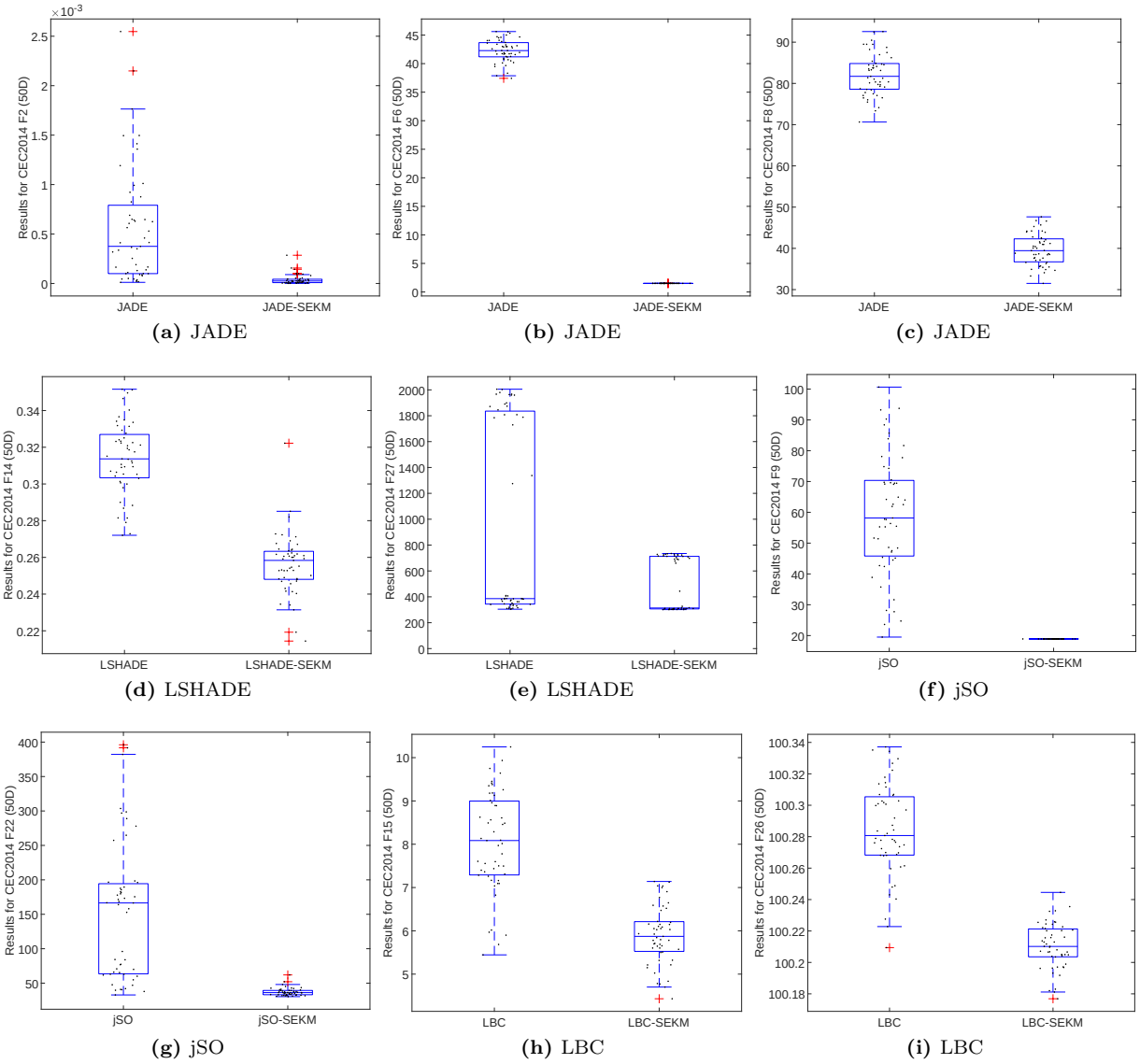
Supplementary Material for "Synergistic Co-evolution with Neural Networks for Evolutionary Optimization"

immediate



(a) JADE **(b)** JADE **(c)** JADE

(d) LSHADE **(e)** LSHADE **(f)** jSO

(g) jSO **(h)** LBC **(i)** LBC

Fig. S-1. Box graph of results obtained by DE-variants and DE-variants-SEKM on CEC2014 test suite (D = 50)

Table S-1
Means and standard deviations of function error values for comparison of DE-variants and DE-variants-SEKM on the CEC2014 benchmark suite (D=10) (+/ = /−)

	JADE		JADE-SEKM			LSHADE		LSHADE-SEKM		
	mean	std	mean	std	Cohen's d (effect size)	mean	std	mean	std	Cohen's d (effect size)
F1	**0.00E+00**	**0.00E+00**	**0.00E+00=**	**0.00E+00**	nan (v)	1.31E+06	9.36E+06	**3.63E+04=**	**1.82E+05**	-1.93E-01 (v)
F2	**0.00E+00**	**0.00E+00**	**0.00E+00=**	**0.00E+00**	nan (v)	**0.00E+00**	**0.00E+00**	**0.00E+00=**	**0.00E+00**	nan (v)
F3	**0.00E+00**	**0.00E+00**	**0.00E+00=**	**0.00E+00**	nan (v)	**2.99E+02**	2.14E+03	3.11E+02=	**1.27E+03**	6.62E-03 (v)
F4	2.80E+01	1.39E+01	**9.71E+00+**	**1.17E+01**	-1.42E+00 (l)	**3.38E+01**	1.46E+01	3.48E+01=	**0.00E+00**	9.63E-02 (v)
F5	1.98E+01	**1.42E+00**	**1.96E+01=**	1.52E+00	-1.44E-01 (v)	1.97E+01	**2.65E+00**	**1.41E+01+**	8.80E+00	-8.57E-01 (l)
F6	3.21E-01	5.60E-01	**2.19E-05+**	**1.54E-04**	-8.11E-01 (l)	**2.26E-01**	**8.78E-01**	2.97E-01=	1.03E+00	7.42E-02 (v)
F7	**1.61E-02**	**1.03E-02**	1.90E-02=	1.14E-02	2.70E-01 (s)	9.17E-04	3.72E-03	**2.90E-04=**	**1.45E-03**	-2.22E-01 (s)
F8	**0.00E+00**	**0.00E+00**	**0.00E+00=**	**0.00E+00**	nan (v)	**0.00E+00**	**0.00E+00**	**0.00E+00=**	**0.00E+00**	nan (v)
F9	4.46E+00	**8.70E-01**	**2.09E+00+**	9.30E-01	-2.63E+00 (l)	1.95E+00	8.13E-01	**1.95E-02+**	**1.39E-01**	-3.31E+00 (l)
F10	7.80E+00	4.37E+00	**5.37E+00+**	**3.66E+00**	-6.02E-01 (m)	2.38E+02	3.60E+02	**1.83E+02=**	**2.66E+02**	-1.74E-01 (v)
F11	2.11E+02	9.40E+01	**1.50E+02+**	**7.90E+01**	-7.00E-01 (m)	3.80E+02	4.69E+02	**1.67E+02+**	**3.47E+02**	-5.16E-01 (m)
F12	**3.46E-01**	9.13E-02	3.63E-01=	**6.73E-02**	2.19E-01 (s)	5.03E-01	3.30E-01	**4.03E-01=**	**3.09E-01**	-3.12E-01 (s)
F13	1.01E-01	1.83E-02	**8.49E-02+**	**1.78E-02**	-8.73E-01 (l)	6.52E-02	1.63E-02	**5.26E-02+**	**9.71E-03**	-9.45E-01 (l)
F14	1.13E-01	3.19E-02	**9.04E-02+**	**2.62E-02**	-7.89E-01 (m)	1.07E-01	3.39E-02	**6.16E-02+**	**1.47E-02**	-1.75E+00 (l)
F15	6.45E-01	1.18E-01	**5.94E-01+**	**8.60E-02**	-4.93E-01 (s)	**4.19E-01**	**8.34E-02**	5.51E-01=	9.89E-01	1.E-01 (v)
F16	2.13E+00	**2.25E-01**	**1.41E+00+**	2.89E-01	-2.75E+00 (l)	1.65E+00	6.00E-01	**6.29E-01+**	**4.98E-01**	-1.86E+00 (l)
F17	1.32E+01	2.79E+01	**1.24E+01=**	**2.09E+01**	-3.13E-02 (v)	**3.40E+00**	**4.47E+00**	2.14E+03=	1.53E+04	1.98E-01 (v)
F18	6.84E-01	5.23E-01	**6.54E-01=**	**4.24E-01**	-6.27E-02 (v)	**2.19E-01**	**1.82E-01**	3.12E-01=	5.89E-01	2.11E-01 (s)
F19	4.25E-01	2.03E-01	**3.66E-01+**	**1.81E-01**	-3.07E-01 (s)	3.45E-01	1.00E+00	**2.72E-01+**	**7.72E-01**	-8.12E-02 (v)
F20	4.94E-01	1.51E-01	**4.69E-01=**	**1.34E-01**	-1.76E-01 (v)	**2.03E-01**	**1.73E-01**	2.44E-01=	1.80E-01	2.30E-01 (s)
F21	1.54E+00	1.46E+00	**1.28E+00=**	**6.18E-01**	-2.29E-01 (s)	**1.45E+02**	1.03E+03	1.79E+02=	**9.36E+02**	3.44E-02 (v)
F22	2.52E+00	1.97E+00	**2.09E+00=**	**1.81E+00**	-2.28E-01 (s)	3.56E+00	2.20E+01	**1.33E+00+**	**6.66E+00**	-1.37E-01 (v)
F23	**3.29E+02**	**0.00E+00**	**3.29E+02=**	**0.00E+00**	nan (v)	**3.29E+02**	**0.00E+00**	3.29E+02=	1.42E-01	1.98E-01 (v)
F24	1.10E+02	**2.11E+00**	**1.05E+02+**	3.28E+00	-1.64E+00 (l)	1.06E+02	**2.66E+00**	**1.05E+02=**	3.38E+00	-2.42E-01 (s)
F25	1.67E+02	4.00E+01	**1.14E+02+**	**1.85E+01**	-1.70E+00 (l)	1.48E+02	3.83E+01	**1.05E+02+**	**7.34E+00**	-1.55E+00 (l)
F26	1.00E+02	2.22E-02	**1.00E+02+**	**1.30E-02**	-1.43E+00 (l)	1.00E+02	2.78E-01	**1.00E+02+**	**5.23E-02**	-3.61E-01 (s)
F27	8.62E+01	1.55E+02	**7.86E+01=**	**1.49E+02**	-5.03E-02 (v)	7.14E+01	1.46E+02	**7.77E+00+**	**4.18E+01**	-5.94E-01 (m)
F28	3.93E+02	4.29E+01	**3.92E+02+**	**3.98E+01**	-2.80E-02 (v)	3.91E+02	2.30E+01	**3.73E+02+**	**7.03E+00**	-1.03E+00 (l)
F29	**2.22E+02**	**7.40E-01**	2.23E+02=	8.30E-01	3.00E-01 (s)	1.26E+03	4.48E+03	**4.96E+02=**	**5.71E+02**	-2.40E-01 (s)
F30	4.73E+02	2.13E+01	**4.68E+02=**	**1.01E+01**	-2.71E-01 (s)	6.18E+02	5.16E+02	**4.80E+02=**	**7.28E+01**	-3.73E-01 (s)
number of			14/16/0					12/18/0		

