

Supplemental file of “Handling Stagnation in Differential Evolution using Elitism Centroid based Operations”

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FIG. S4. THE VALUES OF d_G ACHIEVED BY GAR-DES AND CMX-DES AGAINST GENERATION G ON 30-DIMENSIONAL CEC2014 BENCHMARK FUNCTIONS F3, F9, F19 AND F25 OVER 51 INDEPENDENT RUNS.

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TABLE S1 A SUMMARY OF SOME ADVANCES METHODS FOR DE

Advances	Algorithm	Characteristic
mutation/crossover strategies	RBDE	Introduces rank-based differential mutation to impose evolutionary pressure.
	SaDE	Uses four adaptive mutation strategies at different stages of the search.
	JADE	Introduces a “current-to-pbest/1” strategy to improve mutation.
	EPSDE	Improves DE performance by ensemble of mutation strategies.
	CoDE	Employs three well-studied strategies and selects the best one.
	MPEDE	Encloses different mutation strategies into a multi-population framework.
	CoBiDE	Introduces a covariance matrix learning based crossover operator.
	DEGoS	Dynamically adjusts search strategy for stagnant individuals.
	EDE	Reduces individual stagnation probability using a biased selection operation.
	TDE	Constructs an archive of non-stagnant individuals to regenerate solutions.
	TVRS	Replaces stagnant individuals with non-stagnant ones for crossover.
	CDE-AP	Enhances mutation information exchange via archive collection of non-dominated solutions.
	ACoS	Uses an Eigen coordinate system reflecting the function landscape features.
	ODFDE	Adjust strategies by dimensional information
	ESADE	Evolutionary scale adaptability
	CLSDE	SaDE-like adaptation for multiple chaotic maps
	jDE	Encodes F and CR into solutions, adjusts them adaptively.
	JADE	Uses success history of F and CR to generate new parameters via distributions.
	SHADE	Enhances JADE by introducing a success history parameter adaptation scheme.
	CoBiDE	Introduces a bimodal distribution parameter scheme.
	SinDE	Uses a sinusoidal function for setting F and CR values.
	L-SHADE	Introduces a linear population size reduction to enhance SHADE performance.
parameter settings/adaptation	L-SHADE_cnEpSin	Enhances L-SHADE using sinusoidal parameter settings.
	MDEALS	Incorporates Alopex local search into DE to improve performance.
	TPDE	Uses a two-phase based basin identification to improve DE performance.
	EJADE	Improves JADE with a dual crossover strategy.
	DTDE	Enhances DE with a domain transform technique.
	LDE	Combines offline knowledge with online adaptation for DE.
	DDEBQ	Incorporates aging mechanism to eliminate individuals in DE.
	IDPDE	Assigns values to F and CR based on individual fitness ranking.
	ADE	Adjusts F and CR based on population and individual status.
	QLDE	Q-learning model as a parameter controller.
	GPALS	Reinforcement learning paradigm to tune parameters.
	IMODE	Hybrid adaptive DE with a local search.
	CELDE	Introduces component decomposition and integration.

TABLE S2 PARAMETER SETTINGS FOR DES, SPS-DES, CMX-DES

Algorithm	Parameter settings
DE/rand/1/bin, SPS-DE/rand/1/bin, CMX-DE/rand/1/bin	$F = 0.7$, $CR = 0.5$, $NP = 5 \times D$, $Q = 32$
DE/best/1/bin, SPS-DE/best/1/bin, CMX-DE/best/1/bin	$F = 0.7$, $CR = 0.5$, $NP = 5 \times D$, $Q = 32$
SaDE, SPS-SaDE, CMX-SaDE	$LP = 50$, $NP = 5 \times D$, $Q = 32$
RBDE, SPS-RBDE, CMX-RBDE	$F = 0.7$, $CR = 0.5$, $\beta = 3.0$, $NP = 5 \times D$, $Q = 32$
JADE, SPS-JADE, CMX-JADE	$p = 0.05$, $c = 0.1$, $\mu_F = 0.7$, $\mu_{CR} = 0.5$, $NP = 5 \times D$, $Q = 32$
SHADE, SPS-SHADE, CMX-SHADE	$M_F = \{0.7\}$, $M_{CR} = \{0.5\}$, $H = NP$, $NP = 5 \times D$, $Q = 32$

TABLE S3 ERROR VALUES OF DE/RAND/1/BIN, DE/BEST/1/BIN, SaDE AND THEIR CORRESPONDING ELITISM CENTROID
BASED MUTATION AND CROSSOVER VARIANTS OVER THE 30-DIMENSIONAL CEC2014 BENCHMARK SET

	DE/rand/1/bin	CMX-DE/rand/1/bin		DE/best/1/bin	CMX-DE/best/1/bin		SaDE	CMX-SaDE	
	Mean(Std)	Mean(Std)	Sig.	Mean(Std)	Mean(Std)	Sig.	Mean(Std)	Mean(Std)	Sig.
F1	1.02E+08(1.90E+07)	5.56E+05(1.89E+05)	+	2.70E+07(8.47E+06)	1.14E+05(1.30E+05)	+	1.22E+05(8.42E+04)	1.19E+05(7.74E+04)	=
F2	1.96E+05(3.27E+04)	5.30E-03(2.07E-03)	+	0.00E+00(0.00E+00)	0.00E+00(0.00E+00)	=	0.00E+00(0.00E+00)	0.00E+00(0.00E+00)	=
F3	2.72E+02(4.34E+01)	5.16E-07(2.88E-07)	+	3.35E-05(2.13E-05)	0.00E+00(0.00E+00)	+	0.00E+00(0.00E+00)	0.00E+00(0.00E+00)	=
F4	1.41E+02(6.73E+00)	7.41E+01(9.22E-01)	+	8.43E+01(3.13E+01)	6.78E+00(1.84E+01)	+	3.28E+00(1.32E+01)	2.19E+00(9.52E+00)	=
F5	2.09E+01(4.54E-02)	2.09E+01(4.61E-02)	=	2.09E+01(5.05E-02)	2.01E+01(1.59E-01)	+	2.09E+01(6.69E-02)	2.09E+01(4.99E-02)	-
F6	3.12E+01(1.08E+00)	2.98E-03(5.31E-04)	+	1.06E+00(1.31E+00)	1.23E+00(1.32E+00)	=	2.95E-01(6.78E-01)	5.05E-01(9.75E-01)	=
F7	3.28E-01(1.34E-01)	3.11E-09(5.83E-09)	+	5.50E-03(1.12E-02)	3.67E-03(5.11E-03)	=	1.93E-04(1.38E-03)	3.38E-04(1.71E-03)	=
F8	1.26E+02(7.46E+00)	2.42E+01(2.54E+01)	+	9.05E+01(2.04E+01)	2.52E+01(8.48E+00)	+	1.28E+01(2.28E+00)	1.69E+01(1.67E+01)	=
F9	2.01E+02(7.18E+00)	3.82E+00(1.92E+00)	+	1.81E+02(1.11E+01)	3.89E+01(1.49E+01)	+	1.06E+02(1.43E+01)	1.27E+01(3.05E+00)	+
F10	4.10E+03(2.14E+02)	3.36E+03(5.98E+02)	+	1.44E+03(1.07E+03)	6.51E+02(3.32E+02)	+	7.16E+02(1.18E+02)	1.47E+03(8.55E+02)	-
F11	6.64E+03(2.39E+02)	1.40E+03(1.17E+03)	+	6.45E+03(2.80E+02)	2.46E+03(7.47E+02)	+	5.86E+03(2.98E+02)	1.85E+03(1.04E+03)	+
F12	2.04E+00(2.14E-01)	2.43E+00(2.90E-01)	-	2.04E+00(2.13E-01)	1.95E-01(1.91E-01)	+	1.91E+00(2.35E-01)	2.26E+00(2.65E-01)	-
F13	5.06E-01(5.50E-02)	1.16E-01(2.59E-02)	+	3.75E-01(4.84E-02)	2.78E-01(7.59E-02)	+	2.71E-01(3.70E-02)	1.28E-01(2.40E-02)	+
F14	2.90E-01(4.45E-02)	3.03E-01(2.69E-02)	-	3.71E-01(2.06E-01)	3.47E-01(1.71E-01)	=	2.58E-01(2.64E-02)	2.64E-01(3.39E-02)	=
F15	1.99E+01(1.19E+00)	4.37E+00(3.40E+00)	+	1.65E+01(1.22E+00)	3.24E+00(8.61E-01)	+	1.10E+01(9.98E-01)	2.87E+00(6.75E-01)	+
F16	1.26E+01(1.79E-01)	9.21E+00(1.01E+00)	+	1.21E+01(2.40E-01)	1.04E+01(9.65E-01)	+	1.21E+01(2.84E-01)	9.45E+00(7.68E-01)	+
F17	2.78E+06(7.19E+05)	1.15E+05(3.16E+04)	+	6.41E+05(3.45E+05)	1.13E+04(7.94E+03)	+	1.17E+03(3.71E+02)	1.20E+03(2.87E+02)	=
F18	7.70E+04(3.24E+04)	3.61E+02(4.84E+02)	+	1.62E+03(9.67E+02)	2.80E+03(3.13E+03)	=	6.35E+01(1.57E+01)	6.48E+01(1.58E+01)	=
F19	1.13E+01(5.05E-01)	3.10E+00(4.65E-01)	+	6.44E+00(1.04E+00)	4.09E+00(1.32E+00)	+	4.90E+00(4.71E-01)	2.98E+00(6.65E-01)	+
F20	1.07E+03(2.79E+02)	5.79E+01(7.05E+01)	+	1.20E+02(1.84E+01)	1.20E+02(5.56E+01)	=	2.26E+01(8.33E+00)	2.87E+01(1.12E+01)	-
F21	3.11E+05(8.59E+04)	1.51E+04(6.32E+03)	+	3.34E+04(1.11E+04)	3.54E+03(3.51E+03)	+	3.50E+02(1.55E+02)	3.61E+02(1.75E+02)	=
F22	2.65E+02(7.02E+01)	1.54E+02(3.03E+01)	+	2.86E+02(1.44E+02)	3.04E+02(1.62E+02)	=	1.59E+02(6.40E+01)	1.61E+02(5.72E+01)	=
F23	3.15E+02(3.49E-03)	3.15E+02(1.61E-09)	+	3.15E+02(4.02E-13)	3.15E+02(4.02E-13)	=	3.15E+02(4.02E-13)	3.15E+02(4.02E-13)	=
F24	2.20E+02(2.98E+00)	2.22E+02(2.65E-01)	-	2.25E+02(3.62E+00)	2.25E+02(4.82E+00)	=	2.24E+02(5.37E-01)	2.24E+02(6.52E-01)	=
F25	2.25E+02(3.17E+00)	2.07E+02(2.50E+00)	+	2.09E+02(1.94E+00)	2.04E+02(1.08E+00)	+	2.03E+02(3.25E+00)	2.03E+02(3.11E+00)	=
F26	1.00E+02(4.76E-02)	1.00E+02(1.92E-02)	+	1.00E+02(6.32E-02)	1.00E+02(1.00E-01)	+	1.00E+02(3.28E-02)	1.00E+02(2.17E-02)	+
F27	5.58E+02(6.42E+01)	3.00E+02(7.81E-03)	+	3.58E+02(4.64E+01)	3.77E+02(5.04E+01)	=	3.31E+02(4.44E+01)	3.21E+02(4.00E+01)	+
F28	1.00E+03(1.60E+01)	7.97E+02(1.83E+01)	+	8.20E+02(8.78E+01)	8.58E+02(1.44E+02)	-	8.46E+02(3.02E+01)	8.51E+02(3.27E+01)	=
F29	1.53E+04(3.38E+03)	1.34E+03(8.71E+01)	+	3.30E+03(1.44E+03)	1.13E+03(2.73E+02)	+	7.79E+02(7.19E+01)	7.69E+02(6.44E+01)	=
F30	7.68E+03(1.40E+03)	1.08E+03(2.53E+02)	+	2.15E+03(7.21E+02)	1.84E+03(7.22E+02)	+	8.88E+02(3.18E+02)	1.06E+03(3.68E+02)	-
+/-		26/1/3			19/10/1			8/17/5	

TABLE S4 ERROR VALUES OF RBDE, JADE, SHADE AND THEIR CORRESPONDING ELITISM CENTROID BASED MUTATION AND CROSSOVER VARIANTS OVER THE 30-DIMENSIONAL CEC2014 BENCHMARK SET

