table S6 (continued)

RDWOA	1.9205E+03	2.4903E+01	7.1762E+03	3.7309E+03	3.6111E+05	3.2744E+05
I-GWO	1.9074E+03	8.4720E-01	5.1063E+03	2.7570E+03	7.8531E+04	5.5312E+04
SOGWO	1.9514E+03	3.0908E+01	3.5465E+04	3.7143E+04	6.2602E+05	4.7616E+05
AOSMA	1.9208E+03	2.6142E+01	3.2180E+04	1.3857E+04	5.2869E+05	4.5776E+05
CKGSA	2.0614E+03	5.6935E+01	2.3292E+04	6.4372E+03	2.6299E+05	3.7275E+05
MSBSO	1.9101E+03	1.4646E+00	3.0956E+03	1.4578E+03	4.1283E+03	2.4395E+03
	F22		F23		F24	
	Mean	SD	Mean	SD	Mean	SD
MSSSA	**2.3048E+03**	1.1932E+02	**2.5000E+03**	**0.0000E+00**	2.6000E+03	1.8066E-06
SSA	2.9316E+03	2.1688E+02	2.5000E+03	0.0000E+00	2.6000E+03	9.6000E-03
HFPSO	2.4791E+03	1.4900E+02	2.6362E+03	3.4471E+00	2.6019E+03	1.0916E+00
ALCPSO	2.6950E+03	1.9535E+02	2.6152E+03	7.3665E+03	2.6412E+03	7.7198E+00
CLPSO	2.6622E+03	1.1939E+02	2.6213E+03	2.1479E+00	2.6358E+03	3.1224E+00
SADE	2.4632E+03	1.1571E+02	2.6152E+03	1.8125E-06	2.6290E+03	4.2311E+00
RDWOA	2.6887E+03	1.6503E+02	2.5000E+03	0.0000E+00	2.6000E+03	2.1375E-04
I-GWO	2.6959E+03	1.8527E+02	2.6153E+03	3.1200E-02	2.6000E+03	8.1000E-03
SOGWO	2.6944E+03	1.7563E+02	2.6418E+03	1.5066E+01	2.6000E+03	1.4200E-02
AOSMA	2.9200E+03	2.3494E+02	2.5000E+03	0.0000E+00	**2.6000E+03**	**0.0000E+00**
CKGSA	3.2041E+03	2.9303E+02	2.6809E+03	3.5904E+01	2.6349E+03	9.6903E+00
MSBSO	2.6902E+03	2.4104E+02	2.6356E+03	1.2800E-02	2.6012E+03	1.3049E-01
	F25		F26		F27	
	Mean	SD	Mean	SD	Mean	SD
MSSSA	**2.7000E+03**	**0.0000E+00**	**2.7002E+03**	4.9260E-01	**2.9000E+03**	**0.0000E+00**
SSA	2.7000E+03	0.0000E+00	2.7304E+03	4.6341E+01	2.9000E+03	0.0000E+00