	jSO		jSO-SEKM			LBC		LBC-SEKM		
	mean	std	mean	std	Cohen's d (effect size)	mean	std	mean	std	Cohen's d (effect size)
F1	**0.00E+00**	**0.00E+00**	**0.00E+00=**	**0.00E+00**	nan (v)	**3.73E+01**	**5.44E+01**	8.90E+01=	1.95E+02	3.61E-01 (s)
F2	**0.00E+00**	**0.00E+00**	**0.00E+00=**	**0.00E+00**	nan (v)	**0.00E+00**	**0.00E+00**	**0.00E+00=**	**0.00E+00**	nan (v)
F3	**0.00E+00**	**0.00E+00**	**0.00E+00=**	**0.00E+00**	nan (v)	**0.00E+00**	**0.00E+00**	**0.00E+00=**	**0.00E+00**	nan (v)
F4	**2.81E+01**	1.37E+01	3.48E+01-	**0.00E+00**	6.91E-01 (m)	2.91E+00	6.29E+00	**5.66E-02+**	**5.04E-02**	-6.41E-01 (m)
F5	1.91E+01	3.30E+00	**4.70E-01+**	**2.85E+00**	-6.04E+00 (l)	1.62E+01	**7.50E+00**	**5.21E+00+**	7.98E+00	-1.41E+00 (l)
F6	1.75E-02	1.25E-01	**0.00E+00=**	**0.00E+00**	-1.98E-01 (v)	9.74E-04	4.96E-03	**7.47E-07+**	**4.85E-06**	-2.77E-01 (s)
F7	**1.25E-07**	**7.97E-07**	1.45E-04=	1.04E-03	1.98E-01 (v)	2.38E-03	3.79E-03	**1.50E-03=**	**3.32E-03**	-2.45E-01 (s)
F8	4.49E-01	6.39E-01	**0.00E+00+**	**0.00E+00**	-9.93E-01 (l)	**0.00E+00**	**0.00E+00**	**0.00E+00=**	**0.00E+00**	nan (v)
F9	2.17E+00	8.86E-01	**9.95E-01+**	**0.00E+00**	-1.E+00 (l)	2.81E+00	**8.36E-01**	**2.66E+00=**	1.06E+00	-1.65E-01 (v)
F10	5.02E+01	3.69E+01	**3.57E+01+**	**2.62E+01**	-4.54E-01 (s)	**0.00E+00**	**0.00E+00**	**0.00E+00=**	**0.00E+00**	nan (v)
F11	1.36E+02	1.29E+02	**3.35E+01+**	**4.83E+01**	-1.05E+00 (l)	9.64E+01	7.32E+01	**4.91E+01+**	**5.01E+01**	-7.55E-01 (m)
F12	3.83E-01	2.37E-01	**3.43E-01=**	**2.18E-01**	-1.77E-01 (v)	1.15E-01	5.47E-02	**9.53E-02=**	**4.13E-02**	-3.98E-01 (s)
F13	7.35E-02	3.35E-02	**7.00E-02=**	**2.27E-02**	-1.21E-01 (v)	1.02E-01	2.70E-02	**8.03E-02+**	**2.55E-02**	-8.23E-01 (l)
F14	1.08E-01	4.82E-02	**9.70E-02=**	**3.15E-02**	-2.61E-01 (s)	**1.08E-01**	3.30E-02	1.19E-01=	**3.19E-02**	3.17E-01 (s)
F15	**4.89E-01**	**1.18E-01**	5.04E-01=	1.23E-01	1.23E-01 (v)	**4.38E-01**	9.23E-02	4.69E-01=	**8.24E-02**	3.47E-01 (s)
F16	1.14E+00	4.44E-01	**2.44E-01+**	**7.00E-02**	-2.83E+00 (l)	1.61E+00	2.90E-01	**1.39E+00+**	**2.49E-01**	-8.04E-01 (l)
F17	**4.00E+00**	**4.15E+00**	5.28E+00=	6.99E+00	2.23E-01 (s)	**7.22E+00**	**5.44E+00**	7.37E+00=	7.32E+00	2.23E-02 (v)
F18	1.97E-01	1.67E-01	**1.57E-01=**	**1.46E-01**	-2.53E-01 (s)	**2.87E-01**	**2.E-01**	2.96E-01=	3.23E-01	2.75E-02 (v)
F19	1.57E-01	2.07E-01	**8.10E-02+**	**3.84E-02**	-5.13E-01 (m)	6.87E-02	3.30E-02	**4.43E-02+**	**2.49E-02**	-8.36E-01 (l)
F20	3.77E-01	**2.00E-01**	**3.25E-01=**	2.06E-01	-2.58E-01 (s)	2.24E-01	1.64E-01	**1.90E-01=**	**1.56E-01**	-2.13E-01 (s)
F21	**4.27E-01**	**2.83E-01**	5.09E-01=	3.27E-01	2.65E-01 (s)	**2.33E-01**	**1.71E-01**	2.64E-01=	2.17E-01	1.61E-01 (v)
F22	3.25E+00	6.69E+00	**6.95E-01+**	**2.10E+00**	-5.16E-01 (m)	2.38E-02	1.77E-02	**1.95E-02=**	**1.61E-02**	-2.54E-01 (s)
F23	**3.29E+02**	**0.00E+00**	**3.29E+02=**	**0.00E+00**	nan (v)	**3.29E+02**	**0.00E+00**	**3.29E+02=**	**0.00E+00**	nan (v)
F24	1.06E+02	2.84E+00	**1.01E+02+**	**2.33E+00**	-2.00E+00 (l)	1.09E+02	**1.E+00**	**1.07E+02+**	3.41E+00	-8.72E-01 (l)
F25	1.38E+02	3.14E+01	**1.11E+02+**	**3.98E+00**	-1.20E+00 (l)	1.27E+02	8.39E+00	**1.27E+02=**	**5.84E+00**	-4.24E-02 (v)
F26	1.00E+02	2.56E-02	**1.00E+02+**	**2.27E-02**	-5.51E-01 (m)	1.00E+02	2.94E-02	**1.00E+02+**	**2.83E-02**	-5.77E-01 (m)
F27	4.02E+01	1.20E+02	**2.06E+01=**	**7.98E+01**	-1.92E-01 (v)	2.38E+00	**3.83E-01**	**1.89E+00+**	4.18E-01	-1.22E+00 (l)
F28	3.82E+02	3.24E+01	**3.59E+02+**	**1.39E+00**	-9.98E-01 (l)	3.40E+02	1.16E+01	**3.35E+02+**	**1.02E+01**	-4.60E-01 (s)
F29	2.22E+02	4.02E-01	**2.22E+02=**	**3.47E-01**	-2.09E-01 (s)	**2.72E+02**	**8.66E+01**	3.72E+02-	1.26E+02	9.33E-01 (l)
F30	4.64E+02	6.58E+00	**4.63E+02=**	**2.41E-01**	-3.39E-01 (s)	**4.69E+02**	1.68E+01	4.70E+02=	**7.67E+00**	6.84E-02 (v)
number of			12/17/1					11/18/1		