	RBDE	CMX-RBDE		JADE	CMX-JADE		SHADE	CMX-SHADE	
	Mean(Std)	Mean(Std)	Sig.	Mean(Std)	Mean(Std)	Sig.	Mean(Std)	Mean(Std)	Sig.
F1	6.90E+07(1.53E+07)	2.21E+05(1.25E+05)	+	2.48E+02(6.71E+02)	6.72E+01(3.24E+02)	+	4.79E+02(1.20E+03)	7.25E+02(1.55E+03)	-
F2	2.40E+00(8.18E-01)	7.98E-07(4.77E-07)	+	0.00E+00(0.00E+00)	0.00E+00(0.00E+00)	=	0.00E+00(0.00E+00)	0.00E+00(0.00E+00)	=
F3	9.68E-01(2.26E-01)	0.00E+00(0.00E+00)	+	1.55E+01(1.51E+01)	2.08E+00(4.85E+00)	+	0.00E+00(0.00E+00)	0.00E+00(0.00E+00)	=
F4	8.09E+01(3.60E+00)	7.00E+01(3.53E+00)	+	0.00E+00(0.00E+00)	1.24E+00(8.88E+00)	=	0.00E+00(0.00E+00)	0.00E+00(0.00E+00)	=
F5	2.09E+01(5.44E-02)	2.09E+01(4.43E-02)	=	2.03E+01(3.66E-02)	2.01E+01(1.44E-01)	+	2.03E+01(3.49E-02)	2.00E+01(4.52E-02)	+
F6	2.61E+01(3.25E+00)	9.88E-02(4.73E-01)	+	1.25E+01(1.16E+00)	3.20E+00(2.09E+00)	+	5.50E+00(4.26E+00)	3.85E-02(1.66E-01)	+
F7	1.50E-06(4.09E-06)	0.00E+00(0.00E+00)	+	5.85E-10(4.18E-09)	0.00E+00(0.00E+00)	=	0.00E+00(0.00E+00)	0.00E+00(0.00E+00)	=
F8	1.20E+02(6.53E+00)	1.45E+01(1.89E+01)	+	0.00E+00(0.00E+00)	0.00E+00(0.00E+00)	=	0.00E+00(0.00E+00)	0.00E+00(0.00E+00)	=
F9	1.89E+02(8.43E+00)	4.62E+00(1.97E+00)	+	3.63E+01(4.33E+00)	1.33E+01(7.87E+00)	+	2.80E+01(3.54E+00)	7.43E+00(2.07E+00)	+
F10	3.83E+03(2.37E+02)	6.63E+02(5.32E+02)	+	6.69E-03(7.04E-03)	5.23E-02(2.74E-02)	-	1.50E-01(3.35E-01)	3.17E+00(1.71E+01)	=
F11	6.44E+03(3.07E+02)	1.25E+03(1.15E+03)	+	2.18E+03(2.20E+02)	1.62E+03(4.50E+02)	+	1.99E+03(1.65E+02)	1.26E+03(4.20E+02)	+
F12	2.06E+00(2.85E-01)	2.40E+00(3.94E-01)	-	4.05E-01(6.50E-02)	7.96E-02(3.67E-02)	+	3.17E-01(3.95E-02)	8.51E-02(4.24E-02)	+
F13	4.57E-01(7.74E-02)	1.17E-02(2.52E-02)	+	2.16E-01(2.80E-02)	1.05E-01(3.02E-02)	+	2.19E-01(2.97E-02)	9.44E-02(2.06E-02)	+
F14	2.71E-01(3.33E-02)	2.84E-01(3.27E-02)	=	2.22E-01(3.53E-02)	2.66E-01(3.87E-02)	-	2.14E-01(2.24E-02)	2.62E-01(3.75E-02)	-
F15	1.80E+01(1.17E+00)	3.18E+00(1.63E+00)	+	4.01E+00(3.87E-01)	2.82E+00(6.00E-01)	+	3.70E+00(3.31E-01)	3.01E+00(6.49E-01)	+
F16	1.24E+01(2.37E-01)	8.87E+00(1.03E+00)	+	9.73E+00(2.91E-01)	8.59E+00(7.10E-01)	+	9.54E+00(3.48E-01)	8.69E+00(7.74E-01)	+
F17	1.78E+06(5.23E+05)	9.65E+04(3.34E+04)	+	9.57E+04(3.63E+05)	2.65E+04(8.25E+04)	=	8.14E+02(2.84E+02)	3.88E+02(2.17E+02)	+
F18	4.53E+03(2.90E+03)	8.30E+02(1.04E+03)	+	2.70E+02(1.66E+03)	2.89E+01(1.74E+01)	+	1.34E+01(8.84E+00)	1.01E+01(7.25E+00)	+
F19	6.63E+00(1.00E+00)	2.28E+00(5.85E-01)	+	4.53E+00(7.08E-01)	3.87E+00(6.59E-01)	+	4.05E+00(6.91E-01)	2.25E+00(8.46E-01)	+
F20	1.92E+02(2.60E+01)	3.35E+01(2.19E+01)	+	3.13E+03(1.71E+03)	2.96E+03(2.09E+03)	=	5.15E+00(2.35E+00)	5.60E+00(2.28E+00)	=
F21	8.84E+04(2.69E+04)	8.62E+03(7.09E+03)	+	3.74E+04(6.78E+04)	3.32E+04(5.49E+04)	=	1.43E+02(1.04E+02)	1.31E+02(1.14E+02)	=
F22	1.88E+02(7.27E+01)	1.41E+02(4.36E+01)	+	1.96E+02(6.44E+01)	2.28E+02(1.21E+02)	=	1.10E+02(5.39E+01)	1.74E+02(7.57E+01)	-
F23	3.15E+02(2.04E-07)	3.15E+02(4.50E-13)	+	3.15E+02(4.02E-13)	3.15E+02(4.02E-13)	=	3.15E+02(4.02E-13)	3.15E+02(2.57E-13)	+
F24	2.02E+02(3.67E-01)	2.19E+02(6.47E+00)	-	2.24E+02(1.14E+00)	2.24E+02(1.24E+00)	=	2.23E+02(9.91E-01)	2.23E+02(1.43E+00)	=
F25	2.19E+02(1.33E+00)	2.05E+02(1.66E+00)	+	2.04E+02(1.12E+00)	2.04E+02(1.44E+00)	=	2.04E+02(8.10E-01)	2.04E+02(1.38E+00)	-
F26	1.00E+02(3.75E-02)	1.00E+02(2.16E-02)	+	1.00E+02(3.22E-02)	1.00E+02(2.49E-02)	+	1.00E+02(2.39E-02)	1.00E+02(2.62E-02)	+
F27	3.04E+02(7.34E-01)	3.01E+02(5.21E+00)	+	3.09E+02(2.85E+01)	3.04E+02(1.65E+01)	=	3.01E+02(5.21E+00)	3.01E+02(8.21E+00)	=
F28	8.40E+02(7.02E+01)	7.95E+02(1.45E+01)	+	8.08E+02(1.78E+01)	7.94E+02(1.57E+01)	+	7.90E+02(1.57E+01)	8.07E+02(2.48E+01)	-
F29	6.12E+03(1.71E+03)	1.42E+03(1.67E+02)	+	8.32E+02(3.20E+02)	7.83E+02(2.24E+02)	=	7.18E+02(4.84E+00)	6.91E+02(1.09E+02)	=
F30	3.43E+03(5.08E+02)	1.16E+03(3.36E+02)	+	1.30E+03(3.70E+02)	1.53E+03(6.06E+02)	=	1.17E+03(3.87E+02)	1.22E+03(4.89E+02)	=
+/-		26/2/2			14/14/2			13/12/5	

TABLE S5 ERROR VALUES OF SPS-DE/RAND/1/BIN, SPS-DE/BEST/1/BIN, SPS-SaDE AND THEIR CORRESPONDING ELITISM CENTROID BASED MUTATION AND CROSSOVER VARIANTS OVER THE 30-DIMENSIONAL CEC2014 BENCHMARK SET

	SPS-DE/rand/1/bin	CMX-DE/rand/1/bin		SPS-DE/best/1/bin	CMX-DE/best/1/bin		SPS-SaDE	CMX-SaDE	
	Mean(Std)	Mean(Std)	Sig.	Mean(Std)	Mean(Std)	Sig.	Mean(Std)	Mean(Std)	Sig.
F1	4.43E+07(8.53E+06)	5.56E+05(1.89E+05)	+	1.02E+06(5.56E+05)	1.14E+05(1.30E+05)	+	1.34E+05(8.30E+04)	1.19E+05(7.74E+04)	=
F2	6.43E+04(1.21E+04)	5.30E-03(2.07E-03)	+	0.00E+00(0.00E+00)	0.00E+00(0.00E+00)	=	0.00E+00(0.00E+00)	0.00E+00(0.00E+00)	=
F3	8.47E+01(1.48E+01)	5.16E-07(2.88E-07)	+	7.69E-06(3.81E-06)	0.00E+00(0.00E+00)	+	0.00E+00(0.00E+00)	0.00E+00(0.00E+00)	=
F4	8.14E+01(1.57E+00)	7.41E+01(9.22E-01)	+	9.66E+00(2.20E+01)	6.78E+00(1.84E+01)	=	5.13E+00(1.65E+01)	2.19E+00(9.52E+00)	=
F5	2.09E+01(4.50E-02)	2.09E+01(4.61E-02)	-	2.09E+01(5.07E-02)	2.01E+01(1.59E-01)	+	2.09E+01(5.70E-02)	2.09E+01(4.99E-02)	-
F6	2.85E+00(5.84E-01)	2.98E-03(5.31E-04)	+	1.12E+00(1.19E+00)	1.23E+00(1.32E+00)	=	2.10E-01(4.72E-01)	5.05E-01(9.75E-01)	=
F7	8.67E-03(2.12E-03)	3.11E-09(5.83E-09)	+	5.75E-03(7.54E-03)	3.67E-03(5.11E-03)	=	0.00E+00(0.00E+00)	3.38E-04(1.71E-03)	=
F8	9.86E+01(7.44E+00)	2.42E+01(2.54E+01)	+	2.05E+01(5.99E+00)	2.52E+01(8.48E+00)	-	7.22E-01(8.69E-01)	1.69E+01(1.67E+01)	-
F9	1.81E+02(1.00E+01)	3.82E+00(1.92E+00)	+	1.47E+02(3.45E+01)	3.89E+01(1.49E+01)	+	1.93E+01(6.28E+00)	1.27E+01(3.05E+00)	+
F10	2.85E+03(2.68E+02)	3.36E+03(5.98E+02)	-	2.59E+02(1.73E+02)	6.51E+02(3.32E+02)	-	2.27E+02(5.18E+01)	1.47E+03(8.55E+02)	-
F11	6.28E+03(2.77E+02)	1.40E+03(1.17E+03)	+	4.45E+03(1.93E+03)	2.46E+03(7.47E+02)	+	1.71E+03(6.92E+02)	1.85E+03(1.04E+03)	=
F12	9.68E-01(4.63E-01)	2.43E+00(2.90E-01)	-	6.79E-01(3.15E-01)	1.95E-01(1.91E-01)	+	1.50E+00(3.83E-01)	2.26E+00(2.65E-01)	-
F13	4.28E-01(4.46E-02)	1.16E-01(2.59E-02)	+	3.04E-01(4.33E-02)	2.78E-01(7.59E-02)	+	1.91E-01(3.89E-02)	1.28E-01(2.40E-02)	+
F14	2.80E-01(2.55E-02)	3.03E-01(2.69E-02)	-	3.17E-01(1.56E-01)	3.47E-01(1.71E-01)	-	2.57E-01(3.15E-02)	2.64E-01(3.39E-02)	=
F15	1.72E+01(9.54E-01)	4.37E+00(3.40E+00)	+	1.50E+01(1.15E+00)	3.24E+00(8.61E-01)	+	2.88E+00(6.43E-01)	2.87E+00(6.75E-01)	=
F16	1.20E+01(3.15E-01)	9.21E+00(1.01E+00)	+	1.15E+01(2.84E-01)	1.04E+01(9.65E-01)	+	1.09E+01(3.98E-01)	9.45E+00(7.68E-01)	+
F17	1.01E+06(3.75E+05)	1.15E+05(3.16E+04)	+	2.91E+04(1.80E+04)	1.13E+04(7.94E+03)	+	1.22E+03(4.42E+02)	1.20E+03(2.87E+02)	=
F18	8.77E+02(1.23E+03)	3.61E+02(4.84E+02)	+	5.47E+03(5.87E+03)	2.80E+03(3.13E+03)	+	6.33E+01(1.60E+01)	6.48E+01(1.58E+01)	-
F19	5.77E+00(2.80E-01)	3.10E+00(4.65E-01)	+	5.36E+00(1.08E+00)	4.09E+00(1.32E+00)	+	3.50E+00(8.37E-01)	2.98E+00(6.65E-01)	+
F20	3.07E+02(8.12E+01)	5.79E+01(7.05E+01)	+	8.99E+01(3.16E+01)	1.20E+02(5.56E+01)	-	2.25E+01(9.80E+00)	2.87E+01(1.12E+01)	-
F21	6.80E+04(4.24E+04)	1.51E+04(6.32E+03)	+	9.30E+03(6.60E+03)	3.54E+03(3.51E+03)	+	3.12E+02(1.47E+02)	3.61E+02(1.75E+02)	=
F22	9.95E+01(9.61E+01)	1.54E+02(3.03E+01)	-	2.88E+02(1.33E+02)	3.04E+02(1.62E+02)	=	9.11E+01(7.08E+01)	1.61E+02(5.72E+01)	-
F23	3.15E+02(4.64E-04)	3.15E+02(1.61E-09)	+	3.15E+02(4.02E-13)	3.15E+02(4.02E-13)	=	3.15E+02(4.02E-13)	3.15E+02(4.02E-13)	=
F24	2.04E+02(3.74E-01)	2.22E+02(2.65E-01)	-	2.22E+02(7.77E+00)	2.25E+02(4.82E+00)	-	2.24E+02(6.76E-01)	2.24E+02(6.52E-01)	=
F25	2.11E+02(2.02E+00)	2.07E+02(2.50E+00)	+	2.03E+02(5.56E-01)	2.04E+02(1.08E+00)	-	2.02E+02(2.70E+00)	2.03E+02(3.11E+00)	=
F26	1.00E+02(4.11E-02)	1.00E+02(1.92E-02)	+	1.00E+02(3.95E-02)	1.00E+02(1.00E-01)	=	1.00E+02(2.83E-02)	1.00E+02(2.17E-02)	+
F27	3.29E+02(8.12E+00)	3.00E+02(7.81E-03)	+	3.74E+02(5.41E+01)	3.77E+02(5.04E+01)	=	3.24E+02(4.00E+01)	3.21E+02(4.00E+01)	=
F28	8.06E+02(1.72E+01)	7.97E+02(1.83E+01)	+	8.19E+02(9.04E+01)	8.58E+02(1.44E+02)	=	8.39E+02(3.13E+01)	8.51E+02(3.27E+01)	=
F29	2.17E+03(2.92E+02)	1.34E+03(8.71E+01)	+	1.20E+03(2.37E+02)	1.13E+03(2.73E+02)	=	7.82E+02(6.60E+01)	7.69E+02(6.44E+01)	=
F30	2.23E+03(6.10E+02)	1.08E+03(2.53E+02)	+	1.68E+03(6.53E+02)	1.84E+03(7.22E+02)	=	9.12E+02(3.23E+02)	1.06E+03(3.68E+02)	-
+/-		24/0/6			13/11/6			5/17/8	

TABLE S6 ERROR VALUES OF SPS-RBDE, SPS-JADE, SPS-SHADE AND THEIR CORRESPONDING ELITISM CENTROID BASED MUTATION AND CROSSOVER VARIANTS
OVER THE 30-DIMENSIONAL CEC2014 BENCHMARK SET