HFPSO	2.7053E+03	1.8279E+00	2.7005E+03	1.0468E-01	3.4026E+03	8.4895E+01
ALCPSO	2.7120E+03	4.0985E+00	2.7572E+03	7.4413E+01	3.4594E+03	2.3677E+02
CLPSO	2.7176E+03	2.3566E+00	2.7012E+03	1.1117E+00	3.2308E+03	9.3229E+01
SADE	2.7107E+03	1.7832E+00	2.7336E+03	4.7787E+01	3.1671E+03	7.1839E+01
RDWOA	2.70000E+03	0.0000E+00	2.7052E+03	2.2307E+01	2.9437E+03	2.3970E+02
I-GWO	2.7051E+03	1.3787E+00	2.7070E+03	2.5284E+01	3.1299E+03	9.2673E+01
SOGWO	2.7122E+03	6.1314E+00	2.7438E+03	5.0192E+01	3.3956E+03	1.1041E+02
AOSMA	2.7000E+03	0.0000E+00	2.7080E+03	1.8136E+01	2.9000E+03	0.0000E+00
CKGSA	2.7145E+03	3.1360E+00	2.7951E+03	1.8974E+01	4.6232E+03	5.1021E+02
MSBSO	2.7041E+03	1.3496E+00	2.7004E+03	**7.1000E-02**	3.1172E+03	4.9654E+01
	F28		F29		F30	
	Mean	SD	Mean	SD	Mean	SD
MSSSA	**3.0000E+03**	**0.0000E+00**	**3.1000E+03**	**0.0000E+00**	**3.2000E+03**	**0.0000E+00**
SSA	3.0000E+03	0.0000E+00	3.1000E+03	0.0000E+00	3.2000E+03	2.4829E-11
HFPSO	3.2899E+03	3.5366E+01	2.0290E+07	3.1206E+07	4.9458E+03	7.5779E+02
ALCPSO	4.5326E+03	5.0163E+02	3.2319E+06	3.8309E+06	1.5080E+04	1.6249E+04
CLPSO	4.4001E+03	3.7178E+02	1.3881E+05	6.7807E+04	4.7743E+04	2.0075E+04
SADE	3.7192E+03	4.2719E+01	4.1771E+03	3.0898E+02	5.4430E+03	5.6543E+02
RDWOA	3.0000E+03	0.0000E+00	3.2079E+06	4.2805E+06	8.6075E+03	2.3091E+03
I-GWO	3.7350E+03	1.0717E+02	1.4641E+04	4.0862E+03	8.2708E+03	2.1668E+03
SOGWO	4.0579E+03	3.3879E+02	2.1553E+06	4.7911E+06	8.3098E+04	5.3825E+04
AOSMA	3.0000E+03	0.0000E+00	2.0058E+06	3.6911E+06	2.2499E+04	1.6071E+04
CKGSA	7.4374E+03	8.3785E+02	2.8583E+07	5.1086E+07	1.6521E+05	2.7757E+05