Table S-2
Means and standard deviations of function error values for comparison of DE-variants and DE-variants-SEKM on the CEC2014 benchmark suite (D=50) (+/ = /−)

	JADE		JADE-SEKM			LSHADE		LSHADE-SEKM		
	mean	std	mean	std	Cohen's d (effect size)	mean	std	mean	std	Cohen's d (effect size)
F1	**6.21E+04**	**3.45E+04**	6.74E+04=	4.01E+04	1.43E-01 (v)	1.18E+07	8.39E+07	**1.46E+05+**	**1.04E+06**	-1.96E-01 (v)
F2	5.61E-04	5.85E-04	**3.79E-05+**	**5.01E-05**	-1.26E+00 (l)	**0.00E+00**	**0.00E+00**	**0.00E+00=**	**0.00E+00**	nan (v)
F3	6.69E+02	1.30E+02	**9.61E+01+**	**3.03E+01**	-6.07E+00 (l)	5.93E+04	8.56E+04	**1.01E+03=**	**2.05E+03**	-9.62E-01 (l)
F4	**8.73E+01**	1.38E+01	9.81E+01-	**0.00E+00**	1.10E+00 (l)	2.92E+01	3.64E+01	**4.02E+00+**	**1.48E+01**	-9.05E-01 (l)
F5	2.08E+01	**3.39E-02**	**2.08E+01=**	3.98E-02	-1.94E-01 (v)	2.09E+01	3.60E-02	**2.09E+01=**	**3.49E-02**	-1.33E-01 (v)
F6	4.23E+01	1.93E+00	**1.50E+00+**	**2.22E-05**	-2.98E+01 (l)	1.69E+01	2.60E+01	**2.73E+00+**	**5.07E+00**	-7.55E-01 (m)
F7	**0.00E+00**	**0.00E+00**	**0.00E+00=**	**0.00E+00**	nan (v)	1.02E-03	2.E-03	**0.00E+00+**	**0.00E+00**	-4.98E-01 (s)
F8	8.22E+01	5.00E+00	**3.97E+01+**	**3.79E+00**	-9.59E+00 (l)	1.04E+01	4.02E+00	**2.19E+00+**	**7.18E-01**	-2.83E+00 (l)
F9	1.92E+02	1.15E+01	**1.79E+01+**	**1.32E+00**	-2.12E+01 (l)	**2.63E+01**	**3.71E+00**	2.64E+01-	3.15E+01	7.35E-03 (v)
F10	4.11E+03	2.45E+02	**4.10E+03=**	**2.02E+02**	-5.28E-02 (v)	**8.92E+03**	3.30E+03	9.56E+03=	**2.26E+03**	2.26E-01 (s)
F11	**9.27E+03**	**3.46E+02**	9.28E+03=	4.18E+02	4.51E-03 (v)	**1.05E+04**	1.06E+03	1.07E+04=	**8.97E+02**	1.82E-01 (v)
F12	1.25E+00	**9.78E-02**	**1.24E+00=**	1.26E-01	-9.56E-02 (v)	1.80E+00	**1.29E-01**	**1.80E+00=**	1.59E-01	-3.72E-02 (v)
F13	3.22E-01	3.23E-02	**2.35E-01+**	**2.03E-02**	-3.23E+00 (l)	2.13E-01	2.22E-02	**1.61E-01+**	**1.60E-02**	-2.65E+00 (l)
F14	3.16E-01	2.37E-02	**2.74E-01+**	**1.44E-02**	-2.14E+00 (l)	3.14E-01	1.97E-02	**2.54E-01+**	**1.40E-02**	-3.51E+00 (l)
F15	1.87E+01	1.06E+00	**1.30E+01+**	**9.54E-01**	-5.60E+00 (l)	7.73E+00	1.16E+00	**4.01E+00+**	**2.65E-01**	-4.43E+00 (l)
F16	2.09E+01	**2.61E-01**	**2.07E+01+**	3.00E-01	-6.06E-01 (m)	2.06E+01	**1.09E+00**	**1.99E+01+**	1.29E+00	-6.13E-01 (m)
F17	**1.46E+03**	**4.11E+02**	1.50E+03=	4.24E+02	9.36E-02 (v)	1.70E+07	4.46E+07	**4.04E+04=**	**1.27E+05**	-5.39E-01 (m)
F18	7.89E+01	2.52E+01	**7.77E+01=**	**2.13E+01**	-5.22E-02 (v)	1.03E+02	1.64E+01	**9.98E+01=**	**8.92E+00**	-2.46E-01 (s)
F19	**1.28E+01**	5.57E+00	1.33E+01-	**3.20E-01**	1.43E-01 (v)	2.77E+01	8.93E+01	**6.91E+00+**	**2.74E+00**	-3.28E-01 (s)
F20	7.98E+02	4.77E+02	**2.59E+02+**	**2.04E+02**	-1.47E+00 (l)	2.38E+04	5.47E+04	**4.10E+02=**	**1.40E+03**	-6.06E-01 (m)
F21	**5.13E+02**	**1.65E+02**	5.16E+02=	1.68E+02	2.17E-02 (v)	4.27E+06	1.10E+07	**8.70E+05=**	**2.49E+06**	-4.26E-01 (s)
F22	7.06E+02	1.34E+02	**5.19E+02+**	**1.09E+02**	-1.54E+00 (l)	5.26E+02	8.41E+02	**2.02E+02+**	**4.32E+02**	-4.85E-01 (s)
F23	3.44E+02	**0.00E+00**	**3.38E+02=**	2.82E+01	-2.83E-01 (s)	**3.44E+02**	**0.00E+00**	3.44E+02-	1.61E+00	3.45E-01 (s)
F24	2.72E+02	1.83E+00	**2.00E+02+**	**1.65E-02**	-5.56E+01 (l)	2.81E+02	4.33E+01	**2.18E+02+**	**3.19E+01**	-1.65E+00 (l)
F25	2.06E+02	2.20E+00	**2.00E+02+**	**0.00E+00**	-4.04E+00 (l)	2.05E+02	**4.90E-01**	**2.00E+02+**	1.41E+00	-4.86E+00 (l)
F26	**1.00E+02**	**2.68E-02**	1.10E+02-	3.00E+01	4.57E-01 (s)	**1.02E+02**	**3.21E+00**	1.04E+02-	1.96E+01	1.45E-01 (v)
F27	4.29E+02	1.65E+02	**3.79E+02+**	**2.24E-03**	-4.32E-01 (s)	9.36E+02	7.40E+02	**4.24E+02+**	**1.46E+02**	-9.61E-01 (l)
F28	1.21E+03	2.98E+01	**1.12E+03+**	**4.65E+00**	-4.07E+00 (l)	1.40E+03	3.84E+02	**1.19E+03+**	**2.22E+02**	-6.74E-01 (m)
F29	6.92E+05	4.93E+06	**8.14E+02+**	**2.95E+01**	-1.98E-01 (v)	3.55E+07	**4.51E-08**	**3.54E+07+**	1.24E+05	-1.31E+00 (l)
F30	**8.29E+03**	3.31E+02	8.70E+03-	**1.55E+00**	1.73E+00 (l)	2.78E+05	2.89E+05	**9.34E+03+**	**4.89E+03**	-1.32E+00 (l)
number of			16/10/4					15/13/2		