	SPS-RBDE	CMX-RBDE		SPS-JADE	CMX-JADE		SPS-SHADE	CMX-SHADE	
	Mean(Std)	Mean(Std)	Sig.	Mean(Std)	Mean(Std)	Sig.	Mean(Std)	Mean(Std)	Sig.
F1	2.24E+07(7.05E+06)	2.21E+05(1.25E+05)	+	7.22E+01(2.71E+02)	6.72E+01(3.24E+02)	=	1.12E+03(2.46E+03)	7.25E+02(1.55E+03)	=
F2	1.31E+00(5.43E-01)	7.98E-07(4.77E-07)	+	0.00E+00(0.00E+00)	0.00E+00(0.00E+00)	=	0.00E+00(0.00E+00)	0.00E+00(0.00E+00)	=
F3	2.94E-01(7.99E-02)	0.00E+00(0.00E+00)	+	1.37E+01(1.15E+01)	2.08E+00(4.85E+00)	+	0.00E+00(0.00E+00)	0.00E+00(0.00E+00)	=
F4	7.14E+01(4.65E-01)	7.00E+01(3.53E+00)	+	0.00E+00(0.00E+00)	1.24E+00(8.88E+00)	=	4.24E-06(3.02E-05)	0.00E+00(0.00E+00)	=
F5	2.09E+01(4.52E-02)	2.09E+01(4.43E-02)	-	2.02E+01(6.79E-02)	2.01E+01(1.44E-01)	+	2.02E+01(7.96E-02)	2.00E+01(4.52E-02)	+
F6	1.56E-01(1.30E-01)	9.88E-02(4.73E-01)	+	2.00E+00(1.50E+00)	3.20E+00(2.09E+00)	-	4.92E-02(2.32E-01)	3.85E-02(1.66E-01)	=
F7	6.97E-08(3.76E-08)	0.00E+00(0.00E+00)	+	0.00E+00(0.00E+00)	0.00E+00(0.00E+00)	=	0.00E+00(0.00E+00)	0.00E+00(0.00E+00)	=
F8	7.55E+01(9.69E+00)	1.45E+01(1.89E+01)	+	0.00E+00(0.00E+00)	0.00E+00(0.00E+00)	=	0.00E+00(0.00E+00)	0.00E+00(0.00E+00)	=
F9	1.74E+02(1.20E+01)	4.62E+00(1.97E+00)	+	2.25E+01(6.42E+00)	1.33E+01(7.87E+00)	+	1.81E+01(5.94E+00)	7.43E+00(2.07E+00)	+
F10	1.86E+03(3.31E+02)	6.63E+02(5.32E+02)	+	1.32E-02(1.44E-02)	5.23E-02(2.74E-02)	-	4.91E-02(1.61E-01)	3.17E+00(1.71E+01)	-
F11	6.25E+03(2.61E+02)	1.25E+03(1.15E+03)	+	1.28E+03(3.40E+02)	1.62E+03(4.50E+02)	-	1.16E+03(3.80E+02)	1.26E+03(4.20E+02)	=
F12	9.07E-01(4.05E-01)	2.40E+00(3.94E-01)	-	1.01E-01(4.44E-02)	7.96E-02(3.67E-02)	+	8.59E-02(3.37E-02)	8.51E-02(4.24E-02)	=
F13	3.84E-01(4.09E-02)	1.17E-01(2.52E-02)	+	1.16E-01(2.91E-02)	1.05E-01(3.02E-02)	+	7.85E-02(1.74E-02)	9.44E-02(2.06E-02)	-
F14	2.79E-01(1.08E-01)	2.84E-01(3.27E-02)	-	2.77E-01(4.47E-02)	2.66E-01(3.87E-02)	=	2.54E-01(3.41E-02)	2.62E-01(3.75E-02)	=
F15	1.68E+01(1.01E+00)	3.18E+00(1.63E+00)	+	2.57E+00(5.23E-01)	2.82E+00(6.00E-01)	-	2.97E+00(6.44E-01)	3.01E+00(6.49E-01)	=
F16	1.17E+01(2.89E-01)	8.87E+00(1.03E+00)	+	8.44E+00(6.75E-01)	8.59E+00(7.10E-01)	=	8.00E+00(6.59E-01)	8.69E+00(7.74E-01)	-
F17	4.30E+05(2.07E+05)	9.65E+04(3.34E+04)	+	9.42E+03(3.23E+04)	2.65E+04(8.25E+04)	=	7.60E+02(3.27E+02)	3.88E+02(2.17E+02)	+
F18	9.61E+02(1.55E+03)	8.30E+02(1.04E+03)	=	3.65E+01(3.37E+01)	2.89E+01(1.74E+01)	=	1.38E+01(8.05E+00)	1.01E+01(7.25E+00)	+
F19	5.04E+00(4.64E-01)	2.28E+00(5.85E-01)	+	3.72E+00(6.45E-01)	3.87E+00(6.59E-01)	=	2.82E+00(7.43E-01)	2.25E+00(8.46E-01)	+
F20	1.13E+02(1.34E+01)	3.35E+01(2.19E+01)	+	2.93E+03(2.21E+03)	2.96E+03(2.09E+03)	=	5.66E+00(2.47E+00)	5.60E+00(2.28E+00)	=
F21	1.76E+04(1.03E+04)	8.62E+03(7.09E+03)	+	6.72E+03(1.76E+04)	3.32E+04(5.49E+04)	=	1.77E+02(9.32E+01)	1.31E+02(1.14E+02)	+
F22	1.38E+02(1.43E+02)	1.41E+02(4.36E+01)	=	1.70E+02(8.29E+01)	2.28E+02(1.21E+02)	-	1.24E+02(9.81E+01)	1.74E+02(7.57E+01)	-
F23	3.15E+02(3.72E-08)	3.15E+02(4.50E-13)	+	3.15E+02(4.02E-13)	3.15E+02(4.02E-13)	=	3.15E+02(4.16E-13)	3.15E+02(2.57E-13)	+
F24	2.01E+02(1.01E-01)	2.19E+02(6.47E+00)	-	2.25E+02(2.50E+00)	2.24E+02(1.24E+00)	=	2.23E+02(8.37E-01)	2.23E+02(1.43E+00)	=
F25	2.07E+02(1.41E+00)	2.05E+02(1.66E+00)	+	2.04E+02(1.34E+00)	2.04E+02(1.44E+00)	=	2.04E+02(9.55E-01)	2.04E+02(1.38E+00)	=
F26	1.00E+02(4.22E-02)	1.00E+02(2.16E-02)	+	1.00E+02(3.24E-02)	1.00E+02(2.49E-02)	=	1.00E+02(2.03E-02)	1.00E+02(2.62E-02)	=
F27	3.01E+02(1.70E-01)	3.01E+02(5.21E+00)	+	3.11E+02(2.95E+01)	3.04E+02(1.65E+01)	=	3.00E+02(0.00E+00)	3.01E+02(8.21E+00)	=
F28	7.99E+02(2.05E+01)	7.95E+02(1.45E+01)	+	7.83E+02(1.84E+01)	7.94E+02(2.01E+01)	-	7.99E+02(2.14E+01)	8.07E+02(2.48E+01)	=
F29	1.68E+03(2.95E+02)	1.42E+03(1.67E+02)	+	7.81E+02(1.95E+02)	7.83E+02(2.24E+02)	=	7.20E+02(8.36E+00)	6.91E+02(1.09E+02)	=
F30	1.28E+03(3.84E+02)	1.16E+03(3.36E+02)	=	1.39E+03(4.31E+02)	1.53E+03(6.06E+02)	=	1.26E+03(4.89E+02)	1.22E+03(4.89E+02)	=
+/-		23/3/4			5/19/6			7/19/4	

TABLE S7 PARAMETER SETTINGS FOR CMX-DEs AND GAR-DEs

Algorithm	Parameter settings	Algorithm	Parameter settings
CMX-DE/rand/1/bin	$F = 0.5$, $CR = 0.9$, $NP = 5 \times D$, $Q = 32$	GAR-DE/rand/1/bin,	$F = 0.5$, $CR = 0.9$, $NP = 5 \times D$, $M = 10$, $\alpha = 0.2$, $g = 3$, $Q = 60$
CMX-DE/best/1/bin	$F = 0.7$, $CR = 0.5$, $NP = 5 \times D$, $Q = 32$	GAR-DE/best/1/bin	$F = 0.7$, $CR = 0.5$, $NP = 5 \times D$, $M = 10$, $\alpha = 0.2$, $g = 3$, $Q = 60$
CMX-SaDE	$LP = 50$, $NP = 5 \times D$, $Q = 32$	GAR-SaDE	$LP = 50$, $NP = 5 \times D$, $M = 10$, $\alpha = 0.2$, $g = 3$, $Q = 60$
CMX-RBDE	$F = 0.5$, $CR = 0.9$, $\beta = 3.0$, $NP = 5 \times D$, $Q = 32$	GAR-RBDE	$F = 0.5$, $CR = 0.9$, $\beta = 3.0$, $NP = 5 \times D$, $M = 10$, $\alpha = 0.2$, $g = 3$, $Q = 60$
CMX-JADE	$p = 0.05$, $c = 0.1$, $\mu_F = 0.7$, $\mu_{CR} = 0.5$, $NP = 5 \times D$, $Q = 32$	GAR-JADE	$p = 0.05$, $c = 0.1$, $\mu_F = 0.5$, $\mu_{CR} = 0.9$, $NP = 5 \times D$, $M = 10$, $\alpha = 0.2$, $g = 3$, $Q = 60$
CMX-SHADE	$M_F = \{0.7\}$, $M_{CR} = \{0.5\}$, $H = NP$, $NP = 5 \times D$, $Q = 32$	GAR-SHADE	$M_F = \{0.5\}$, $M_{CR} = \{0.9\}$, $H = NP$, $NP = 5 \times D$, $M = 10$, $\alpha = 0.2$, $g = 3$, $Q = 60$

TABLE S8 ERROR VALUES OF GAR-DE/RAND/1/BIN, GAR-DE/BEST/1/BIN, GAR-SaDE AND THEIR CORRESPONDING ELITISM CENTROID BASED MUTATION AND CROSSOVER VARIANTS OVER THE 30-DIMENSIONAL CEC2014 BENCHMARK SET

	GAR-DE/rand/1/bin			CMX-DE/rand/1/bin			GAR-DE/best/1/bin			CMX-DE/best/1/bin			GAR-SaDE			CMX-SaDE		
	Mean(Std)			Mean(Std)		Sig.	Mean(Std)			Mean(Std)		Sig.	Mean(Std)			Mean(Std)		Sig.
F1	9.44E+04(5.49E+04)	2.27E+04(2.16E+04)	+		9.88E+07(2.35E+07)		1.05E+05(8.49E+04)	+		1.38E+04(1.73E+04)			1.15E+04(9.31E+03)		=			
F2	8.39E-08(7.82E-08)	1.20E-08(1.39E-08)	+		2.43E+07(6.72E+06)		0.00E+00(0.00E+00)	+		0.00E+00(0.00E+00)			0.00E+00(0.00E+00)		=			
F3	0.00E+00(0.00E+00)	0.00E+00(0.00E+00)	=		1.97E+03(5.94E+02)		0.00E+00(0.00E+00)	+		0.00E+00(0.00E+00)			0.00E+00(0.00E+00)		=			
F4	2.97E+00(1.28E+01)	1.51E+00(8.84E+00)	+		1.78E+02(1.96E+01)		1.02E+01(2.20E+01)	+		3.86E-02(6.85E-02)			6.43E-02(9.95E-02)		=			
F5	2.05E+01(1.12E-01)	2.10E+01(4.88E-02)	-		2.09E+01(5.01E-02)		2.00E+01(4.07E-02)	+		2.06E+01(4.19E-02)			2.01E+01(1.52E-01)		+			
F6	4.95E-01(7.12E-01)	2.25E-01(4.54E-01)	+		2.69E+01(3.33E+00)		1.10E+00(1.14E+00)	+		8.85E-01(9.67E-01)			1.99E+00(1.25E+00)		-			
F7	1.45E-04(1.04E-03)	0.00E+00(0.00E+00)	=		1.12E+00(5.83E-02)		5.22E-03(7.06E-03)	+		3.38E-04(1.71E-03)			1.01E-03(4.00E-03)		=			
F8	2.57E+01(9.37E+00)	2.69E+01(3.20E+01)	+		1.05E+02(1.88E+01)		2.78E+01(9.57E+00)	+		0.00E+00(0.00E+00)			7.80E-02(2.70E-01)		-			
F9	3.67E+01(1.88E+01)	3.18E+01(4.80E+01)	+		2.06E+02(1.23E+01)		3.60E+01(1.33E+01)	+		2.80E+01(7.04E+00)			1.64E+01(2.57E+00)		+			
F10	6.93E+02(4.37E+02)	4.36E+03(1.48E+03)	-		2.44E+03(7.23E+02)		6.33E+02(3.00E+02)	+		1.28E+01(2.78E+00)			3.42E+00(2.90E+00)		+			
F11	2.83E+03(7.20E+02)	6.37E+03(3.22E+02)	-		6.82E+03(2.31E+02)		2.32E+03(8.31E+02)	+		1.73E+03(4.39E+02)			1.64E+03(5.20E+02)		=			
F12	2.54E-01(1.79E-01)	2.47E+00(2.76E-01)	-		2.05E+00(2.46E-01)		2.20E-01(1.92E-01)	+		8.62E-01(1.25E-01)			7.97E-02(4.38E-02)		+			
F13	3.38E-01(5.88E-02)	2.01E-01(2.98E-02)	+		4.97E-01(6.63E-02)		2.78E-01(7.60E-02)	+		2.60E-01(3.53E-02)			1.23E-01(2.01E-02)		+			
F14	2.73E-01(4.67E-02)	2.54E-01(3.05E-02)	+		3.47E-01(7.93E-02)		4.20E-01(2.18E-01)	=		2.35E-01(3.19E-02)			2.48E-01(2.39E-02)		-			
F15	7.07E+00(3.91E+00)	1.25E+01(2.00E+00)	-		2.29E+01(1.75E+00)		3.28E+00(9.94E-01)	+		6.22E+00(3.02E+00)			2.99E+00(6.79E-01)		+			
F16	9.91E+00(1.12E+00)	1.11E+01(5.07E-01)	-		1.27E+01(2.12E-01)		1.01E+01(9.98E-01)	+		1.08E+01(4.37E-01)			9.65E+00(1.12E+00)		+			
F17	7.23E+02(4.24E+02)	2.36E+02(2.31E+02)	+		2.84E+06(1.09E+06)		1.59E+04(1.48E+04)	+		9.03E+02(3.05E+02)			8.70E+02(2.82E+02)		=			
F18	1.38E+01(7.90E+00)	5.28E+00(7.24E+00)	+		2.09E+02(1.59E+05)		3.31E+03(3.47E+03)	+		6.48E+01(2.20E+01)			6.88E+01(2.53E+01)		=			
F19	2.86E+00(5.11E-01)	3.11E+00(5.99E-01)	-		1.15E+01(1.24E+00)		4.33E+00(9.69E-01)	+		2.79E+00(5.43E-01)			2.80E+00(6.42E-01)		=			
F20	1.18E+01(5.35E+00)	3.81E+00(2.64E+00)	+		2.59E+03(1.35E+03)		1.39E+02(6.08E+01)	+		2.10E+01(1.50E+01)			1.89E+01(1.04E+01)		=			
F21	3.61E+02(3.14E+02)	1.24E+02(1.81E+02)	+		3.16E+05(1.93E+05)		3.53E+03(4.52E+03)	+		2.73E+02(1.06E+02)			2.91E+02(1.18E+02)		=			
F22	2.16E+02(1.90E+02)	5.80E+01(3.38E+01)	+		3.60E+02(1.16E+02)		1.41E+02(1.24E+02)	+		3.08E+01(1.76E+01)			2.12E+01(4.73E+01)		+			
F23	3.15E+02(4.02E-13)	3.15E+02(4.16E-13)	=		3.16E+02(1.22E-01)		3.15E+02(1.99E-13)	+		3.15E+02(3.19E-13)			3.15E+02(2.80E-13)		-			
F24	2.08E+02(1.05E+01)	2.10E+02(1.09E+01)	+		2.31E+02(1.71E+00)		2.25E+02(6.75E+00)	+		2.25E+02(1.15E+00)			2.25E+02(1.27E+00)		=			
F25	2.03E+02(1.67E-01)	2.03E+02(5.14E-02)	+		2.19E+02(3.29E+00)		2.04E+02(8.13E-01)	+		2.05E+02(2.50E+00)			2.05E+02(2.72E+00)		=			
F26	1.00E+02(4.52E-02)	1.00E+02(2.90E-02)	+		1.00E+02(6.42E-02)		1.34E+02(4.75E+01)	=		1.00E+02(3.55E-02)			1.00E+02(2.23E-02)		+			
F27	3.34E+02(4.69E+01)	3.36E+02(4.71E+01)	+		4.67E+02(1.46E+01)		4.01E+02(2.80E-01)	+		3.47E+02(3.70E+01)			3.41E+02(3.77E+01)		=			
F28	8.14E+02(2.51E+01)	8.06E+02(2.26E+01)	=		1.03E+03(4.80E+01)		7.99E+02(6.70E+01)	+		8.16E+02(3.70E+01)			8.46E+02(3.07E+01)		-			
F29	6.09E+02(2.19E+02)	6.69E+02(1.63E+02)	=		1.48E+04(5.92E+03)		1.14E+03(2.44E+02)	+		6.72E+02(1.37E+02)			6.60E+02(1.47E+02)		=			
F30	5.98E+02(1.66E+02)	5.45E+02(1.64E+02)	+		5.30E+03(1.01E+03)		1.78E+03(9.40E+02)	+		7.48E+02(2.15E+02)			8.79E+02(3.51E+02)		=			
+/-		18/5/7					28/2/0						9/16/5					

TABLE S9 ERROR VALUES OF GAR-RBDE, GAR-JADE, GAR-SHADE AND THEIR CORRESPONDING ELITISM CENTROID BASED MUTATION AND CROSSOVER VARIANTS OVER THE 30-DIMENSIONAL CEC2014 BENCHMARK SET