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Table S6 (continued)

MSBSO	3.2384E+03	8.7863E+00	5.1533E+03	1.2374E+03	3.9629E+03	2.8254E+02
	+/=/-	Mean rank	Total rank			
MSSSA	–	**1.3700**	**1**			
SSA	25/5/0	6.3000	7			
HFPSO	30/0/0	5.9700	5			
ALCPSO	30/0/0	7.0000	8			
CLPSO	30/0/0	8.1300	10			
SADE	28/0/2	5.1000	3			
RDWOA	26/4/0	5.5000	4			
I-GWO	29/0/1	6.0700	6			
SOGWO	30/0/0	9.6300	11			
AOSMA	25/4/1	7.3700	9			
CKGSA	28/0/2	10.0300	12			
MSBSO	25/1/4	4.8000	2			

The best results are in bold. MSSSA, multi-strategy enhanced sparrow search algorithm; SSA, sparrow search algorithm; SD, standard deviation.

Table S7 Statistical results of the MSSSA and other algorithms on 10 CEC2019 benchmark functions

	F31		F32		F33	
	Mean	SD	Mean	SD	Mean	SD
MSSSA	**1.0000E+00**	**0.0000E+00**	**4.2623E+00**	**1.3990E-01**	**1.4060E+00**	**2.1830E-01**
SSA	1.0000E+00	0.0000E+00	4.3310E+00	2.2770E-01	6.5160E+00	2.2109E+00
HFPSO	9.4846E+04	1.0934E+05	2.2753E+02	9.1550E+01	1.7752E+00	1.3434E+00
ALCPSO	2.2945E+07	9.5487E+07	4.2847E+02	1.5121E+02	2.4465E+00	1.9883E+00
CLPSO	1.8613E+06	1.0268E+06	2.2689E+03	5.7949E+02	5.0057E+00	1.1612E+00
SADE	1.8823E+01	5.4715E+01	1.2493E+02	6.1089E+01	2.6864E+00	7.2930E-01
RDWOA	1.0000E+00	0.0000E+00	4.5568E+00	3.0869E-01	1.4870E+00	2.2457E-01
I-GWO	2.3790E+04	4.1946E+04	3.2128E+02	9.1181E+01	2.0786E+00	1.8200E+00
SOGWO	3.7854E+03	9.4953E+03	3.3135E+02	2.4164E+02	2.4123E+00	1.4137E+00
AOSMA	1.0000E+00	0.0000E+00	4.7490E+00	3.5447E-01	3.6221E+00	1.9490E+00
CKGSA	1.4378E+09	9.0829E+08	3.2119E+04	9.0925E+03	4.3998E+00	2.3239E+00
MSBSO	1.9270E+03	5.1465E+03	2.0192E+02	6.9830E+01	1.7100E+00	1.1246E+00
	F34		F35		F36	
	Mean	SD	Mean	SD	Mean	SD
MSSSA	7.7989E+00	**1.8040E+00**	1.0377E+00	2.9500E-02	**1.0000E+00**	**0.0000E+00**
SSA	4.3204E+01	2.6804E+01	1.3613E+00	3.7160E-01	6.2074E+00	1.6806E+00
HFPSO	1.7767E+01	8.6602E+00	1.1182E+00	5.7100E-02	1.7634E+00	8.2430E-01
ALCPSO	1.0944E+01	4.2192E+00	1.1144E+00	6.8000E-02	2.5074E+00	1.3357E+00
CLPSO	9.7686E+00	1.8111E+00	1.1031E+00	3.7600E-02	1.7353E+00	2.9838E-01
SADE	**7.0860E+00**	2.7010E+00	**1.0119E+00**	1.6200E-02	1.0000E+00	0.0000E+00
RDWOA	1.4462E+01	5.0735E+00	1.2362E+00	1.1560E-01	4.5065E+00	1.5827E+00
I-GWO	9.7253E+00	5.7135E+00	1.4710E+00	1.1520E-01	1.0956E+00	1.5660E-01
SOGWO	1.6073E+01	8.0126E+00	1.6484E+00	4.8130E-01	2.5489E+00	8.9030E-01
AOSMA	2.6612E+01	9.2001E+00	1.2530E+00	1.7622E-01	4.9815E+00	1.7543E+00
CKGSA	4.1328E+01	9.4777E+00	1.0249E+00	**1.5700E-02**	4.2485E+00	1.1149E+00
MSBSO	9.1255E+00	4.2541E+00	1.0910E+00	7.5700E-02	1.0000E+00	1.4377E-06
	F37		F38		F39	

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Table S7 (continued)