	jSO		jSO-SEKM			LBC		LBC-SEKM		
	mean	std	mean	std	Cohen's d (effect size)	mean	std	mean	std	Cohen's d (effect size)
F1	9.21E+04	4.83E+04	**3.23E+04+**	**1.13E+04**	-1.71E+00 (l)	2.26E+06	5.06E+05	**1.83E+06+**	**1.17E+05**	-1.17E+00 (l)
F2	1.86E-05	4.86E-05	**2.29E-08+**	**6.15E-08**	-5.41E-01 (m)	5.81E+02	4.41E+02	**3.85E+02=**	**1.03E+01**	-6.27E-01 (m)
F3	9.54E-07	2.96E-06	**2.55E-08+**	**6.74E-08**	-4.44E-01 (s)	2.23E+01	2.39E+01	**1.23E+00+**	**1.11E+00**	-1.24E+00 (l)
F4	9.58E+01	2.48E+00	**8.58E+01+**	**5.33E-01**	-5.60E+00 (l)	9.67E+01	1.50E+00	**9.33E+01+**	**5.91E-02**	-3.26E+00 (l)
F5	**2.10E+01**	1.62E-01	2.10E+01=	**1.43E-01**	1.06E-01 (v)	**2.05E+01**	5.76E-02	2.05E+01=	**4.62E-02**	2.57E-01 (s)
F6	8.65E-02	8.60E-02	**4.89E-03+**	**3.23E-02**	-1.26E+00 (l)	2.42E+01	2.06E+00	**1.44E+01+**	**1.94E+00**	-4.91E+00 (l)
F7	**0.00E+00**	**0.00E+00**	**0.00E+00=**	**0.00E+00**	nan (v)	**2.86E-06**	4.70E-06	8.13E-06-	**3.52E-06**	1.27E+00 (l)
F8	3.69E+01	1.12E+01	**1.99E+01+**	**0.00E+00**	-2.15E+00 (l)	**0.00E+00**	**0.00E+00**	**0.00E+00=**	**0.00E+00**	nan (v)
F9	5.94E+01	1.96E+01	**1.89E+01+**	**0.00E+00**	-2.92E+00 (l)	**8.60E+01**	**8.09E+00**	8.E+01=	1.25E+01	2.66E-01 (s)
F10	3.81E+03	6.80E+02	**3.48E+03+**	**6.64E+02**	-4.92E-01 (s)	2.20E+00	2.15E+00	**2.11E+00=**	**1.42E+00**	-5.14E-02 (v)
F11	7.44E+03	9.16E+02	**7.26E+03=**	**8.73E+02**	-2.01E-01 (s)	3.74E+03	3.82E+02	**3.64E+03=**	**3.78E+02**	-2.66E-01 (s)
F12	1.62E+00	7.10E-01	**1.48E+00=**	**5.92E-01**	-2.05E-01 (s)	4.62E-01	**6.29E-02**	**4.17E-01+**	7.26E-02	-6.52E-01 (m)
F13	3.04E-01	3.94E-02	**2.35E-01+**	**2.72E-02**	-2.02E+00 (l)	3.43E-01	3.76E-02	**3.00E-01+**	**2.31E-02**	-1.37E+00 (l)
F14	**3.23E-01**	2.95E-02	3.30E-01=	**1.51E-02**	3.29E-01 (s)	**2.81E-01**	1.76E-02	3.00E-01-	**1.22E-02**	1.23E+00 (l)
F15	1.19E+01	1.75E+00	**9.10E+00+**	**1.54E+00**	-1.71E+00 (l)	8.05E+00	1.16E+00	**5.90E+00+**	**6.69E-01**	-2.28E+00 (l)
F16	1.95E+01	**7.40E-01**	**1.82E+01+**	8.95E-01	-1.63E+00 (l)	1.82E+01	**4.25E-01**	**1.78E+01+**	5.03E-01	-9.17E-01 (l)
F17	6.32E+02	2.73E+02	**4.86E+02+**	**1.86E+02**	-6.24E-01 (m)	1.27E+05	6.61E+04	**6.87E+04+**	**2.45E+04**	-1.17E+00 (l)
F18	**2.43E+01**	**6.59E+00**	5.08E+01-	1.05E+01	3.02E+00 (l)	**3.34E+01**	**1.51E+01**	9.46E+01-	2.04E+01	3.41E+00 (l)
F19	1.11E+01	5.85E-01	**1.04E+01+**	**1.32E-01**	-1.73E+00 (l)	2.25E+01	1.11E+01	**1.01E+01+**	**5.44E-01**	-1.57E+00 (l)
F20	1.22E+01	3.33E+00	**1.18E+01=**	**3.20E+00**	-1.23E-01 (v)	5.83E+02	3.78E+02	**2.93E+02+**	**1.53E+02**	-1.01E+00 (l)
F21	4.08E+02	1.67E+02	**3.89E+02=**	**1.16E+02**	-1.31E-01 (v)	8.06E+04	3.96E+04	**7.86E+04=**	**3.85E+04**	-5.29E-02 (v)
F22	1.54E+02	1.00E+02	**3.72E+01+**	**5.73E+00**	-1.65E+00 (l)	3.57E+02	1.20E+02	**2.32E+02+**	**1.05E+02**	-1.10E+00 (l)
F23	**3.44E+02**	**0.00E+00**	**3.44E+02=**	**0.00E+00**	nan (v)	3.44E+02	**3.82E-02**	**3.44E+02+**	7.75E-02	-1.02E+00 (l)
F24	2.70E+02	**2.01E+00**	**2.03E+02+**	1.04E+01	-8.86E+00 (l)	2.65E+02	1.69E+00	**2.05E+02+**	**8.33E-01**	-4.48E+01 (l)
F25	2.05E+02	3.03E-01	**2.00E+02+**	**0.00E+00**	-2.47E+01 (l)	2.12E+02	1.04E+00	**2.00E+02+**	**0.00E+00**	-1.61E+01 (l)
F26	**1.00E+02**	**4.26E-02**	1.08E+02-	2.71E+01	4.05E-01 (s)	1.00E+02	2.93E-02	**1.00E+02+**	**1.46E-02**	-3.20E+00 (l)
F27	**3.10E+02**	1.92E+01	3.32E+02-	**8.23E-01**	1.61E+00 (l)	8.49E+02	2.08E+02	**5.27E+02+**	**2.96E+01**	-2.17E+00 (l)
F28	1.14E+03	5.63E+01	**1.12E+03=**	**6.63E-01**	-3.59E-01 (s)	1.21E+03	3.29E+01	**1.13E+03+**	**5.24E+00**	-3.66E+00 (l)
F29	8.23E+02	4.19E+01	**8.17E+02=**	**3.64E+01**	-1.34E-01 (v)	4.75E+03	6.58E+03	**2.93E+03+**	**3.83E+03**	-3.38E-01 (s)
F30	8.30E+03	3.38E+02	**8.05E+03+**	**5.92E-01**	-1.05E+00 (l)	7.95E+03	1.10E+03	**7.91E+03+**	**4.18E+02**	-4.89E-02 (v)
number of			17/10/3					20/7/3		

Table S-3
Means and standard deviations of function error values for comparison of PSO-variants and PSO-variants-SEKM on the CEC2014 benchmark suite (D=10) (+/ = /−)