	GAR-RBDE			CMX-RBDE			GAR-JADE			CMX-JADE			GAR-SHADE			CMX-SHADE		
	Mean(Std)			Mean(Std)		Sig.	Mean(Std)			Mean(Std)		Sig.	Mean(Std)			Mean(Std)		Sig.
F1	2.27E+05(1.26E+05)	2.13E+05(1.42E+05)	=		7.34E-03(5.11E-02)		2.42E-02(1.22E-01)			3.35E+02(1.00E+03)			9.33E+02(1.23E+03)		-			
F2	6.50E-02(4.61E-01)	4.69E+01(3.14E+02)	+		0.00E+00(0.00E+00)		0.00E+00(0.00E+00)			0.00E+00(0.00E+00)			0.00E+00(0.00E+00)		=			
F3	6.44E+00(4.04E+01)	1.73E-01(8.55E-01)	=		0.00E+00(0.00E+00)		3.24E+00(6.19E+00)			0.00E+00(0.00E+00)			0.00E+00(0.00E+00)		=			
F4	1.25E+01(2.52E+01)	4.12E+00(1.35E+01)	=		1.24E+00(8.88E+00)		0.00E+00(0.00E+00)			0.00E+00(0.00E+00)			0.00E+00(0.00E+00)		=			
F5	2.06E+01(1.52E-01)	2.09E+01(4.41E-02)	-		2.06E+01(2.46E-01)		2.01E+01(1.82E-01)	+		2.03E+01(1.62E-01)			2.00E+01(1.25E-02)		+			
F6	8.82E-01(1.01E+00)	8.20E-01(1.11E+00)	=		3.35E-01(4.97E-01)		3.93E+00(1.88E+00)			2.06E+00(1.27E+00)			9.27E-01(1.31E+00)		+			
F7	7.25E-04(2.57E-03)	1.06E-03(3.46E-03)	=		7.73E-04(2.77E-03)		0.00E+00(0.00E+00)	+		1.93E-03(4.01E-03)			1.93E-04(1.38E-03)		+			
F8	2.44E+01(8.17E+00)	2.33E+01(2.90E+01)	+		0.00E+00(0.00E+00)		0.00E+00(0.00E+00)			1.36E+01(4.36E+00)			0.00E+00(0.00E+00)		+			
F9	4.89E+01(2.41E+01)	1.46E+01(5.28E+00)	+		2.54E+01(7.92E+00)		1.24E+01(7.21E+00)	+		3.22E+01(9.99E+00)			9.83E+00(2.39E+00)		+			
F10	7.55E+02(4.60E+02)	1.58E+03(1.99E+03)	=		4.93E-02(1.97E-02)		6.53E-02(4.10E-02)			2.49E+02(2.06E+02)			3.05E+00(1.67E+01)		+			
F11	3.17E+03(9.85E+02)	3.93E+03(2.63E+03)	=		2.39E+03(6.18E+02)		1.45E+03(4.01E+02)	+		2.35E+03(6.10E+02)			1.40E+03(4.47E+02)		+			
F12	3.59E-01(2.93E-01)	2.39E+00(3.16E-01)	-		6.56E-01(4.95E-01)		1.29E-01(2.88E-01)	+		9.59E-02(9.10E-02)			7.86E-02(4.10E-02)		=			
F13	3.19E-01(6.15E-02)	1.80E-01(3.32E-02)	+		2.16E-01(3.63E-02)		1.05E-01(2.52E-02)	+		2.14E-01(4.52E-02)			1.08E-01(2.04E-02)		+			
F14	3.34E-01(6.03E-02)	2.70E-01(3.32E-02)	+		2.67E-01(4.32E-02)		2.85E-01(4.23E-02)			2.62E-01(5.06E-02)			2.71E-01(5.03E-02)		=			
F15	9.33E+00(5.70E+00)	3.93E+00(2.94E+00)	+		3.39E+00(1.04E+00)		2.73E+00(5.77E-01)	+		3.29E+00(1.03E+00)			2.66E+00(5.82E-01)		+			
F16	1.02E+01(1.08E+00)	1.04E+01(5.14E-01)	=		9.57E+00(7.87E-01)		8.78E+00(7.28E-01)	+		9.98E+00(6.52E-01)			8.82E+00(5.88E-01)		+			
F17	3.97E+03(4.24E+03)	3.49E+03(9.05E+03)	+		8.41E+02(3.16E+02)		6.74E+04(1.70E+05)			1.06E+03(3.89E+02)			8.75E+02(2.92E+02)		+			
F18	1.97E+01(1.11E+01)	8.08E+00(4.16E+00)	+		4.17E+01(2.05E+01)		2.09E+02(7.96E+02)			7.41E+01(2.52E+01)			3.22E+01(2.06E+01)		+			
F19	3.41E+00(8.52E-01)	3.15E+00(8.17E-01)	=		4.21E+00(1.09E+00)		3.90E+00(5.33E-01)			5.35E+00(8.23E+00)			3.17E+00(8.85E-01)		+			
F20	3.01E+01(3.97E+01)	1.59E+01(2.91E+01)	+		1.34E+01(7.22E+00)		3.49E+03(2.46E+03)			1.41E+01(7.47E+00)			7.49E+00(2.91E+00)		+			
F21	5.09E+02(3.88E+02)	1.70E+02(1.90E+02)	+		2.42E+02(1.04E+02)		5.97E+04(6.78E+04)			3.01E+02(1.23E+02)			2.49E+02(1.11E+02)		=			
F22	3.03E+02(2.02E+02)	5.45E+01(5.05E+01)	+		1.10E+02(8.77E+01)		1.86E+02(9.65E+01)			1.51E+02(1.13E+02)			1.45E+02(7.20E+01)		=			
F23	3.15E+02(4.90E-13)	3.15E+02(7.80E-13)	=		3.15E+02(4.02E-13)		3.15E+02(3.73E-13)	+		3.15E+02(4.02E-13)			3.15E+02(4.55E-13)		+			
F24	2.25E+02(2.94E+00)	2.25E+02(2.58E+00)	=		2.26E+02(3.96E+00)		2.25E+02(1.40E+00)	+		2.27E+02(4.34E+00)			2.24E+02(1.70E+00)		+			
F25	2.03E+02(4.07E-01)	2.03E+02(4.62E-01)	=		2.03E+02(6.48E-01)		2.03E+02(7.10E-01)			2.03E+02(6.87E-01)			2.06E+02(2.43E+00)		-			
F26	1.00E+02(6.50E-02)	1.00E+02(3.30E-02)	+		1.00E+02(3.72E-02)		1.00E+02(2.65E-02)	+		1.00E+02(5.28E-02)			1.00E+02(2.17E-02)		+			
F27	3.35E+02(4.37E+01)	3.39E+02(4.15E+01)	=		3.32E+02(3.78E+01)		3.01E+02(5.72E+00)	+		3.64E+02(4.17E+01)			3.14E+02(3.25E+01)		+			
F28	8.39E+02(3.07E+01)	8.29E+02(3.87E+01)	+		8.33E+02(4.69E+01)		7.86E+02(2.27E+01)	+		8.67E+02(3.54E+01)			8.37E+02(2.79E+01)		+			
F29	1.71E+05(1.21E+06)	9.04E+02(1.89E+02)	=		7.11E+02(6.59E+01)		8.14E+02(2.68E+02)			7.18E+02(2.51E+01)			7.11E+02(6.78E+01)		=			
F30	9.95E+02(5.11E+02)	8.76E+02(4.70E+02)	=		1.39E+03(5.92E+02)		1.40E+03(5.56E+02)			1.43E+03(5.77E+02)			1.46E+03(5.45E+02)		=			
+/=-		13/15/2			12/13/5		12/13/5			12/13/5			19/9/2					

TABLE S10 ERROR VALUES OF CMX-SHADE AND TEN COMPETITIVE DE VARIANTS ON THE 30-DIMENSIONAL CEC2013 BENCHMARK SET OVER 51 INDEPENDENT RUNS

Mean Std	jDE	SaDE	EPSDE	JADE	CoDE	CoBiDE	SHADE	MPEDA	IDE	sinDE	CMX-SHADE
F1	0.00E+00 = 0.00E+00	0.00E+00 = 0.00E+00	0.00E+00 = 0.00E+00	0.00E+00 = 0.00E+00	0.00E+00 = 0.00E+00	0.00E+00 = 0.00E+00	0.00E+00 = 0.00E+00	0.00E+00 = 0.00E+00	0.00E+00 = 0.00E+00	0.00E+00 = 0.00E+00	0.00E+00 0.00E+00
F2	1.30E+05 + 8.21E+04	1.80E+05 + 9.41E+04	1.07E+06 + 4.79E+06	1.05E+04 = 9.65E+03	7.70E+04 + 4.33E+04	8.89E+04 + 6.53E+04	1.06E+04 = 7.45E+03	6.91E+01 - 3.71E+02	3.57E+05 + 2.30E+05	2.44E+06 + 9.20E+05	8.90E+03 7.41E+03
F3	9.37E+05 + 1.55E+06	5.67E+06 + 7.39E+06	9.93E+07 + 2.48E+08	4.59E+05 + 2.67E+06	1.47E+06 + 3.63E+06	1.51E+05 + 9.28E+05	2.58E+05 = 1.52E+06	3.70E+01 = 1.47E+02	2.02E+05 = 5.61E+05	1.39E+05 + 3.02E+05	1.36E+05 5.68E+05
F4	1.88E+01 = 1.47E+01	2.70E+01 + 7.07E+01	6.67E+03 + 2.65E+04	9.96E+03 + 1.59E+04	1.07E-01 + 3.40E-01	9.69E-04 + 9.68E-04	1.98E-04 = 4.55E-04	1.06E-04 - 3.29E-04	8.23E+02 + 3.71E+02	4.33E+03 + 1.26E+03	4.01E-04 1.74E-03
F5	0.00E+00 = 0.00E+00	0.00E+00 = 0.00E+00	0.00E+00 = 0.00E+00	0.00E+00 = 0.00E+00	0.00E+00 = 0.00E+00	0.00E+00 = 0.00E+00	0.00E+00 = 0.00E+00	0.00E+00 = 0.00E+00	0.00E+00 = 0.00E+00	0.00E+00 = 0.00E+00	0.00E+00 0.00E+00
F6	1.26E+01 + 8.15E+00	2.03E+01 + 2.17E+01	9.46E+00 + 1.30E+00	5.70E-01 = 4.07E+00	5.51E+00 + 1.04E+01	6.12E+00 + 8.94E+00	0.00E+00 = 0.00E+00	1.14E+00 + 5.20E+00	7.67E+00 + 3.00E+00	1.54E+01 + 3.73E+00	1.04E+00 5.18E+00
F7	2.11E+00 - 1.57E+00	8.04E+00 + 5.13E+00	5.09E+01 + 3.24E+01	5.13E+00 = 5.52E+00	1.12E+01 + 1.05E+01	3.25E+00 = 3.56E+00	3.28E+00 = 3.49E+00	1.35E+00 - 1.02E+00	6.54E-01 - 6.87E-01	2.38E-01 - 3.32E-01	3.73E+00 3.18E+00
F8	2.09E+01 + 5.52E-02	2.09E+01 + 5.94E-02	2.09E+01 + 4.67E-02	2.09E+01 + 1.12E-01	2.07E+01 + 1.21E-01	2.09E+01 + 7.69E-02	2.07E+01 + 1.99E-01	2.09E+01 + 3.60E-02	2.09E+01 + 5.24E-02	2.10E+01 + 4.74E-02	2.06E+01 2.16E-01
F9	2.48E+01 + 5.24E+00	1.44E+01 + 3.31E+00	3.40E+01 + 3.52E+00	2.65E+01 + 1.82E+00	1.43E+01 - 3.23E+00	1.09E+01 - 2.69E+00	2.76E+01 + 1.48E+00	1.44E+01 + 5.17E+00	2.06E+01 + 6.87E+00	1.39E+01 - 3.52E+00	2.02E+01 2.99E+00
F10	4.29E-02 - 2.53E-02	1.60E-01 + 7.89E-02	9.70E-02 = 5.75E-02	5.44E-02 - 3.01E-02	3.61E-02 - 2.11E-02	3.85E-02 - 2.51E-02	8.23E-02 = 4.80E-02	2.19E-02 - 1.56E-02	3.92E-02 - 2.26E-02	2.88E-02 - 1.78E-02	7.95E-02 4.57E-02
F11	0.00E+00 = 0.00E+00	2.38E+00 + 1.59E+00	0.00E+00 = 0.00E+00	0.00E+00 = 0.00E+00	1.95E-02 = 1.39E-01	1.95E-02 = 1.39E-01	0.00E+00 = 0.00E+00	0.00E+00 = 0.00E+00	0.00E+00 = 0.00E+00	3.35E-02 + 1.82E-01	0.00E+00 0.00E+00
F12	6.13E+01 + 8.78E+00	3.36E+01 + 8.15E+00	4.88E+01 + 9.74E+00	2.38E+01 + 3.91E+00	3.74E+01 + 1.15E+01	3.87E+01 + 1.07E+01	2.23E+01 + 3.80E+00	2.15E+01 + 7.32E+00	3.20E+01 + 6.45E+00	2.88E+01 + 6.88E+00	1.63E+01 3.83E+00
F13	9.18E+01 + 1.71E+01	7.33E+01 + 2.14E+01	7.59E+01 + 2.16E+01	5.05E+01 + 1.32E+01	7.93E+01 + 2.45E+01	7.77E+01 + 2.56E+01	4.98E+01 + 1.12E+01	3.81E+01 + 1.56E+01	5.33E+01 + 1.71E+01	7.24E+01 + 1.85E+01	2.91E+01 1.22E+01
F14	1.22E-03 - 4.95E-03	3.56E+02 + 1.27E+02	4.15E-01 + 6.29E-01	3.31E-02 + 2.86E-02	2.80E+00 + 3.21E+00	1.41E+02 + 5.29E+01	2.69E-02 = 2.58E-02	8.68E+00 + 3.78E+00	3.30E+01 + 1.44E+01	4.06E+01 + 1.57E+01	2.20E-02 2.01E-02
F15	5.15E+03 + 4.25E+02	6.13E+03 + 3.34E+02	6.59E+03 + 7.41E+02	3.24E+03 + 2.96E+02	3.32E+03 + 5.48E+02	3.08E+03 + 5.24E+02	3.16E+03 + 2.73E+02	4.38E+03 + 5.36E+02	3.08E+03 + 3.41E+02	2.98E+03 + 4.83E+02	2.73E+03 4.68E+02
F16	2.36E+00 + 2.78E-01	2.37E+00 + 2.26E-01	2.50E+00 + 2.60E-01	1.70E+00 + 7.85E-01	3.73E-01 = 2.36E-01	3.04E-01 - 5.76E-01	8.85E-01 + 2.08E-01	2.45E+00 + 3.59E-01	1.32E+00 + 2.72E-01	1.62E+00 + 2.83E-01	5.40E-01 4.65E-01
F17	3.04E+01 + 1.32E-06	4.99E+01 + 3.86E+00	3.04E+01 + 5.58E-03	3.04E+01 + 1.39E-14	3.04E+01 + 1.02E-02	3.59E+01 + 1.30E+00	3.04E+01 + 1.39E-14	3.06E+01 + 5.45E-02	3.26E+01 + 4.77E-01	3.37E+01 + 7.87E-01	3.04E+01 4.15E-14
F18	1.60E+02 + 1.43E+01	1.67E+02 + 1.09E+01	1.31E+02 + 1.18E+01	7.56E+01 + 6.31E+00	6.56E+01 + 9.08E+00	6.95E+01 + 1.30E+01	7.21E+01 + 5.41E+00	9.86E+01 + 1.15E+01	6.79E+01 + 7.35E+00	7.91E+01 + 1.48E+01	4.00E+01 4.85E+00
F19	1.66E+00 + 1.66E-01	6.70E+00 + 1.20E+00	1.86E+00 + 2.31E-01	1.43E+00 + 1.00E-01	1.59E+00 + 3.53E-01	1.88E+00 + 4.41E-01	1.34E+00 + 1.11E-01	2.05E+00 + 2.92E-01	1.27E+00 + 1.65E-01	2.23E+00 + 3.35E-01	1.02E+00 1.85E-01
F20	1.16E+01 + 3.70E-01	1.13E+01 + 4.15E-01	1.29E+01 + 6.22E-01	1.04E+01 + 7.16E-01	1.04E+01 + 5.48E-01	1.08E+01 + 5.92E-01	1.08E+01 + 5.32E-01	1.03E+01 + 6.32E-01	1.01E+01 + 3.72E-01	1.01E+01 = 6.72E-01	9.85E+00 5.41E-01
F21	2.85E+02 - 5.83E+01	3.29E+02 + 7.29E+01	2.87E+02 - 6.84E+01	2.99E+02 = 4.73E+01	3.25E+02 = 8.58E+01	3.72E+02 + 9.82E+01	2.97E+02 = 4.92E+01	3.22E+02 = 6.49E+01	3.03E+02 = 6.41E+01	2.80E+02 = 7.21E+01	2.93E+02 3.69E+01
F22	1.16E+02 + 1.22E+01	4.98E+02 + 4.62E+02	3.13E+02 + 1.21E+02	1.00E+02 = 3.52E+01	1.19E+02 + 1.52E+01	2.85E+02 + 1.41E+02	1.02E+02 = 1.95E+01	1.22E+02 + 6.96E+00	1.27E+02 + 7.18E+00	1.58E+02 + 3.03E+01	1.06E+02 9.49E-01
F23	5.08E+03 + 4.50E+02	6.17E+03 + 3.78E+02	6.66E+03 + 6.46E+02	3.37E+03 + 4.16E+02	3.56E+03 + 6.26E+02	3.13E+03 = 6.63E+02	3.63E+03 + 3.31E+02	4.48E+03 + 5.12E+02	3.26E+03 + 4.69E+02	2.96E+03 = 4.34E+02	2.89E+03 6.54E+02
F24	2.07E+02 + 7.07E+00	2.21E+02 + 6.69E+00	2.93E+02 + 4.94E+00	2.12E+02 + 1.18E+01	2.22E+02 + 7.61E+00	2.09E+02 = 8.84E+00	2.07E+02 = 5.66E+00	2.07E+02 = 4.00E+00	2.00E+02 - 3.99E-01	2.00E+02 - 6.23E-03	2.06E+02 4.88E+00
F25	2.56E+02 = 1.29E+01	2.58E+02 + 7.10E+00	2.99E+02 + 3.12E+00	2.78E+02 + 6.64E+00	2.55E+02 = 6.82E+00	2.49E+02 = 6.65E+00	2.69E+02 + 1.62E+01	2.47E+02 - 5.15E+00	2.18E+02 - 2.32E+01	2.43E+02 - 4.96E+00	2.54E+02 1.06E+01
F26	2.00E+02 + 4.57E-03	2.12E+02 + 3.53E+01	3.60E+02 + 5.81E+01	2.00E+02 = 4.64E-04	2.12E+02 + 3.82E+01	2.03E+02 + 1.79E+01	2.00E+02 = 4.19E-04	2.00E+02 - 3.86E-06	2.00E+02 + 7.28E-03	2.07E+02 + 2.54E+01	2.02E+02 1.52E+01
F27	4.32E+02 = 1.50E+02	5.29E+02 + 7.24E+01	1.22E+03 + 4.43E+01	7.06E+02 + 2.09E+02	6.14E+02 + 9.48E+01	5.24E+02 + 1.24E+02	4.02E+02 = 1.07E+02	3.72E+02 = 3.56E+01	3.10E+02 - 1.03E+01	3.14E+02 - 3.94E+01	3.84E+02 7.93E+01
F28	3.00E+02 = 9.09E-14	3.22E+02 + 1.54E+02	3.00E+02 - 6.43E-14	3.00E+02 + 2.30E-13	3.00E+02 - 0.00E+00	3.00E+02 + 2.26E-13	3.00E+02 = 1.44E-13	3.00E+02 - 6.43E-14	3.00E+02 - 0.00E+00	3.00E+02 - 0.00E+00	3.00E+02 1.61E-13
NoB	7	2	5	7	4	5	7	9	8	6	13
win/ tie/lose	17/7/4	25/2/1	22/4/2	18/9/1	19/6/3	18/7/3	12/16/0	13/7/8	16/6/6	16/5/7	