	Mean	SD	Mean	SD	Mean	SD
MSSSA	4.2321E+02	1.8638E+02	3.0359E+00	**1.6070E-01**	1.0971E+00	**2.4300E-02**
SSA	9.7732E+02	2.6908E+02	4.3483E+00	3.6540E-01	1.3943E+00	1.5610E-01
HFPSO	7.2439E+02	2.7951E+02	3.8940E+00	4.4780E-01	1.1253E+00	5.3600E-02
ALCPSO	4.8113E+02	2.0729E+02	3.4521E+00	6.1010E-01	**1.0897E+00**	3.1600E-02
CLPSO	5.4749E+02	**1.5081E+02**	3.6112E+00	2.3030E-01	1.1974E+00	4.6400E-02
SADE	5.2661E+02	1.6545E+02	3.4556E+00	2.9070E-01	1.1568E+00	2.9000E-02
RDWOA	5.9570E+02	2.3186E+02	3.4382E+00	4.3720E-01	1.2117E+00	8.5600E-02
I-GWO	4.8554E+02	4.0527E+02	**2.8468E+00**	4.9150E-01	1.1357E+00	3.4700E-02
SOGWO	8.0863E+02	3.4630E+02	3.5888E+00	5.1020E-01	1.1920E+00	6.3600E-02
AOSMA	8.8792E+02	3.9312E+02	3.9817E+00	3.8973E-01	1.2870E+00	1.0126E-01
CKGSA	1.7124E+03	3.3851E+02	5.2336E+00	1.6510E-01	1.1241E+00	5.3700E-02
MSBSO	**4.0755E+02**	2.6756E+02	2.8612E+00	6.3280E-01	1.1248E+00	4.7100E-02
	F40					
	Mean	SD	+/ = /−	Mean rankd	Total rank	
MSSSA	**1.8023E+01**	5.7388E-01		**1.7000**	**1**	
SSA	2.1039E+01	1.3090E-01	9/1/0	9.5000	12	
HFPSO	2.0997E+01	**9.0000E-03**	10/0/0	7.3000	7	
ALCPSO	1.9769E+01	5.1023E+00	9/0/1	6.1000	5	
CLPSO	2.1019E+01	9.3750E-01	10/0/0	8.1000	9	
SADE	1.9136E+01	5.4755E+00	7/1/2	4.2000	3	
RDWOA	2.1001E+01	1.3400E-02	9/0/1	6.2000	6	
I-GWO	1.9341E+01	6.2183E+00	9/0/1	5.5000	4	
SOGWO	2.0941E+01	3.1872E+00	10/0/0	8.1000	10	
AOSMA	1.9188E+01	5.6776E+00	9/1/0	7.8000	8	
CKGSA	2.0976E+01	4.6800E-02	9/0/1	9.1000	11	
MSBSO	2.0035E+01	5.0214E+00	7/1/2	3.8000	2	

The best results are in bold. MSSSA, multi-strategy enhanced sparrow search algorithm; SSA, sparrow search algorithm; SD, standard deviation.

Table S8 Scalability results for the MSSSA and SSA in 10 classical functions

	Dim	MSSSA		SSA	
		Mean	SD	Mean	SD
F41	30	**0.0000E+00**	0.0000E+00	1.4468E-77	7.9243E-77
	50	**0.0000E+00**	0.0000E+00	2.7386E-71	1.4999E-70
	100	**0.0000E+00**	0.0000E+00	4.2353E-63	2.3198E-62
	200	**0.0000E+00**	0.0000E+00	7.6476E-78	4.1489E-77
	500	**0.0000E+00**	0.0000E+00	8.1425E-71	3.1048E-70
	1000	**0.0000E+00**	0.0000E+00	7.0920E-66	3.8845E-65
F42	30	**0.0000E+00**	0.0000E+00	7.2639E-43	3.7665E-42
	50	**0.0000E+00**	0.0000E+00	1.1089E-38	5.9320E-38
	100	**0.0000E+00**	0.0000E+00	1.1564E-39	6.3236E-39
	200	**0.0000E+00**	0.0000E+00	1.9849E-37	1.0762E-36
	500	**0.0000E+00**	0.0000E+00	2.3071E-36	1.2636E-35
	1000	**0.0000E+00**	0.0000E+00	2.2721E-34	8.7184E-34
F43	30	**0.0000E+00**	0.0000E+00	4.5796E-66	2.5083E-65
	50	**0.0000E+00**	0.0000E+00	1.1327E-63	6.2039E-63
	100	**0.0000E+00**	0.0000E+00	2.8279E-52	1.5489E-51

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Table S8 (continued)