	CLPSO		CLPSO-SEKM			GLPSO		GLPSO-SEKM		
	mean	std	mean	std	Cohen's d (effect size)	mean	std	mean	std	Cohen's d (effect size)
F1	1.43E+07	3.21E+07	**1.62E+05+**	**1.21E+05**	-6.24E-01 (m)	**1.10E+03**	9.72E+02	1.29E+03=	**9.12E+02**	2.06E-01 (s)
F2	2.38E+08	6.19E+08	**9.67E+03+**	**1.79E+03**	-5.43E-01 (m)	5.07E+02	5.89E+02	**4.20E+02=**	**4.12E+02**	-1.71E-01 (v)
F3	1.34E+04	2.18E+04	**2.85E+02+**	**1.71E+02**	-8.48E-01 (l)	1.75E+02	**2.54E+02**	**1.60E+02=**	3.28E+02	-5.15E-02 (v)
F4	5.65E+01	4.53E+01	**3.41E+01+**	**4.79E+00**	-6.95E-01 (m)	**2.44E+01**	1.56E+01	3.00E+01-	**4.35E+00**	4.E-01 (s)
F5	2.03E+01	**1.04E-01**	**1.99E+01=**	2.85E+00	-1.81E-01 (v)	1.81E+01	**6.01E+00**	**1.42E+01=**	9.25E+00	-4.95E-01 (s)
F6	3.09E+00	2.18E+00	**1.76E+00+**	**2.02E+00**	-6.33E-01 (m)	2.02E-01	4.78E-01	**1.22E-01=**	**3.69E-01**	-1.89E-01 (v)
F7	4.63E+00	3.71E+00	**3.70E-01+**	**2.10E-01**	-1.62E+00 (l)	4.66E-02	3.26E-02	**4.14E-02=**	**2.56E-02**	-1.78E-01 (v)
F8	8.97E+00	5.94E+00	**4.E+00+**	**1.99E+00**	-9.24E-01 (l)	**0.00E+00**	**0.00E+00**	**0.00E+00=**	**0.00E+00**	nan (v)
F9	1.59E+01	7.09E+00	**1.07E+01+**	**5.87E+00**	-8.00E-01 (l)	5.76E+00	2.39E+00	**5.36E+00=**	**2.01E+00**	-1.77E-01 (v)
F10	3.83E+02	2.43E+02	**3.17E+02=**	**2.06E+02**	-2.91E-01 (s)	3.51E-01	6.66E-01	**2.41E-01=**	**1.01E-01**	-2.31E-01 (s)
F11	5.12E+02	**2.50E+02**	**3.59E+02+**	2.85E+02	-5.71E-01 (m)	1.24E+02	1.13E+02	**8.54E+01+**	**1.11E+02**	-3.46E-01 (s)
F12	**5.61E-01**	4.34E-01	7.64E-01-	**4.21E-01**	4.74E-01 (s)	7.46E-02	7.40E-02	**4.61E-02=**	**3.54E-02**	-4.90E-01 (s)
F13	2.95E-01	5.93E-02	**2.02E-01+**	**4.01E-02**	-1.83E+00 (l)	6.02E-02	1.61E-02	**4.93E-02+**	**1.27E-02**	-7.45E-01 (m)
F14	5.31E-01	1.31E+00	**1.61E-01=**	**4.58E-02**	-4.00E-01 (s)	8.19E-02	3.96E-02	**2.97E-02+**	**1.30E-02**	-1.77E+00 (l)
F15	5.55E+00	1.17E+01	**2.03E+00=**	**5.64E-01**	-4.24E-01 (s)	7.42E-01	2.32E-01	**7.00E-01=**	**2.23E-01**	-1.84E-01 (v)
F16	2.47E+00	5.01E-01	**2.24E+00+**	**3.57E-01**	-5.14E-01 (m)	1.06E+00	6.03E-01	**5.93E-01+**	**5.40E-01**	-8.24E-01 (l)
F17	1.16E+04	1.13E+04	**9.87E+03=**	**9.92E+03**	-1.64E-01 (v)	1.51E+03	1.85E+03	**1.08E+03=**	**1.37E+03**	-2.62E-01 (s)
F18	**6.13E+03**	**9.61E+03**	7.02E+03=	1.04E+04	8.93E-02 (v)	5.62E+03	5.61E+03	**5.62E+03=**	**3.50E+03**	-6.90E-04 (v)
F19	4.56E+00	**1.19E+00**	**3.19E+00+**	1.35E+00	-1.08E+00 (l)	**5.75E-01**	5.14E-01	6.16E-01=	**4.95E-01**	8.12E-02 (v)
F20	1.18E+03	1.72E+03	**1.02E+02+**	**1.24E+02**	-8.E-01 (l)	5.26E+02	8.69E+02	**2.54E+01+**	**3.42E+01**	-8.14E-01 (l)
F21	3.33E+03	8.85E+03	**3.00E+02+**	**3.22E+02**	-4.84E-01 (s)	3.56E+01	4.75E+01	**2.83E+01=**	**4.17E+01**	-1.64E-01 (v)
F22	6.03E+01	8.08E+01	**2.71E+01+**	**3.63E+01**	-5.30E-01 (m)	**9.90E-01**	**2.82E+00**	6.45E+00=	2.38E+01	3.23E-01 (s)
F23	3.47E+02	1.67E+01	**3.29E+02+**	**4.06E-08**	-1.48E+00 (l)	**3.29E+02**	**0.00E+00**	**3.29E+02=**	**0.00E+00**	nan (v)
F24	1.21E+02	6.83E+00	**1.14E+02+**	**5.00E+00**	-1.10E+00 (l)	1.14E+02	4.74E+00	**1.13E+02+**	**3.87E+00**	-3.94E-01 (s)
F25	1.97E+02	**1.94E+01**	**1.95E+02=**	2.36E+01	-7.04E-02 (v)	1.74E+02	**3.52E+01**	**1.57E+02+**	3.66E+01	-4.75E-01 (s)
F26	1.00E+02	1.72E-01	**1.00E+02+**	**2.72E-02**	-1.20E+00 (l)	1.00E+02	2.11E-02	**1.00E+02+**	**9.55E-03**	-2.01E+00 (l)
F27	3.20E+02	**1.66E+02**	**2.01E+02+**	1.98E+02	-6.52E-01 (m)	1.87E+02	1.87E+02	**1.47E+02+**	**1.86E+02**	-2.15E-01 (s)
F28	5.14E+02	**9.93E+01**	**4.90E+02=**	1.20E+02	-2.18E-01 (s)	4.24E+02	5.80E+01	**4.13E+02=**	**4.91E+01**	-2.07E-01 (s)
F29	**4.19E+04**	**2.86E+05**	1.85E+05=	6.39E+05	2.89E-01 (s)	1.09E+05	4.42E+05	**3.41E+04=**	**2.41E+05**	-2.11E-01 (s)
F30	9.37E+02	4.08E+02	**8.14E+02=**	**2.64E+02**	-3.59E-01 (s)	6.68E+02	1.66E+02	**6.63E+02=**	**1.48E+02**	-2.72E-02 (v)
number pf			19/10/1					9/20/1		