TABLE S11 ERROR VALUES OF CMX-SHADE AND TEN COMPETITIVE DE VARIANTS ON THE 50-DIMENSIONAL CEC2013 BENCHMARK SET OVER 51 INDEPENDENT RUNS

Mean Std	jDE	SaDE	EPSDE	JADE	CoDE	CoBiDE	SHADE	MPEDA	IDE	sinDE	CMX-SHADE
F1	0.00E+00 = 0.00E+00	0.00E+00 = 0.00E+00	0.00E+00 = 0.00E+00	0.00E+00 = 0.00E+00	0.00E+00 = 0.00E+00	0.00E+00 = 0.00E+00	0.00E+00 = 0.00E+00	0.00E+00 = 0.00E+00	0.00E+00 = 0.00E+00	0.00E+00 = 0.00E+00	0.00E+00 = 0.00E+00
F2	4.72E+05 + 1.85E+05	4.66E+05 + 1.45E+05	5.65E+06 + 9.36E+06	2.33E+04 = 1.21E+04	2.56E+05 + 8.40E+04	3.61E+05 + 1.38E+05	3.12E+04 = 1.59E+04	8.48E+04 + 4.47E+04	1.34E+06 + 6.52E+05	4.10E+06 + 1.56E+06	2.73E+04 + 1.24E+04
F3	3.55E+06 + 4.11E+06	3.22E+07 + 3.66E+07	2.77E+09 + 1.19E+10	3.61E+06 + 6.83E+06	9.59E+06 + 1.04E+07	4.57E+06 + 7.82E+06	1.09E+06 = 2.02E+06	9.14E+05 = 2.52E+06	2.58E+05 = 3.33E+05	3.97E+04 = 1.03E+05	1.98E+06 + 3.91E+06
F4	1.11E+02 + 1.13E+02	9.96E+01 + 1.34E+02	1.59E+03 + 3.02E+03	8.47E+03 = 1.88E+04	1.73E-01 + 2.50E-01	7.41E-02 + 7.54E-02	4.34E-03 = 1.46E-02	3.11E-01 = 1.24E+00	7.73E+03 + 1.53E+03	6.24E+03 + 1.80E+03	1.23E-03 = 1.12E-03
F5	0.00E+00 = 0.00E+00	0.00E+00 = 0.00E+00	0.00E+00 = 0.00E+00	0.00E+00 = 0.00E+00	0.00E+00 = 0.00E+00	0.00E+00 = 0.00E+00	0.00E+00 = 0.00E+00	0.00E+00 = 0.00E+00	0.00E+00 = 0.00E+00	0.00E+00 = 0.00E+00	0.00E+00 = 0.00E+00
F6	4.36E+01 + 2.99E-01	4.75E+01 + 1.22E+01	3.67E+01 - 1.89E+00	4.34E+01 + 1.44E-13	4.37E+01 - 1.11E+00	4.35E+01 + 2.38E-02	4.34E+01 = 1.04E-13	4.36E+01 - 7.95E-01	4.34E+01 + 4.03E-04	4.34E+01 + 6.61E-10	4.34E+01 + 1.74E-13
F7	1.31E+01 - 7.01E+00	3.26E+01 - 8.01E+00	7.54E+01 + 3.06E+01	2.51E+01 = 1.10E+01	4.38E+01 + 1.46E+01	2.64E+01 + 9.14E+00	2.50E+01 = 8.09E+00	1.36E+01 - 6.86E+00	2.80E+00 - 1.33E+00	6.52E-01 = 4.71E-01	2.20E+01 + 8.53E+00
F8	2.11E+01 + 5.05E-02	2.11E+01 + 3.77E-02	2.11E+01 + 4.21E-02	2.11E+01 + 7.65E-02	2.10E+01 + 8.34E-02	2.11E+01 + 6.23E-02	2.09E+01 = 1.68E-01	2.11E+01 + 3.38E-02	2.11E+01 + 4.84E-02	2.11E+01 + 3.60E-02	2.09E+01 = 1.71E-01
F9	5.10E+01 + 6.28E+00	3.35E+01 + 4.38E+00	6.97E+01 + 3.36E+00	5.40E+01 + 2.42E+00	3.16E+01 - 5.10E+00	2.54E+01 - 4.16E+00	5.61E+01 + 2.14E+00	3.14E+01 + 4.85E+00	3.70E+01 = 5.77E+00	3.37E+01 + 5.38E+00	4.09E+01 + 4.37E+00
F10	6.03E-02 - 4.93E-02	2.03E-01 + 9.43E-02	1.21E-01 + 5.77E-02	5.97E-02 - 3.92E-02	4.62E-02 - 2.33E-02	6.44E-02 - 3.60E-02	8.11E-02 = 4.67E-02	2.75E-02 = 2.20E-02	5.25E-02 - 3.08E-02	8.09E-02 = 4.48E-02	8.80E-02 + 6.04E-02
F11	0.00E+00 = 0.00E+00	1.67E+01 + 5.58E+00	5.07E-01 + 1.78E+00	0.00E+00 = 0.00E+00	7.80E-01 + 1.08E+00	2.15E-01 + 6.69E-01	0.00E+00 = 0.00E+00	0.00E+00 = 0.00E+00	0.00E+00 = 0.00E+00	5.71E+00 + 2.51E+00	0.00E+00 = 0.00E+00
F12	1.08E+02 + 1.90E+01	9.15E+01 + 1.87E+01	1.61E+02 + 2.11E+01	5.84E+01 + 8.59E+00	9.58E+01 + 1.95E+01	8.91E+01 + 2.12E+01	5.49E+01 + 9.02E+00	5.32E+01 + 1.18E+01	7.12E+01 + 8.18E+00	5.93E+01 + 1.59E+01	4.73E+01 = 9.97E+00
F13	1.84E+02 + 3.02E+01	2.02E+02 + 4.14E+01	2.35E+02 + 3.06E+01	1.36E+02 + 1.89E+01	1.89E+02 + 3.94E+01	1.77E+02 + 5.22E+01	1.37E+02 + 2.08E+01	1.27E+02 + 2.92E+01	1.26E+02 + 2.12E+01	1.35E+02 + 3.22E+01	1.13E+02 = 3.04E+01
F14	2.25E-03 - 5.34E-03	6.09E+02 + 1.69E+02	7.11E+02 + 6.78E+02	4.70E-02 + 2.58E-02	2.73E+01 + 1.45E+01	4.66E+02 + 1.62E+02	3.26E-02 = 1.95E-02	6.02E+00 + 2.56E+00	1.69E+02 + 9.06E+01	1.95E+02 + 6.02E+01	3.21E-02 + 1.99E-02
F15	9.84E+03 + 6.68E+02	1.18E+04 + 9.68E+02	1.40E+04 + 5.35E+02	6.91E+03 + 4.82E+02	6.75E+03 + 8.96E+02	6.48E+03 + 7.15E+02	6.82E+03 + 4.28E+02	8.79E+03 + 6.07E+02	6.63E+03 + 4.74E+02	6.50E+03 = 1.03E+03	6.12E+03 = 6.50E+02
F16	3.19E+00 + 2.72E-01	3.10E+00 + 3.03E-01	3.35E+00 + 3.11E-01	2.02E+00 + 8.01E-01	8.30E-01 = 3.53E-01	5.39E-01 - 8.59E-01	1.36E+00 + 1.44E-01	3.13E+00 + 4.05E-01	1.87E+00 + 2.91E-01	1.95E+00 + 3.96E-01	7.22E-01 + 3.42E-01
F17	5.08E+01 + 4.96E-14	8.79E+01 + 6.44E+00	5.11E+01 + 1.41E+00	5.08E+01 + 6.23E-14	5.24E+01 + 5.57E-01	7.63E+01 + 6.33E+00	5.08E+01 + 4.52E-14	5.09E+01 + 3.89E-02	5.78E+01 + 1.72E+00	6.59E+01 + 2.82E+00	5.08E+01 + 6.76E-14
F18	2.82E+02 + 2.21E+01	3.32E+02 + 2.27E+01	3.37E+02 + 2.27E+01	1.42E+02 + 1.17E+01	1.27E+02 + 1.87E+01	1.15E+02 + 2.12E+01	1.33E+02 + 9.40E+00	1.61E+02 + 3.37E+01	2.03E+02 + 1.76E+01	1.48E+02 + 2.08E+01	7.55E+01 = 5.73E+00
F19	2.80E+00 + 2.79E-01	1.36E+01 + 5.48E+00	6.03E+00 + 6.42E-01	2.73E+00 + 2.28E-01	3.15E+00 + 4.94E-01	3.74E+00 + 8.29E-01	2.62E+00 + 2.55E-01	3.38E+00 + 4.19E-01	2.28E+00 + 3.00E-01	5.15E+00 + 8.45E-01	1.97E+00 = 3.21E-01
F20	2.13E+01 + 4.81E-01	2.09E+01 + 4.16E-01	2.24E+01 + 8.15E-01	1.96E+01 + 6.64E-01	1.99E+01 + 8.20E-01	2.02E+01 + 6.25E-01	1.99E+01 + 5.45E-01	1.94E+01 + 7.81E-01	1.94E+01 + 3.88E-01	1.97E+01 + 6.14E-01	1.88E+01 = 8.53E-01
F21	5.72E+02 - 4.11E+02	7.73E+02 + 3.92E+02	6.03E+02 - 4.12E+02	8.57E+02 + 3.51E+02	6.35E+02 - 4.53E+02	3.83E+02 - 3.41E+02	9.52E+02 + 3.01E+02	9.13E+02 + 3.66E+02	7.97E+02 = 3.62E+02	6.84E+02 + 4.41E+02	8.87E+02 + 3.43E+02
F22	2.44E+01 + 2.83E+01	6.24E+02 + 7.41E+02	2.02E+03 + 5.73E+02	1.53E+01 + 1.21E+01	3.64E+01 + 1.17E+01	5.26E+02 + 3.05E+02	1.20E+01 = 4.27E+00	1.94E+01 + 3.91E+00	7.44E+01 + 3.24E+01	2.85E+02 + 2.15E+02	1.15E+01 = 9.37E-01
F23	9.86E+03 + 6.43E+02	1.13E+04 + 1.81E+03	1.41E+04 + 7.16E+02	7.28E+03 + 5.65E+02	7.23E+03 + 1.01E+03	6.75E+03 + 9.34E+02	7.45E+03 + 5.07E+02	8.23E+03 + 1.10E+03	7.19E+03 + 5.66E+02	6.61E+03 + 1.14E+03	6.57E+03 = 7.65E+02
F24	2.38E+02 + 1.29E+01	2.65E+02 + 1.04E+01	3.82E+02 + 3.68E+00	2.45E+02 + 1.39E+01	2.63E+02 + 1.24E+01	2.41E+02 + 1.20E+01	2.30E+02 = 8.69E+00	2.40E+02 + 9.72E+00	2.02E+02 - 1.31E+00	2.06E+02 - 1.18E+01	2.32E+02 + 8.23E+00
F25	3.12E+02 = 2.47E+01	3.18E+02 = 9.23E+00	3.83E+02 + 2.99E+00	3.62E+02 + 1.78E+01	3.14E+02 = 1.16E+01	3.05E+02 - 1.15E+01	3.34E+02 + 3.63E+01	3.01E+02 - 1.04E+01	2.97E+02 - 9.57E+00	2.77E+02 - 8.11E+00	3.15E+02 + 2.11E+01
F26	2.53E+02 = 7.80E+01	2.50E+02 = 7.51E+01	4.75E+02 + 4.42E+00	3.46E+02 + 9.75E+01	3.27E+02 + 7.98E+01	2.53E+02 = 7.89E+01	2.84E+02 = 7.72E+01	2.64E+02 = 6.92E+01	2.27E+02 = 4.66E+01	2.48E+02 = 6.00E+01	2.78E+02 + 6.98E+01
F27	9.55E+02 + 2.64E+02	1.03E+03 + 1.15E+02	2.13E+03 + 3.88E+01	1.38E+03 + 3.29E+02	1.09E+03 + 1.28E+02	9.93E+02 + 1.45E+02	8.44E+02 = 2.25E+02	8.16E+02 = 1.14E+02	3.63E+02 - 4.98E+01	5.92E+02 - 1.82E+02	7.86E+02 + 1.66E+02
F28	4.00E+02 - 2.87E-13	4.61E+02 + 4.34E+02	5.78E+02 + 7.18E+02	4.58E+02 = 4.18E+02	4.59E+02 - 4.19E+02	4.00E+02 - 2.87E-13	4.00E+02 - 2.87E-13	5.16E+02 = 5.82E+02	4.00E+02 - 2.82E-13	4.97E+02 = 5.31E+02	5.16E+02 + 5.81E+02
NoB	6	2	3	5	2	6	6	4	7	5	14
win/ tie/lose	18/5/5	22/5/1	24/2/2	19/8/1	19/4/5	18/4/6	13/14/1	15/8/5	15/7/6	14/8/6	