	200	**0.0000E+00**	0.0000E+00	2.1078E-60	1.0128E-59
	500	**0.0000E+00**	0.0000E+00	6.7473E-57	3.6957E-56
	1000	**0.0000E+00**	0.0000E+00	3.3291E-51	1.8234E-50
F44	30	**1.7444E-306**	0.0000E+00	9.7424E-39	4.0881E-38
	50	**3.2479E-319**	0.0000E+00	3.6809E-49	1.8942E-48
	100	**2.0487E-307**	0.0000E+00	1.0373E-39	5.6815E-39
	200	**4.1958E-302**	0.0000E+00	3.8309E-38	2.0684E-37
	500	**1.7014E-297**	0.0000E+00	7.0110E-37	3.8401E-36
	1000	**4.9668E-295**	0.0000E+00	6.1373E-37	3.3615E-36
F45	30	**2.5023E-09**	4.3167E-09	1.4489E-05	5.4870E-05
	50	**5.4782E-09**	1.1981E-08	7.5757E-05	.6448E-04
	100	**2.1179E-09**	4.1046E-09	7.7152E-05	1.5428E-04
	200	**2.2235E-09**	5.5230E-09	1.3670E-04	1.6826E-04
	500	**1.8349E-09**	2.9093E-09	3.6376E-04	7.1113E-04
	1000	**1.5639E-09**	4.6878E-09	4.8828E-04	1.1000E-03
F46	30	**2.0207E-15**	1.0976E-14	1.4708E-11	3.3448E-11
	50	**3.7370E-15**	2.0415E-14	9.9393E-09	2.1974E-08
	100	**6.2602E-14**	2.2803E-13	1.5756E-07	2.7624E-07
	200	**1.0271E-13**	2.0998E-13	5.8188E-07	1.1624E-06
	500	**7.7835E-13**	5.9805E-13	2.0716E-06	3.3165E-06
	1000	**1.0694E-11**	3.0837E-11	4.8976E-06	9.7877E-06
F47	30	**9.0303E-05**	1.0609E-04	2.1931E-04	1.8872E-04
	50	**8.4654E-05**	7.6827E-05	2.3385E-04	2.2365E-04
	100	**1.2687E-04**	1.9328E-04	3.4690E-04	2.6348E-04
	200	**1.2392E-04**	9.5156E-05	3.5383E-04	4.1157E-04
	500	**1.5671E-04**	1.7353E-04	5.6108E-04	5.3335E-04
	1000	**1.6448E-04**	2.1385E-04	7.4463E-04	9.9385E-04
F48	30	**-1.2542E+04**	5.9694E+01	-8.0457E+03	6.8846E+02
	50	**-2.0935E+04**	6.0732E+01	-1.2538E+04	9.0809E+02
	100	**-4.1860E+04**	6.5708E+01	-2.4496E+04	1.0675E+03
	200	**-8.1905E+04**	4.3305E+03	-4.5565E+04	1.8759E+03
	500	**-2.0832E+05**	4.9307E+03	-9.0804E+04	3.4586E+03
	1000	**-4.1596E+05**	5.7509E+03	-1.4440E+05	8.4375E+03
F49	30	**1.2306E-15**	4.0473E-15	6.5461E-13	1.7937E-12
	50	**2.9689E-15**	5.1344E-15	8.0354E-11	1.2855E-10
	100	**5.9233E-15**	8.1363E-15	2.2902E-09	3.2947E-09
	200	**8.2511E-15**	1.0278E-14	3.2261E-09	5.8321E-09
	500	**3.0727E-14**	6.3508E-14	3.9983E-09	7.0642E-09
	1000	**8.5907E-14**	9.2570E-14	6.8200E-09	1.8022E-08
F50	30	**3.0735E-13**	3.6446E-13	9.9452E-12	2.6754E-11
	50	**3.5509E-13**	5.6558E-13	5.6028E-09	1.3897E-08
	100	**4.2195E-13**	6.6820E-13	1.3045E-07	1.7604E-07
	200	**6.0710E-13**	8.0372E-13	2.5854E-07	4.3076E-07
	500	**6.8893E-13**	8.5077E-13	1.0520E-06	1.6358E-06
	1000	**7.6054E-13**	9.6975E-13	2.1704E-06	3.5437E-06

The best results are in bold. MSSSA, multi-strategy enhanced sparrow search algorithm; SSA, sparrow search algorithm; SD, standard deviation.