	AWPSO		AWPSO-SEKM			EAPSO		EAPSO-SEKM		
	mean	std	mean	std	Cohen's d (effect size)	mean	std	mean	std	Cohen's d (effect size)
F1	**2.11E+05**	**4.54E+05**	2.49E+05-	6.26E+05	6.93E-02 (v)	**1.54E+03**	**7.37E+02**	1.66E+03=	8.96E+02	1.52E-01 (v)
F2	2.95E+03	4.00E+03	**1.63E+03=**	**6.09E+02**	-4.61E-01 (s)	1.51E+03	1.15E+03	**7.82E+02+**	**8.80E+02**	-7.12E-01 (m)
F3	1.65E+02	3.26E+02	**4.58E+01+**	**5.E+01**	-5.11E-01 (m)	1.69E+03	1.85E+03	**8.27E+02+**	**1.32E+03**	-5.35E-01 (m)
F4	**2.98E+01**	1.21E+01	3.38E+01-	**3.53E+00**	4.50E-01 (s)	2.52E+01	1.57E+01	**9.36E+00+**	**1.17E+01**	-1.15E+00 (l)
F5	2.02E+01	**1.16E-01**	**1.71E+01+**	7.45E+00	-5.86E-01 (m)	2.00E+01	**1.63E-04**	**1.96E+01=**	2.80E+00	-1.98E-01 (v)
F6	**8.57E-01**	**8.70E-01**	1.12E+00=	1.16E+00	2.58E-01 (s)	1.51E+00	1.44E+00	**1.04E+00=**	**1.27E+00**	-3.51E-01 (s)
F7	8.99E-01	1.61E+00	**1.49E-01=**	**6.64E-02**	-6.58E-01 (m)	**9.20E-02**	**6.36E-02**	1.09E-01=	7.32E-02	2.44E-01 (s)
F8	3.99E+00	2.30E+00	**2.13E+00+**	**1.46E+00**	-9.69E-01 (l)	5.87E+00	3.E+00	**5.24E+00=**	**2.92E+00**	-1.81E-01 (v)
F9	8.85E+00	3.70E+00	**6.67E+00+**	**3.23E+00**	-6.26E-01 (m)	1.52E+01	7.08E+00	**1.11E+01+**	**5.33E+00**	-6.62E-01 (m)
F10	1.90E+02	1.07E+02	**1.78E+02=**	**9.22E+01**	-1.22E-01 (v)	**1.85E+02**	1.60E+02	1.98E+02=	**1.30E+02**	8.93E-02 (v)
F11	2.93E+02	**1.58E+02**	**2.75E+02=**	2.11E+02	-9.57E-02 (v)	6.54E+02	3.33E+02	**5.57E+02=**	**2.41E+02**	-3.34E-01 (s)
F12	**9.00E-02**	**6.92E-02**	3.11E-01-	2.98E-01	1.02E+00 (l)	8.58E-02	1.11E-01	**8.54E-02=**	**1.10E-01**	-3.65E-03 (v)
F13	1.79E-01	8.77E-02	**1.18E-01+**	**5.63E-02**	-8.28E-01 (l)	1.59E-01	8.02E-02	**1.44E-01=**	**6.34E-02**	-2.01E-01 (s)
F14	1.45E-01	1.50E-01	**5.89E-02+**	**2.67E-02**	-7.95E-01 (m)	2.64E-01	1.10E-01	**2.23E-01=**	**7.33E-02**	-4.34E-01 (s)
F15	9.40E-01	**3.11E-01**	**7.74E-01+**	3.22E-01	-5.25E-01 (m)	**9.29E-01**	3.85E-01	9.31E-01=	**3.04E-01**	5.87E-03 (v)
F16	2.01E+00	4.76E-01	**1.96E+00=**	**3.96E-01**	-1.04E-01 (v)	2.80E+00	**5.47E-01**	**2.63E+00=**	5.79E-01	-2.98E-01 (s)
F17	2.52E+03	3.03E+03	**1.64E+03+**	**1.57E+03**	-3.62E-01 (s)	3.13E+03	2.55E+03	**2.75E+03=**	**1.98E+03**	-1.65E-01 (v)
F18	6.62E+03	7.40E+03	**2.70E+03+**	**2.75E+03**	-7.01E-01 (m)	**7.62E+03**	**8.10E+03**	9.27E+03=	9.05E+03	1.92E-01 (v)
F19	2.36E+00	1.47E+00	**1.77E+00=**	**6.68E-01**	-5.17E-01 (m)	**1.17E+00**	8.48E-01	1.30E+00=	**8.31E-01**	1.56E-01 (v)
F20	2.67E+02	4.78E+02	**4.16E+01+**	**2.99E+01**	-6.66E-01 (m)	4.46E+03	4.64E+03	**1.81E+03+**	**2.28E+03**	-7.23E-01 (m)
F21	1.68E+02	**1.45E+02**	**1.20E+02+**	1.56E+02	-3.22E-01 (s)	1.90E+02	1.75E+02	**1.80E+02=**	**1.57E+02**	-6.36E-02 (v)
F22	3.50E+01	4.09E+01	**2.62E+01=**	**1.61E+01**	-2.84E-01 (s)	8.93E+01	6.96E+01	**8.06E+01=**	**6.61E+01**	-1.29E-01 (v)
F23	3.30E+02	1.81E+00	**3.29E+02=**	**0.00E+00**	-3.47E-01 (s)	3.27E+02	**1.81E+01**	**3.27E+02=**	1.81E+01	-2.09E-05 (v)
F24	1.16E+02	5.05E+00	**1.14E+02+**	**3.95E+00**	-5.12E-01 (m)	1.25E+02	1.49E+01	**1.18E+02+**	**7.00E+00**	-5.26E-01 (m)
F25	1.73E+02	3.71E+01	**1.44E+02+**	**3.26E+01**	-8.27E-01 (l)	1.83E+02	**2.E+01**	**1.71E+02+**	3.40E+01	-3.86E-01 (s)
F26	1.00E+02	3.98E-02	**1.00E+02+**	**2.07E-02**	-2.03E+00 (l)	1.00E+02	1.16E-01	**1.00E+02+**	**6.E-02**	-5.20E-01 (m)
F27	3.03E+02	**1.62E+02**	**2.93E+02=**	1.66E+02	-5.98E-02 (v)	2.66E+02	**1.60E+02**	**2.55E+02=**	1.62E+02	-6.98E-02 (v)
F28	5.02E+02	8.34E+01	**4.74E+02=**	**6.43E+01**	-3.83E-01 (s)	4.36E+02	6.76E+01	**4.21E+02=**	**6.07E+01**	-2.37E-01 (s)
F29	2.87E+05	8.54E+05	**1.36E+05+**	**4.68E+05**	-2.20E-01 (s)	**6.82E+04**	**3.38E+05**	1.48E+05=	5.12E+05	1.83E-01 (v)
F30	**8.50E+02**	**3.47E+02**	1.03E+03-	4.27E+02	4.69E-01 (s)	**1.08E+03**	**4.05E+02**	1.13E+03=	5.13E+02	1.06E-01 (v)
number of			15/11/4					8/22/0		

Table S-4
Means and standard deviations of function error values for comparison of PSO-variants and PSO-variants-SEKM on the CEC2014 benchmark suite (D=30) (+/ = /−)