TABLE S12 ERROR VALUES OF CMX-L-SHADE_CNEPSIN, CMX-L-SHADE AND THE BASELINES ON THE 30-DIMENSIONAL AND 50-DIMENSIONAL CEC2013 BENCHMARK SET OVER 51 INDEPENDENT RUNS

	30-D				50-D			
Mean Std	L-SHADE	CMX-L-SHADE	L-SHADE_cnEpSin	CMX-L-SHADE_cnEpSin	L-SHADE	CMX-L-SHADE	L-SHADE_cnEpSin	CMX-L-SHADE_cnEpSin
F1	0.00E+00 = 0.00E+00	0.00E+00	0.00E+00 = 0.00E+00	0.00E+00	0.00E+00 = 0.00E+00	0.00E+00	0.00E+00 = 0.00E+00	0.00E+00
F2	0.00E+00 = 0.00E+00	0.00E+00	0.00E+00 = 0.00E+00	0.00E+00	7.27E+02 = 7.07E+02	9.57E+02 = 8.20E+02	0.00E+00 = 0.00E+00	0.00E+00
F3	2.91E-02 = 9.91E-02	1.33E-02 = 6.55E-02	0.00E+00 = 0.00E+00	0.00E+00	1.40E+04 = 3.29E+04	1.09E+04 = 2.61E+04	1.57E-04 = 6.87E-04	4.94E-04 = 2.31E-03
F4	0.00E+00 = 0.00E+00	0.00E+00	0.00E+00 = 0.00E+00	0.00E+00	0.00E+00 = 0.00E+00	0.00E+00	0.00E+00 = 0.00E+00	0.00E+00
F5	0.00E+00 = 0.00E+00	0.00E+00	0.00E+00 = 0.00E+00	0.00E+00	0.00E+00 = 0.00E+00	0.00E+00	0.00E+00 = 0.00E+00	0.00E+00
F6	8.80E-01 = 4.82E+00	0.00E+00	1.64E-06 = 4.83E-06	1.66E-06 = 5.97E-06	4.34E+01 = 0.00E+00	4.34E+01 = 0.00E+00	4.34E+01 = 2.37E-02	4.34E+01 = 3.15E-02
F7	7.09E-01 = 6.16E-01	6.56E-01 = 4.41E-01	2.80E-04 = 5.82E-04	5.74E-03 = 1.82E-02	1.87E+00 = 1.25E+00	2.24E+00 = 1.45E+00	5.77E-03 = 2.07E-02	1.57E-03 = 8.80E-04
F8	2.08E+01 - 1.35E-01	2.09E+01 = 6.61E-02	2.09E+01 = 1.29E-01	2.09E+01 = 7.07E-02	2.11E+01 = 1.08E-01	2.11E+01 = 5.58E-02	2.10E+01 - 1.07E-01	2.11E+01 = 3.47E-02
F9	2.63E+01 - 1.55E+00	2.72E+01 = 4.81E+00	2.41E+01 + 1.43E+00	1.04E+01 = 7.12E+00	5.28E+01 + 2.28E+00	3.03E+01 = 1.52E+01	4.98E+01 + 2.62E+00	1.21E+01 = 3.37E+00
F10	4.93E-04 = 1.88E-03	2.47E-04 = 1.35E-03	0.00E+00 = 0.00E+00	0.00E+00	1.26E-02 = 9.44E-03	8.86E-03 = 8.89E-03	0.00E+00 = 0.00E+00	0.00E+00
F11	0.00E+00 = 0.00E+00	0.00E+00	0.00E+00 = 0.00E+00	0.00E+00	0.00E+00 = 0.00E+00	0.00E+00	8.06E-08 + 6.22E-08	3.35E-08 = 2.23E-08
F12	5.17E+00 + 1.61E+00	2.10E+00 = 1.77E+00	1.07E+01 + 2.90E+00	2.05E+00 = 1.22E+00	1.48E+01 + 2.14E+00	1.29E+01 = 4.41E+00	2.06E+01 + 4.24E+00	4.28E+00 = 1.87E+00
F13	6.37E+00 + 2.98E+00	1.83E+00 = 1.69E+00	1.72E+01 + 5.58E+00	2.05E+00 = 1.71E+00	2.06E+01 = 8.58E+00	1.96E+01 = 1.05E+01	3.71E+01 + 1.25E+01	4.92E+00 = 3.66E+00
F14	2.50E-02 = 2.00E-02	2.71E-02 = 2.69E-02	1.00E-01 = 3.29E-02	9.74E-02 = 4.01E-02	2.05E-01 = 4.35E-02	2.02E-01 = 5.00E-02	1.04E+01 = 3.98E+00	1.05E+01 = 3.29E+00
F15	2.68E+03 + 2.63E+02	2.49E+03 = 4.73E+02	2.56E+03 + 2.44E+02	2.06E+03 = 4.28E+02	6.47E+03 = 3.07E+02	6.29E+03 = 5.95E+02	5.98E+03 = 4.36E+02	5.87E+03 = 5.03E+02
F16	7.35E-01 - 1.68E-01	1.50E+00 = 5.79E-01	7.34E-01 - 2.38E-01	1.23E+00 = 5.74E-01	1.26E+00 - 1.37E-01	1.70E+00 = 6.47E-01	1.26E+00 - 1.64E-01	1.59E+00 = 5.20E-01
F17	3.04E+01 = 1.23E-06	3.04E+01 = 1.34E-06	3.04E+01 = 8.59E-05	3.04E+01 = 1.17E-05	5.08E+01 = 1.36E-03	5.08E+01 = 2.04E-03	5.09E+01 = 4.69E-02	5.09E+01 = 4.73E-02
F18	5.21E+01 + 4.21E+00	3.96E+01 = 5.08E+00	6.11E+01 + 3.83E+00	3.67E+01 = 3.79E+00	1.03E+02 + 6.46E+00	7.20E+01 = 1.01E+01	1.25E+02 + 6.68E+00	7.25E+01 = 1.34E+01
F19	1.15E+00 = 6.75E-02	1.22E+00 = 1.84E-01	1.28E+00 = 7.27E-02	1.26E+00 = 1.52E-01	2.51E+00 = 1.65E-01	2.55E+00 = 3.32E-01	2.89E+00 = 1.50E-01	2.81E+00 = 3.32E-01
F20	1.19E+01 + 2.17E+00	9.57E+00 = 1.04E+00	1.10E+01 + 2.03E+00	9.76E+00 = 1.29E+00	1.82E+01 + 5.03E-01	1.78E+01 = 5.87E-01	1.84E+01 + 4.63E-01	1.77E+01 = 7.03E-01
F21	2.93E+02 = 2.54E+01	2.91E+02 = 4.49E+01	3.04E+02 = 5.61E+01	2.95E+02 = 4.14E+01	9.07E+02 = 3.97E+02	8.36E+02 = 4.27E+02	9.09E+02 = 3.71E+02	6.54E+02 = 4.41E+02
F22	1.08E+02 = 1.96E+00	1.08E+02 = 2.23E+00	1.07E+02 = 9.48E-01	1.06E+02 = 7.41E-01	1.37E+01 = 1.60E+00	1.37E+01 = 1.36E+00	2.26E+01 = 3.22E+00	2.11E+01 = 3.26E+00
F23	2.54E+03 + 2.36E+02	2.19E+03 = 4.48E+02	2.25E+03 + 3.25E+02	1.72E+03 = 4.08E+02	5.72E+03 + 3.43E+02	4.53E+03 = 7.74E+02	4.95E+03 + 3.78E+02	3.80E+03 = 7.63E+02
F24	2.00E+02 = 8.22E-01	2.00E+02 = 7.16E-01	2.00E+02 = 1.53E-03	2.00E+02 = 2.80E-03	2.11E+02 = 5.13E+00	2.09E+02 = 4.55E+00	2.00E+02 = 1.32E-02	2.00E+02 = 1.49E-02
F25	2.43E+02 + 7.44E+00	2.40E+02 = 3.32E+00	2.39E+02 = 4.12E+00	2.38E+02 = 4.17E+00	2.78E+02 = 5.88E+00	2.78E+02 = 6.82E+00	2.69E+02 = 5.78E+00	2.69E+02 = 5.20E+00
F26	2.03E+02 + 1.84E+01	2.00E+02 = 1.34E-13	2.00E+02 + 1.45E-13	2.00E+02 = 7.31E-14	2.38E+02 = 5.10E+01	2.42E+02 = 5.25E+01	2.40E+02 = 4.99E+01	2.47E+02 = 5.08E+01
F27	3.02E+02 = 3.33E+00	3.03E+02 = 5.75E+00	3.00E+02 = 4.58E-02	3.00E+02 = 6.25E-02	3.99E+02 = 7.78E+01	3.86E+02 = 5.33E+01	3.08E+02 = 3.90E+01	3.01E+02 = 3.48E-01
F28	3.00E+02 = 0.00E+00	3.00E+02 = 0.00E+00	3.00E+02 - 0.00E+00	3.00E+02 = 1.58E-13	4.00E+02 + 3.26E-13	4.00E+02 = 3.11E-13	4.00E+02 = 2.89E-13	4.00E+02 = 2.95E-13
win/tie/lose		8/17/3		8/18/2		6/21/1		7/19/2

TABLE S13 ERROR VALUES OF CMX-L-SHADE_CNEPSIN AND OTHER STATE-OF-THE-ART EAS AND SIS ON THE 30-DIMENSIONAL AND 50-DIMENSIONAL CEC2013 BENCHMARK SET OVER 51 INDEPENDENT RUNS