	CLPSO		CLPSO-SEKM			GLPSO		GLPSO-SEKM		
	mean	std	mean	std	Cohen's d (effect size)	mean	std	mean	std	Cohen's d (effect size)
F1	1.34E+08	1.25E+08	**8.97E+07=**	**8.97E+07**	-4.03E-01 (s)	2.96E+05	2.00E+05	**2.17E+05+**	**1.70E+05**	-4.25E-01 (s)
F2	1.07E+10	6.26E+09	**2.96E+07+**	**6.95E+06**	-2.41E+00 (l)	3.67E+01	8.12E+01	**9.95E+00+**	**1.80E+01**	-4.55E-01 (s)
F3	1.91E+04	1.40E+04	**5.E+03+**	**1.22E+03**	-1.33E+00 (l)	1.02E+02	1.79E+02	**3.30E+01+**	**3.E+01**	-5.36E-01 (m)
F4	7.65E+02	5.47E+02	**1.33E+02+**	**2.15E+00**	-1.63E+00 (l)	2.74E+01	3.65E+01	**1.70E+01+**	**2.81E+01**	-3.18E-01 (s)
F5	**2.09E+01**	**6.53E-02**	2.09E+01=	7.65E-02	6.37E-02 (v)	**2.09E+01**	1.62E-01	2.09E+01=	**1.46E-01**	2.22E-01 (s)
F6	1.82E+01	**3.39E+00**	**1.67E+01=**	4.07E+00	-3.99E-01 (s)	**4.65E+00**	1.87E+00	4.87E+00=	**1.79E+00**	1.22E-01 (v)
F7	9.43E+01	7.32E+01	**1.31E+00+**	**9.52E-02**	-1.80E+00 (l)	**4.97E-03**	**7.49E-03**	7.92E-03-	8.16E-03	3.76E-01 (s)
F8	9.11E+01	2.08E+01	**6.68E+01+**	**1.91E+01**	-1.22E+00 (l)	7.17E+01	6.39E+01	**0.00E+00+**	**0.00E+00**	-1.59E+00 (l)
F9	1.91E+02	**2.21E+01**	**1.33E+02+**	3.05E+01	-2.19E+00 (l)	4.29E+01	3.94E+01	**2.25E+01+**	**4.62E+00**	-7.27E-01 (m)
F10	2.30E+03	**5.79E+02**	**2.23E+03=**	6.48E+02	-1.19E-01 (v)	1.90E+03	1.87E+03	**2.42E+02+**	**8.45E+02**	-1.14E+00 (l)
F11	**4.90E+03**	**1.36E+03**	5.74E+03-	1.49E+03	5.87E-01 (m)	**1.65E+03**	**1.10E+03**	1.92E+03=	1.43E+03	2.11E-01 (s)
F12	**2.27E+00**	4.57E-01	2.40E+00=	**3.23E-01**	3.35E-01 (s)	1.73E+00	9.08E-01	**1.63E+00=**	**8.96E-01**	-1.10E-01 (v)
F13	2.80E+00	9.75E-01	**5.71E-01+**	**6.62E-02**	-3.22E+00 (l)	2.94E-01	3.92E-02	**1.87E-01+**	**3.17E-02**	-3.00E+00 (l)
F14	4.33E+01	3.02E+01	**1.07E+00+**	**8.18E-02**	-1.98E+00 (l)	3.08E-01	7.79E-02	**2.98E-01=**	**2.93E-02**	-1.73E-01 (v)
F15	1.21E+04	2.84E+04	**1.98E+01+**	**1.77E+00**	-6.00E-01 (m)	1.30E+01	**3.62E+00**	**1.10E+01+**	4.51E+00	-4.83E-01 (s)
F16	1.17E+01	**3.33E-01**	**1.16E+01+**	3.38E-01	-4.55E-01 (s)	1.09E+01	**3.89E-01**	**1.06E+01+**	4.61E-01	-6.60E-01 (m)
F17	3.69E+06	4.57E+06	**2.43E+06+**	**3.09E+06**	-3.23E-01 (s)	3.81E+04	**2.61E+04**	**3.73E+04=**	3.03E+04	-3.06E-02 (v)
F18	6.19E+07	1.44E+08	**2.56E+07=**	**1.03E+08**	-2.90E-01 (s)	**2.43E+03**	**3.05E+03**	3.24E+03=	3.55E+03	2.45E-01 (s)
F19	4.72E+01	3.93E+01	**1.44E+01+**	**1.38E+01**	-1.11E+00 (l)	6.56E+00	1.58E+00	**6.43E+00=**	**1.41E+00**	-8.50E-02 (v)
F20	1.75E+04	1.99E+04	**3.43E+03+**	**1.04E+04**	-8.89E-01 (l)	2.38E+02	5.97E+01	**1.66E+02+**	**2.91E+01**	-1.54E+00 (l)
F21	5.79E+05	1.04E+06	**2.35E+05+**	**2.19E+05**	-4.60E-01 (s)	1.78E+04	1.29E+04	**1.75E+04=**	**1.24E+04**	-2.37E-02 (v)
F22	6.12E+02	2.25E+02	**4.69E+02+**	**1.91E+02**	-6.86E-01 (m)	2.40E+02	**1.01E+02**	**1.E+02+**	1.06E+02	-4.98E-01 (s)
F23	3.63E+02	2.96E+01	**3.27E+02+**	**1.21E+01**	-1.62E+00 (l)	**3.15E+02**	**0.00E+00**	**3.15E+02=**	**0.00E+00**	nan (v)
F24	2.54E+02	1.74E+01	**2.40E+02+**	**2.92E+00**	-1.11E+00 (l)	2.25E+02	2.22E+00	**2.00E+02+**	**3.84E-02**	-1.59E+01 (l)
F25	2.15E+02	8.14E+00	**2.11E+02+**	**5.36E+00**	-5.07E-01 (m)	2.06E+02	**2.89E+00**	**2.03E+02+**	3.34E+00	-8.45E-01 (l)
F26	1.08E+02	2.11E+01	**1.02E+02+**	**1.46E+01**	-2.96E-01 (s)	1.06E+02	2.37E+01	**1.02E+02+**	**1.40E+01**	-2.05E-01 (s)
F27	8.06E+02	2.31E+02	**6.89E+02+**	**2.24E+02**	-5.16E-01 (m)	4.28E+02	6.44E+01	**4.23E+02=**	**5.79E+01**	-9.00E-02 (v)
F28	1.54E+03	3.73E+02	**1.52E+03=**	**3.12E+02**	-6.17E-02 (v)	8.66E+02	5.66E+01	**8.45E+02+**	**3.11E+01**	-4.70E-01 (s)
F29	7.18E+06	7.73E+06	**4.46E+06+**	**6.71E+06**	-3.76E-01 (s)	1.43E+03	4.46E+02	**1.36E+03=**	**3.65E+02**	-1.72E-01 (v)
F30	**8.14E+04**	**7.62E+04**	9.70E+04=	9.57E+04	1.80E-01 (v)	**1.86E+03**	**5.16E+02**	1.93E+03=	6.92E+02	1.28E-01 (v)
number of			21/8/1					16/13/1		

	AWPSO		AWPSO-SEKM			EAPSO		EAPSO-SEKM		
	mean	std	mean	std	Cohen's d (effect size)	mean	std	mean	std	Cohen's d (effect size)
F1	1.31E+07	1.36E+07	**4.36E+06+**	**3.19E+06**	-8.83E-01 (l)	3.92E+05	**2.64E+05**	**3.60E+05=**	2.75E+05	-1.19E-01 (v)
F2	1.34E+09	1.19E+09	**5.39E+01+**	**5.33E+01**	-1.58E+00 (l)	4.69E+01	6.57E+01	**3.64E+01=**	**6.48E+01**	-1.60E-01 (v)
F3	2.07E+02	5.06E+02	**2.65E+01+**	**2.46E+01**	-5.05E-01 (m)	2.63E+02	2.97E+02	**7.07E+01+**	**8.78E+01**	-8.80E-01 (l)
F4	1.45E+02	6.58E+01	**1.01E+02+**	**2.72E+01**	-8.65E-01 (l)	2.93E-01	**1.E-01**	**1.77E-01+**	2.40E-01	-5.40E-01 (m)
F5	**2.09E+01**	9.30E-02	2.09E+01=	**5.12E-02**	4.43E-01 (s)	2.00E+01	**2.60E-02**	**2.00E+01+**	2.71E-02	-1.16E-01 (v)
F6	1.01E+01	3.69E+00	**9.53E+00=**	**3.68E+00**	-1.46E-01 (v)	5.17E+00	**2.48E+00**	**3.47E+00+**	2.79E+00	-6.45E-01 (m)
F7	1.90E+01	1.37E+01	**1.24E-02+**	**1.11E-02**	-1.96E+00 (l)	5.85E-03	**6.09E-03**	**5.22E-03=**	8.83E-03	-8.31E-02 (v)
F8	3.77E+01	1.10E+01	**3.52E+01=**	**7.59E+00**	-2.58E-01 (s)	4.E+01	**1.44E+01**	**4.26E+01+**	1.74E+01	-3.92E-01 (s)
F9	6.15E+01	1.55E+01	**4.75E+01+**	**1.26E+01**	-9.95E-01 (l)	7.19E+01	2.08E+01	**5.84E+01+**	**1.67E+01**	-7.15E-01 (m)
F10	**1.16E+03**	5.54E+02	1.30E+03=	**5.02E+02**	2.61E-01 (s)	1.45E+03	**4.68E+02**	**1.38E+03=**	4.92E+02	-1.59E-01 (v)
F11	2.66E+03	**6.12E+02**	**2.53E+03=**	6.97E+02	-1.95E-01 (v)	2.92E+03	7.11E+02	**2.81E+03=**	**6.16E+02**	-1.68E-01 (v)
F12	**4.09E-01**	**2.65E-01**	7.89E-01-	5.22E-01	9.18E-01 (l)	**4.18E-02**	**3.59E-02**	7.29E-02-	8.13E-02	4.95E-01 (s)
F13	5.43E-01	1.26E-01	**3.44E-01+**	**8.71E-02**	-1.84E+00 (l)	3.38E-01	8.85E-02	**2.93E-01+**	**7.21E-02**	-5.53E-01 (m)
F14	5.30E+00	7.60E+00	**2.70E-01+**	**2.19E-02**	-9.37E-01 (l)	3.12E-01	1.14E-01	**2.73E-01+**	**4.09E-02**	-4.58E-01 (s)
F15	2.61E+01	7.E+01	**4.53E+00+**	**1.22E+00**	-3.87E-01 (s)	**3.54E+00**	**1.01E+00**	3.74E+00=	1.15E+00	1.84E-01 (v)
F16	1.07E+01	7.98E-01	**1.07E+01=**	**6.31E-01**	-6.22E-03 (v)	1.17E+01	**8.10E-01**	**1.13E+01+**	8.98E-01	-5.15E-01 (m)
F17	**4.12E+05**	**4.12E+05**	4.93E+05=	4.93E+05	1.78E-01 (v)	6.27E+04	**3.71E+04**	**5.84E+04=**	3.73E+04	-1.14E-01 (v)
F18	1.67E+05	4.07E+05	**5.95E+03=**	**7.12E+03**	-5.60E-01 (m)	**5.33E+03**	**5.86E+03**	6.17E+03=	6.65E+03	1.34E-01 (v)
F19	1.27E+01	1.22E+01	**9.86E+00=**	**2.24E+00**	-3.28E-01 (s)	6.37E+00	1.17E+01	**3.96E+00=**	**1.27E+00**	-2.90E-01 (s)
F20	5.70E+02	3.42E+02	**4.42E+02=**	**1.94E+02**	-4.63E-01 (s)	9.02E+02	8.99E+02	**5.93E+02+**	**4.47E+02**	-4.35E-01 (s)
F21	2.00E+05	3.05E+05	**1.81E+05=**	**1.62E+05**	-8.09E-02 (v)	3.95E+04	3.44E+04	**2.54E+04+**	**1.83E+04**	-5.10E-01 (m)
F22	3.39E+02	**1.25E+02**	**3.37E+02=**	1.44E+02	-2.09E-02 (v)	4.45E+02	**1.74E+02**	**3.60E+02+**	1.83E+02	-4.80E-01 (s)
F23	3.23E+02	6.59E+00	**3.19E+02+**	**4.68E+00**	-7.09E-01 (m)	**3.15E+02**	**0.00E+00**	**3.15E+02=**	**0.00E+00**	nan (v)
F24	2.30E+02	**7.18E+00**	**2.17E+02+**	9.40E+00	-1.48E+00 (l)	2.23E+02	**5.27E+00**	**2.18E+02+**	9.04E+00	-6.70E-01 (m)
F25	**2.05E+02**	**1.98E+00**	2.06E+02=	2.76E+00	4.52E-01 (s)	**2.04E+02**	**1.47E+00**	2.05E+02=	2.40E+00	3.60E-01 (s)
F26	**1.05E+02**	**1.96E+01**	1.14E+02-	3.47E+01	3.33E-01 (s)	**1.00E+02**	**7.97E-02**	1.06E+02-	2.37E+01	3.44E-01 (s)
F27	5.67E+02	1.64E+02	**5.05E+02=**	**1.54E+02**	-3.91E-01 (s)	**4.21E+02**	7.77E+01	4.35E+02=	**7.76E+01**	1.72E-01 (v)
F28	1.39E+03	3.11E+02	**1.16E+03+**	**1.55E+02**	-9.38E-01 (l)	1.03E+03	2.98E+02	**9.24E+02=**	**1.58E+02**	-4.35E-01 (s)
F29	**1.47E+06**	**3.49E+06**	5.18E+06-	7.64E+06	6.25E-01 (m)	7.61E+05	2.63E+06	**5.48E+05=**	**2.21E+06**	-8.73E-02 (v)
F30	1.46E+04	1.30E+04	**1.01E+04+**	**1.10E+04**	-3.72E-01 (s)	1.94E+03	**6.82E+02**	**1.85E+03=**	8.11E+02	-1.13E-01 (v)
number of			13/14/3					13/15/2		