	30-D				50-D			
Mean Std	cNrGA	DMSDL-PSO	IPOP-CMA-ES	CMX-L-SHADE_cnEpSin	cNrGA	DMSDL-PSO	IPOP-CMA-ES	CMX-L-SHADE_cnEpSin
F1	7.27E+01 + 3.64E+00	0.00E+00 = 0.00E+00	0.00E+00 = 0.00E+00	0.00E+00 = 0.00E+00	1.23E+00 + 4.20E+00	0.00E+00 = 0.00E+00	0.00E+00 = 0.00E+00	0.00E+00 = 0.00E+00
F2	8.21E+06 + 4.34E+06	4.89E-04 + 3.93E-04	0.00E+00 = 0.00E+00	0.00E+00 = 0.00E+00	1.35E+07 + 4.69E+06	2.70E-03 + 1.28E-03	0.00E+00 = 0.00E+00	0.00E+00 = 0.00E+00
F3	8.30E+08 + 1.09E+09	1.20E+07 + 9.32E+06	1.13E+04 + 6.20E+04	0.00E+00 0.00E+00	1.61E+09 + 2.07E+09	1.30E+08 + 7.82E+07	6.30E+02 + 2.47E+03	4.94E-04 2.31E-03
F4	1.77E+04 + 7.64E+03	1.38E-02 + 2.31E-02	0.00E+00 = 0.00E+00	0.00E+00 = 0.00E+00	2.39E+04 + 7.13E+03	5.49E-03 + 8.64E-03	0.00E+00 = 0.00E+00	0.00E+00 = 0.00E+00
F5	5.24E-02 + 1.50E-01	0.00E+00 = 0.00E+00	0.00E+00 = 0.00E+00	0.00E+00 = 0.00E+00	2.24E-01 + 4.86E-01	0.00E+00 = 0.00E+00	0.00E+00 = 0.00E+00	0.00E+00 = 0.00E+00
F6	4.28E+01 + 2.59E+01	0.00E+00 - 0.00E+00	0.00E+00 - 0.00E+00	1.66E-06 = 5.97E-06	4.76E+01 + 1.26E+00	4.34E+01 + 1.71E-07	4.34E+01 + 1.50E-05	4.34E+01 3.15E-02
F7	6.87E+01 + 1.21E+01	5.76E+01 + 1.43E+01	2.12E+03 + 1.16E+04	5.74E-03 = 1.82E-02	8.44E+01 + 1.22E+01	6.99E+01 + 8.41E+00	1.10E+03 + 5.76E+03	1.57E-03 = 8.80E-04
F8	2.10E+01 + 3.69E-02	2.09E+01 = 5.93E-02	2.15E+01 + 1.05E-01	2.09E+01 7.07E-02	2.11E+01 + 3.48E-02	2.11E+01 = 3.39E-02	2.15E+01 + 5.89E-02	2.11E+01 3.47E-02
F9	2.82E+01 + 3.21E+00	2.73E+01 + 1.39E+00	1.52E+01 + 1.19E+01	1.04E+01 7.12E+00	5.55E+01 + 4.84E+00	5.53E+01 + 2.26E+00	5.74E+01 + 2.52E+01	1.21E+01 3.37E+00
F10	1.40E+00 + 3.17E-01	1.16E-01 + 3.53E-02	0.00E+00 = 0.00E+00	0.00E+00 = 0.00E+00	2.10E+00 + 2.98E-01	1.89E-01 + 6.87E-02	0.00E+00 = 0.00E+00	0.00E+00 = 0.00E+00
F11	1.12E+00 + 1.06E+00	0.00E+00 = 0.00E+00	5.11E+00 + 1.93E+01	0.00E+00 0.00E+00	1.01E+00 + 1.11E+00	0.00E+00 - 0.00E+00	2.54E+01 + 9.95E+00	3.35E-08 2.23E-08
F12	4.62E+01 + 1.10E+01	6.88E+01 + 1.22E+01	1.08E+01 - 3.24E+01	2.05E+00 = 1.22E+00	1.05E+02 + 2.33E+01	1.70E+02 + 2.39E+01	2.02E+01 - 7.63E+01	4.28E+00 = 1.87E+00
F13	1.15E+02 + 2.33E+01	1.26E+02 + 1.32E+01	1.70E+01 = 4.17E+01	2.05E+00 = 1.71E+00	2.43E+02 + 3.50E+01	2.80E+02 + 2.70E+01	2.28E+00 - 5.87E+00	4.92E+00 = 3.66E+00
F14	3.44E+00 + 5.56E+00	8.70E-01 + 1.01E+00	3.04E+03 + 1.79E+03	9.74E-02 4.01E-02	1.71E+00 - 2.71E+00	1.05E+01 - 1.03E+01	5.41E+03 + 3.83E+03	1.05E+01 3.29E+00
F15	3.86E+03 + 8.87E+02	3.42E+03 + 4.04E+02	2.64E+03 - 3.00E+03	2.06E+03 = 4.28E+02	8.47E+03 + 2.47E+03	6.92E+03 + 7.52E+02	4.41E+03 - 3.40E+03	5.87E+03 = 5.03E+02
F16	2.37E+00 + 3.18E-01	1.14E+00 = 4.82E-01	4.15E+00 + 3.02E+00	1.23E+00 5.74E-01	3.20E+00 + 3.38E-01	1.11E+00 - 5.71E-01	5.32E+00 + 3.56E+00	1.59E+00 5.20E-01
F17	3.10E+01 + 4.95E-01	3.04E+01 - 1.89E-02	1.63E+02 + 3.04E+02	3.04E+01 = 1.17E-05	5.12E+01 + 5.12E-01	5.08E+01 - 4.02E-04	4.42E+02 + 5.09E+02	5.09E+01 4.73E-02
F18	1.17E+02 + 2.37E+01	8.23E+01 + 1.54E+01	2.04E+02 + 7.94E+01	3.67E+01 3.79E+00	2.48E+02 + 3.15E+01	1.60E+02 + 2.54E+01	4.48E+02 + 4.61E+02	7.25E+01 1.34E+01
F19	1.09E+00 - 3.48E-01	8.24E-01 - 1.96E-01	4.07E+04 + 2.07E+05	1.26E+00 1.52E-01	1.76E+00 - 3.82E-01	1.85E+00 - 3.10E-01	2.42E+03 + 1.26E+04	2.81E+00 3.32E-01
F20	1.12E+01 + 7.78E-01	1.12E+01 + 4.77E-01	1.05E+01 = 1.91E+00	9.76E+00 = 1.29E+00	2.03E+01 + 7.95E-01	2.04E+01 + 1.21E+00	2.03E+01 + 2.75E+00	1.77E+01 7.03E-01
F21	2.90E+02 + 5.81E+01	2.77E+02 + 4.30E+01	2.97E+02 + 1.83E+01	2.95E+02 4.14E+01	6.04E+02 + 4.43E+02	7.96E+02 + 4.34E+02	1.04E+03 + 2.40E+02	6.54E+02 4.41E+02
F22	1.10E+02 + 2.74E+01	1.04E+02 + 2.57E+01	3.05E+03 + 2.28E+03	1.06E+02 7.41E-01	6.14E+01 = 7.58E+01	2.80E+01 + 2.40E+01	4.50E+03 + 2.61E+03	2.11E+01 3.26E+00
F23	3.98E+03 + 7.94E+02	4.14E+03 + 3.59E+02	2.04E+03 - 2.14E+03	1.72E+03 = 4.08E+02	7.26E+03 + 1.21E+03	8.55E+03 + 7.49E+02	5.34E+03 + 3.33E+03	3.80E+03 7.63E+02
F24	2.64E+02 + 8.27E+00	2.65E+02 + 8.79E+00	2.00E+02 - 1.54E-02	2.00E+02 = 2.80E-03	3.23E+02 + 8.40E+00	3.46E+02 + 1.19E+01	2.34E+02 - 7.57E+01	2.00E+02 = 1.49E-02
F25	2.83E+02 + 6.84E+00	2.90E+02 + 4.47E+00	2.66E+02 + 2.71E+01	2.38E+02 4.17E+00	3.59E+02 + 9.47E+00	3.79E+02 + 5.83E+00	3.10E+02 + 4.27E+01	2.69E+02 5.20E+00
F26	2.52E+02 + 7.42E+01	2.00E+02 + 1.01E-01	3.00E+02 + 1.68E-03	2.00E+02 7.31E-14	4.14E+02 + 4.27E+01	2.00E+02 = 1.12E-02	3.49E+02 + 8.29E+01	2.47E+02 5.08E+01
F27	9.71E+02 + 7.90E+01	9.79E+02 + 9.26E+01	3.36E+02 = 1.34E+02	3.00E+02 = 6.25E-02	1.57E+03 + 1.06E+02	1.72E+03 + 4.78E+01	4.42E+02 = 1.53E+02	3.01E+02 = 3.48E-01
F28	3.03E+02 + 7.48E+00	3.00E+02 + 3.82E-13	3.70E+02 + 2.68E+02	3.00E+02 1.58E-13	5.19E+02 + 6.50E+02	4.00E+02 = 2.89E-13	8.07E+02 + 1.02E+03	4.00E+02 2.95E-13
win/tie/lose	27/0/1	20/5/3	13/10/5		25/1/2	18/5/5	17/7/4	

TABLE S14 ERROR VALUES OF CMX-MADDE AND MADDE ON THE 30-DIMENSIONAL AND 50-DIMENSIONAL CEC2014 BENCHMARK SET OVER 51 INDEPENDENT RUNS

	30-D		50-D	
Mean Std	MadDE	CMX-MadDE	MadDE	CMX-MadDE
F1	6.45E+06 + 1.57E+06	5.38E+06 1.11E+06	2.16E+07 + 3.05E+06	1.59E+07 2.42E+06
F2	2.74E+01 = 1.67E+01	2.37E+01 1.52E+01	1.49E+04 = 3.74E+03	1.49E+04 3.74E+03
F3	1.11E+00 + 3.88E-01	7.09E-01 2.81E-01	9.42E+03 + 1.52E+03	7.76E+03 1.66E+03
F4	7.39E+01 = 1.89E+00	7.40E+01 1.81E+00	1.66E+02 = 1.96E+01	1.66E+02 1.96E+01
F5	2.04E+01 = 4.08E-02	2.04E+01 3.99E-02	2.07E+01 = 4.92E-02	2.07E+01 3.77E-02
F6	1.24E+01 + 1.44E+00	1.07E+01 2.65E+00	3.71E+01 + 2.06E+00	2.34E+01 3.33E+00
F7	1.07E-06 = 6.36E-07	9.90E-07 5.46E-07	5.17E-02 = 2.67E-02	5.19E-02 3.36E-02
F8	2.85E+00 = 1.00E+00	2.51E+00 1.18E+00	1.35E+02 = 1.25E+01	1.37E+02 1.28E+01
F9	9.02E+01 + 8.17E+00	8.49E+01 1.14E+01	2.92E+02 = 1.99E+01	2.89E+02 1.77E+01
F10	4.40E+01 = 1.39E+01	4.62E+01 1.94E+01	3.57E+03 = 4.22E+02	3.54E+03 4.93E+02
F11	2.51E+03 = 3.33E+02	2.59E+03 3.57E+02	8.48E+03 = 3.79E+02	8.42E+03 3.20E+02
F12	4.65E-01 = 8.66E-02	4.86E-01 8.86E-02	1.01E+00 = 1.25E-01	1.02E+00 1.09E-01
F13	2.39E-01 = 2.66E-02	2.33E-01 2.96E-02	4.29E-01 = 3.07E-02	4.33E-01 2.33E-02
F14	2.04E-01 = 1.90E-02	2.04E-01 1.89E-02	2.92E-01 = 1.72E-02	2.99E-01 1.64E-02
F15	7.34E+00 + 1.11E+00	5.73E+00 9.59E-01	3.22E+01 + 1.62E+00	2.88E+01 2.49E+00
F16	1.02E+01 = 3.40E-01	1.03E+01 3.90E-01	2.03E+01 = 3.35E-01	2.02E+01 3.82E-01
F17	1.10E+05 - 1.09E+05	1.91E+05 9.66E+04	1.61E+06 + 4.34E+05	8.37E+05 2.26E+05
F18	4.83E+02 + 2.89E+02	2.53E+02 1.02E+02	3.59E+03 + 1.39E+03	2.57E+03 8.70E+02
F19	6.73E+00 + 3.40E-01	6.26E+00 3.55E-01	2.38E+01 = 9.77E+00	2.27E+01 1.04E+01
F20	1.06E+02 = 1.75E+02	1.47E+02 2.74E+02	7.77E+03 + 2.34E+03	6.47E+03 1.68E+03
F21	2.21E+04 = 1.95E+04	1.84E+04 1.68E+04	8.02E+05 + 2.06E+05	5.16E+05 1.37E+05
F22	1.42E+02 = 4.05E+01	1.41E+02 4.26E+01	5.91E+02 = 1.27E+02	5.72E+02 1.39E+02
F23	3.15E+02 = 9.27E-07	3.15E+02 1.27E-06	2.00E+02 = 2.13E-13	2.00E+02 9.09E-14
F24	2.00E+02 = 1.22E-02	2.00E+02 5.45E-03	2.00E+02 + 1.65E-02	2.00E+02 5.27E-03
F25	2.00E+02 = 0.00E+00	2.00E+02 0.00E+00	2.00E+02 = 2.20E-13	2.00E+02 0.00E+00
F26	1.00E+02 + 3.08E-02	1.00E+02 4.10E-02	1.03E+02 = 1.39E+01	1.03E+02 1.39E+01
F27	4.08E+02 + 1.52E+00	4.03E+02 1.16E+00	7.97E+02 + 1.56E+02	7.16E+02 9.31E+01
F28	8.74E+02 + 2.25E+01	8.62E+02 2.58E+01	1.67E+03 = 4.79E+01	1.66E+03 6.64E+01
F29	2.29E+03 + 4.05E+02	1.47E+03 1.37E+02	3.33E+04 + 6.73E+03	1.60E+04 6.09E+03
F30	2.29E+03 + 3.51E+02	1.99E+03 3.04E+02	1.81E+04 + 1.48E+03	1.76E+04 1.46E+03
win/ tie/lose	12/17/1		12/18/0	

TABLE S15
COMPARISON OF CMX-L-SHADE_cnEPSIN WITH OTHER
EVOLUTIONARY ALGORITHMS AND SWARM-INTELLIGENCE BASED
ALGORITHMS ON THE 30-DIMENSIONAL AND 50-DIMENSIONAL
CEC2013 BENCHMARK SET ACCORDING TO MULTI-PROBLEM
WILCOXON'S TEST

CMX-L-SHADE_cnEpSin vs.	R+	R -	p-value
cNrGA	1503.0	93.0	<0.000001
DMSDL-PSO	1313.0	283.0	0.000026
IPOP-CMA-ES	1479.5	116.5	<0.000001

DEFINITION OF ECDF (FOR SECTION IV-E OF THE PAPER)

By normalizing the solution errors (E) to the scale of 0 to 1, the NSE measure aims to capture the relative performance of an algorithm. To be specific, for an algorithm A on a considered function f in the i th run, the NSE measure $NSE_{A,f,i}$ is calculated by

$$NSE_{A,f,i} = \frac{E_{A,f,i} - \min_{A,i}(E_{A,f,i}) + \varepsilon}{\max_{A,i}(E_{A,f,i}) - \min_{A,i}(E_{A,f,i}) + \varepsilon}$$

where $0 < \varepsilon \ll 1$, which is a small constant value to prevent division by zero.

Given the number of algorithms n_A , the number of considered functions n_f and the number of runs n_r , $ECDF$ of $NSEs$ is formulated by

$$ECDF(x) = \frac{1}{n_A \times n_f \times n_r} \sum_{i=1}^{n_A} \sum_{j=1}^{n_f} \sum_{k=1}^{n_r} I(NSE_{i,j,k} \leq x)$$

where $I(\cdot)$ is an indicator function. For the same x value, a larger value of $ECDF$ indicates superior performance.

TABLE S16 TIME COMPLEXITY COMPARISON OF THE CONSIDERED METHODS (IN SECOND)

Algorithm	$T0$	$T1$	$T2$	$(T2-T1)/T0$
DE/rand/1/bin	0.1138	1.0233	2.2663	10.9227
SPS-DE/rand/1/bin			2.4124	12.2065
GAR-DE/rand/1/bin			4.6169	31.5782
CMX-DE/rand/1/bin			2.6978	14.7144

Time complexity comparison procedures follow the suggestion in [1]

$T0$ is the computing time to run the program below:

```
for i=1:1000000
x= 0.55 + (double) i;
x=x + x; x=x/2; x=x*x; x=sqrt(x); x=log(x); x=exp(x); x=x/(x+2);
end
```

$T1$ is the computing time for 30-D CEC2014 F18 with 200000 evaluation; $T2$ is the average time of 5 runs for a specific algorithm A to complete its optimization on 30-D CEC2014 F18 with 200000 evaluation. Thus, the time complexity of algorithm A is given by $(T2-T1)/T0$.

From Table S16, it can be observed that the complexity is $DE < SPS-DE < CMX-DE < GAR-DE$. It is because that the CMX method needs to calculate the elitism centroid vector compared to DE and SPS methods, while it has fewer operations than GAR approach.

- [1] J. J. Liang, B. Y. Qu, and P. N. Suganthan, "Problem definitions and evaluation criteria for the CEC 2014 special session and competition on single objective real-parameter numerical optimization," Comput. Intell. Lab., Zhengzhou Univ., Zhengzhou, China, and Nanyang Technol. Univ., Singapore, Tech. Rep. 201311, Dec. 2013.

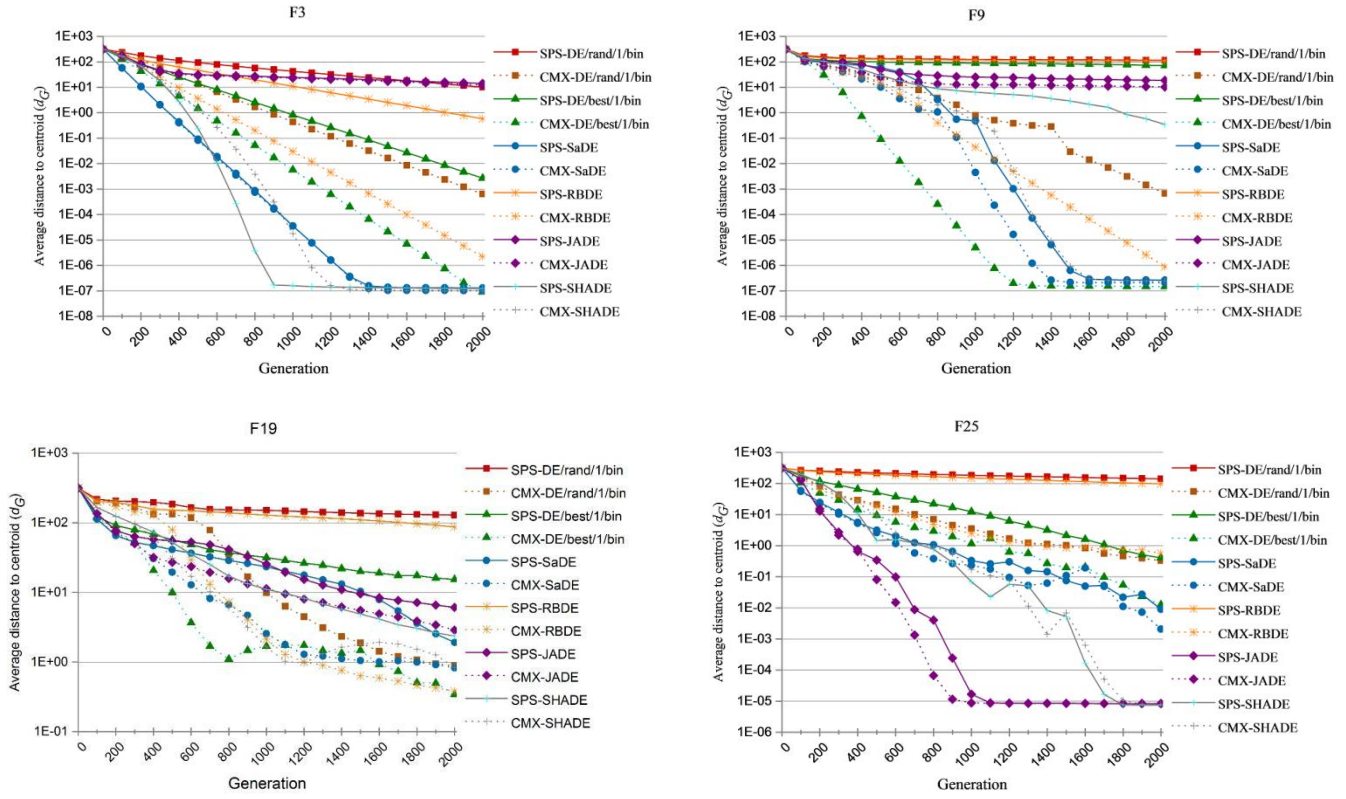


Fig. S1. The values of d_G achieved by SPS-DEs and CMX-DEs against generation G on 30-dimensional CEC2014 benchmark functions F3, F9, F19 and F25 over 51 independent runs.

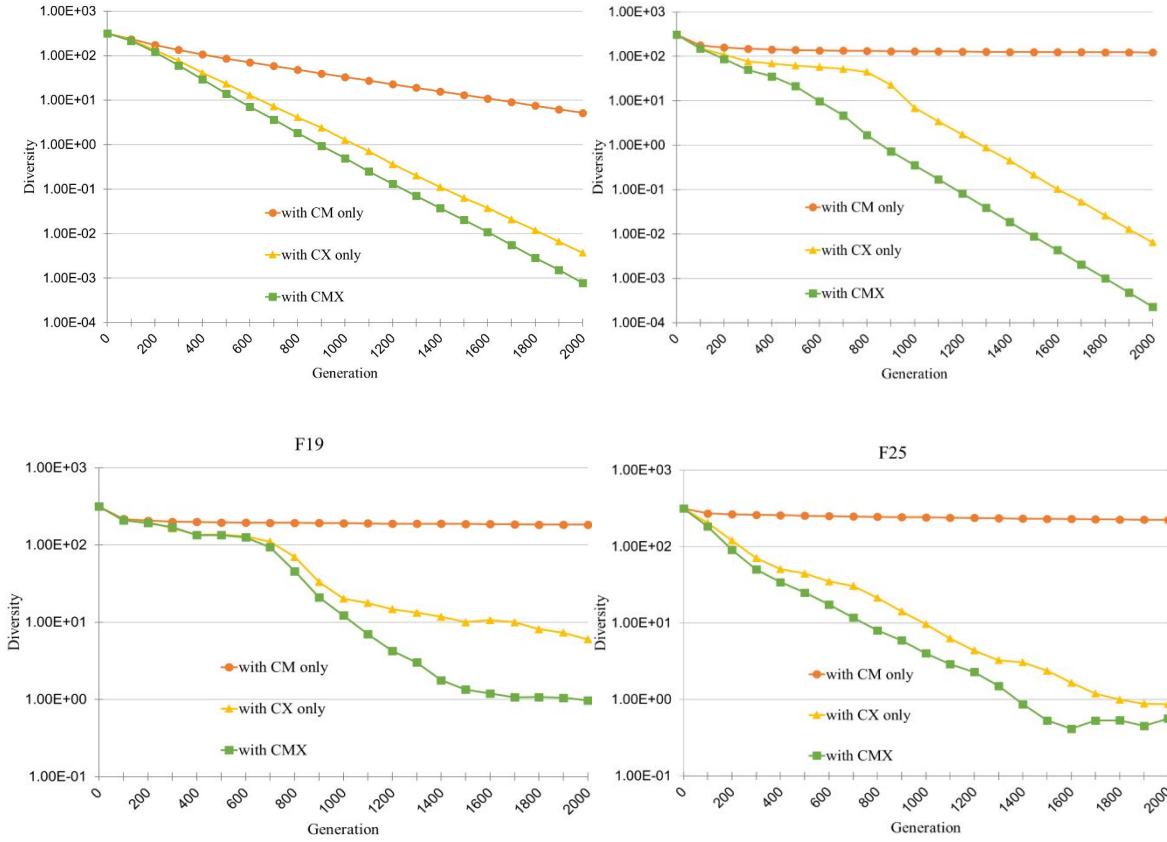


Fig. S2: Convergence of CM, CX and CMX based DE/rand/1 on 30-D unimodal function F3, simple multi-modal function F9, hybrid function F19 and composition function F25. Maximum function evaluations = $10000 \times D$, population size $NP = 5 \times D$, $Q = 32$.

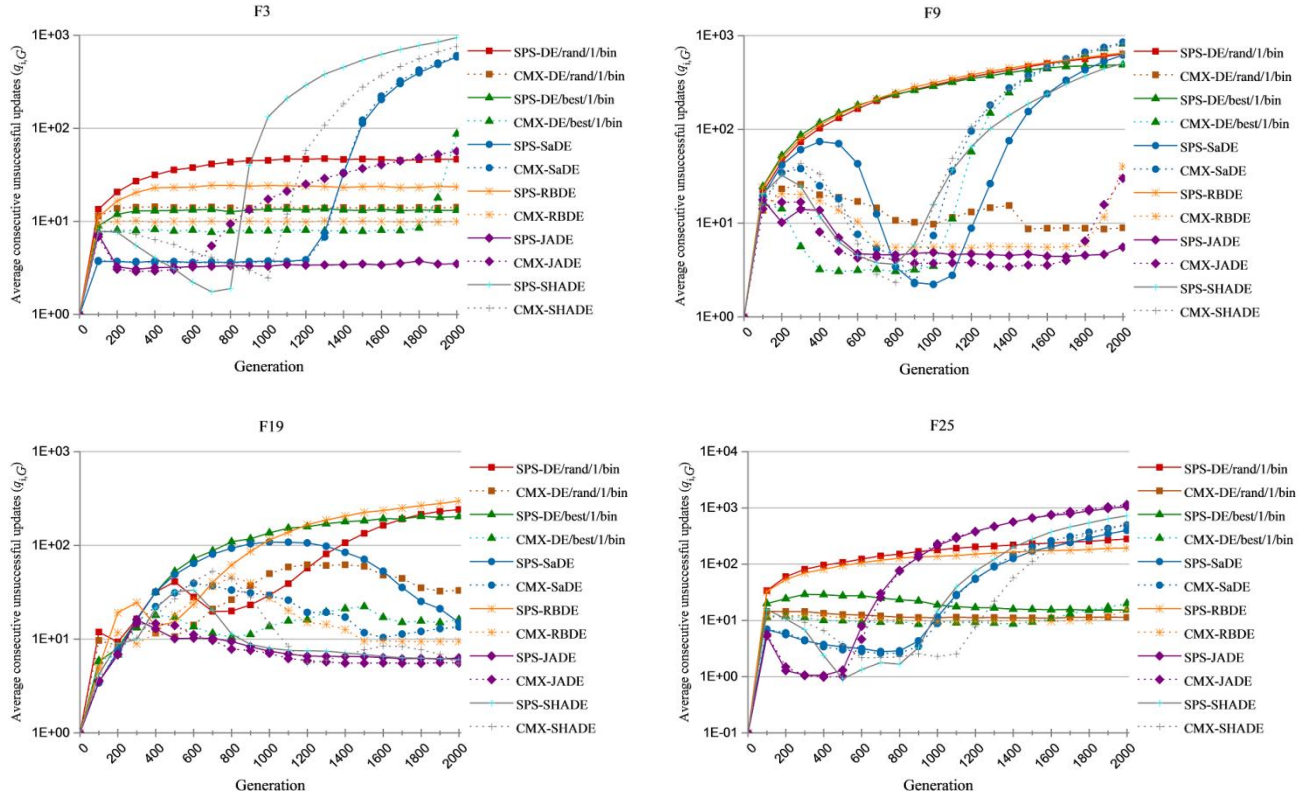


Fig. S3. The values of $q_{l,G}$ achieved by SPS-DEs and CMX-DEs against generation G on 30-dimensional CEC2014 benchmark functions F3, F9, F19 and F25 over 51 independent runs.

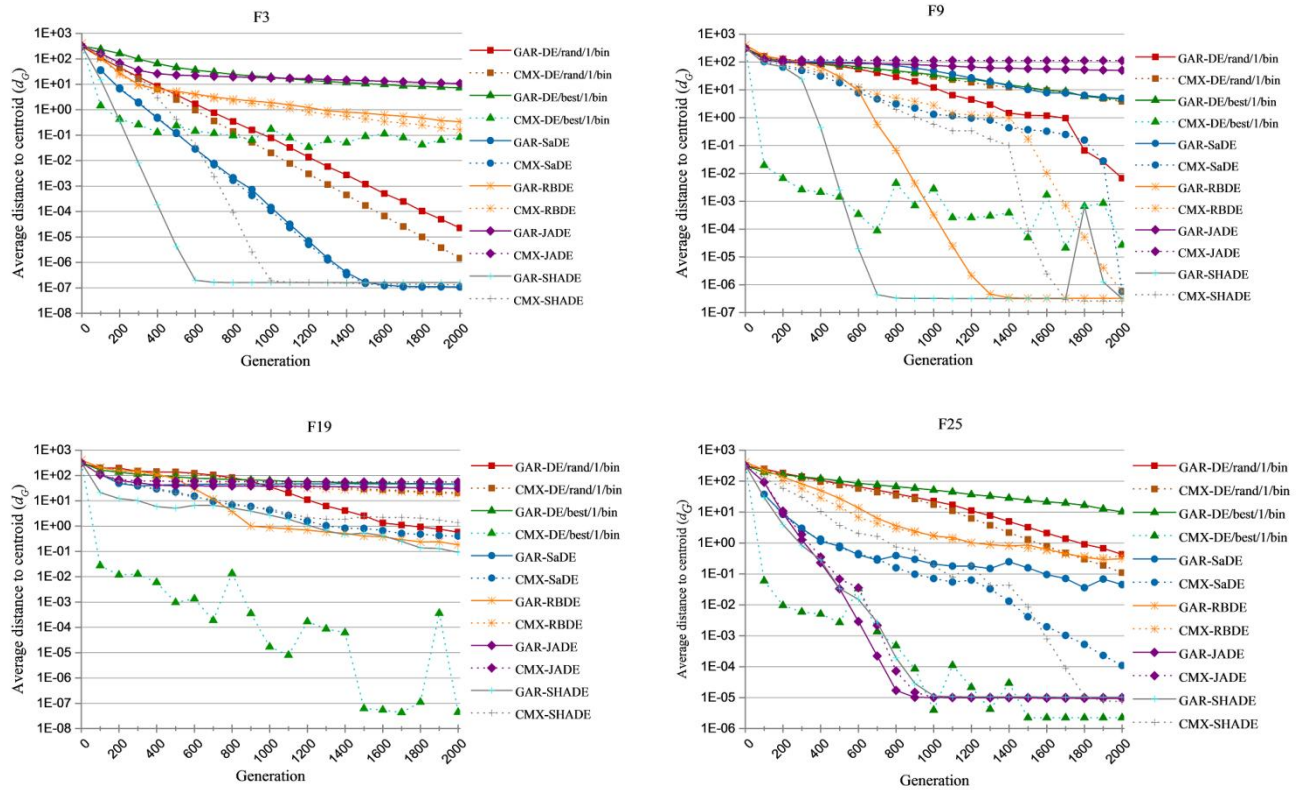


Fig. S4. The values of d_G achieved by GAR-DEs and CMX-DEs against generation G on 30-dimensional CEC2014 benchmark functions F3, F9, F19 and F25 over 51 independent runs.

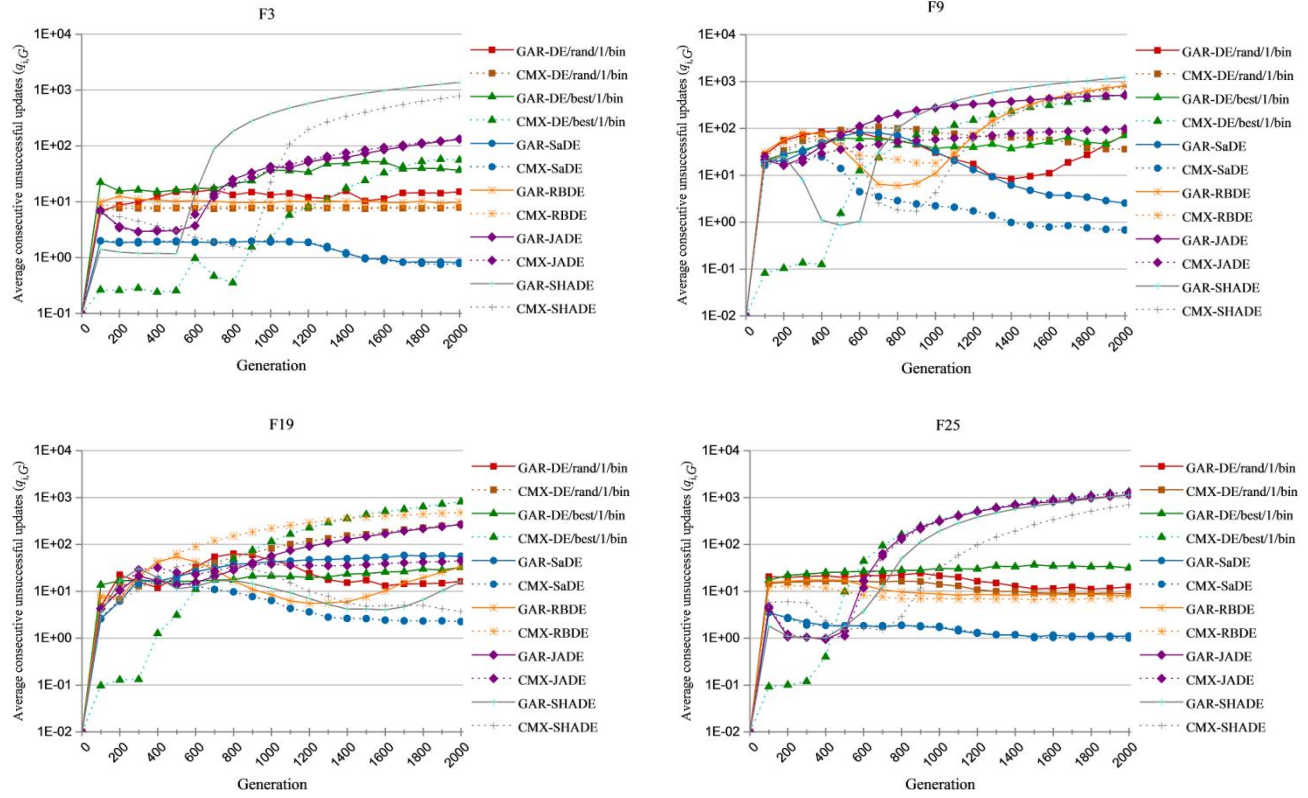


Fig. S5. The values of $q_{i,G}$ achieved by GAR-DEs and CMX-DEs against generation G on 30-dimensional CEC2014 benchmark functions F3, F9, F19 and F25 over 51 independent runs.