Table S-5
Means and standard deviations of function error values for comparison of PSO-variants and PSO-variants-SEKM on the CEC2014 benchmark suite (D=50) (+/ = /−)

	CLPSO		CLPSO-SEKM			GLPSO		GLPSO-SEKM		
	mean	std	mean	std	Cohen's d (effect size)	mean	std	mean	std	Cohen's d (effect size)
F1	3.74E+08	2.46E+08	**2.15E+08+**	**1.86E+08**	-7.28E-01 (m)	1.44E+06	4.83E+05	**1.11E+06+**	**3.69E+05**	-7.83E-01 (m)
F2	4.18E+10	1.33E+10	**7.30E+08+**	**1.29E+08**	-4.36E+00 (l)	8.99E+03	7.71E+03	**4.56E+03+**	**3.60E+02**	-8.11E-01 (l)
F3	5.94E+04	1.95E+04	**3.15E+04+**	**3.20E+03**	-2.00E+00 (l)	1.03E+04	1.67E+03	**2.07E+03+**	**3.16E+02**	-6.86E+00 (l)
F4	3.86E+03	2.53E+03	**2.51E+02+**	**1.77E+01**	-2.02E+00 (l)	**8.E+01**	2.73E+01	9.49E+01-	**5.17E-01**	3.19E-01 (s)
F5	2.11E+01	4.01E-02	**2.11E+01=**	**3.79E-02**	-2.13E-01 (s)	2.11E+01	6.13E-02	**2.11E+01=**	**5.41E-02**	-1.03E-02 (v)
F6	3.81E+01	5.08E+00	**3.17E+01+**	**4.02E+00**	-1.39E+00 (l)	**1.22E+01**	3.72E+00	1.50E+01-	**2.19E+00**	9.12E-01 (l)
F7	3.94E+02	1.85E+02	**7.61E+00+**	**1.06E+00**	-2.95E+00 (l)	5.89E-03	7.52E-03	**4.69E-03=**	**6.29E-03**	-1.74E-01 (v)
F8	2.71E+02	3.54E+01	**2.20E+02+**	**3.07E+01**	-1.54E+00 (l)	2.15E+02	1.41E+02	**1.49E+01+**	**5.92E+01**	-1.86E+00 (l)
F9	4.55E+02	4.00E+01	**3.58E+02+**	**2.90E+01**	-2.79E+00 (l)	2.75E+02	1.12E+02	**3.65E+01+**	**5.76E+00**	-3.01E+00 (l)
F10	**7.15E+03**	**9.01E+02**	7.23E+03=	1.13E+03	8.12E-02 (v)	9.76E+03	**2.96E+03**	**8.35E+03=**	4.13E+03	-3.93E-01 (s)
F11	**1.20E+04**	1.84E+03	1.31E+04-	**7.79E+02**	7.71E-01 (m)	1.12E+04	**1.89E+03**	**1.08E+04=**	2.21E+03	-1.99E-01 (v)
F12	**3.24E+00**	3.37E-01	3.34E+00=	**3.16E-01**	3.01E-01 (s)	3.22E+00	**4.20E-01**	**3.21E+00=**	5.49E-01	-3.25E-02 (v)
F13	3.97E+00	9.82E-01	**5.59E-01+**	**3.16E-02**	-4.91E+00 (l)	4.90E-01	7.51E-02	**3.97E-01+**	**5.55E-02**	-1.40E+00 (l)
F14	1.00E+02	5.08E+01	**1.01E+00+**	**9.16E-02**	-2.76E+00 (l)	4.32E-01	1.40E-01	**3.60E-01+**	**2.98E-02**	-7.11E-01 (m)
F15	2.25E+05	3.68E+05	**4.71E+01+**	**4.21E+00**	-8.66E-01 (l)	3.28E+01	**2.15E+00**	**3.13E+01+**	3.22E+00	-5.55E-01 (m)
F16	**2.17E+01**	3.40E-01	2.18E+01=	**3.22E-01**	3.84E-01 (s)	2.09E+01	**3.37E-01**	**2.09E+01=**	3.89E-01	-4.60E-02 (v)
F17	1.44E+07	1.43E+07	**1.31E+07=**	**1.18E+07**	-1.00E-01 (v)	1.41E+05	**7.66E+04**	**1.06E+05+**	7.97E+04	-4.54E-01 (s)
F18	6.36E+08	5.38E+08	**6.18E+06+**	**3.98E+07**	-1.65E+00 (l)	**1.18E+03**	**1.35E+03**	2.08E+03=	2.20E+03	4.89E-01 (s)
F19	2.77E+02	1.76E+02	**8.93E+01+**	**1.15E+02**	-1.27E+00 (l)	3.53E+01	1.95E+01	**1.91E+01+**	**3.15E+00**	-1.15E+00 (l)
F20	3.59E+04	2.68E+04	**6.75E+03+**	**7.30E+03**	-1.48E+00 (l)	1.07E+03	3.12E+02	**5.96E+02+**	**2.93E+02**	-1.56E+00 (l)
F21	5.56E+06	**4.01E+06**	**4.81E+06=**	4.44E+06	-1.77E-01 (v)	**1.01E+05**	5.66E+04	1.08E+05=	**5.03E+04**	1.38E-01 (v)
F22	1.33E+03	**3.62E+02**	**1.16E+03+**	4.39E+02	-4.18E-01 (s)	4.64E+02	2.83E+02	**3.30E+02+**	**1.49E+02**	-5.93E-01 (m)
F23	5.98E+02	1.15E+02	**3.54E+02+**	**2.90E+01**	-2.90E+00 (l)	3.44E+02	**0.00E+00**	**3.27E+02+**	4.69E+01	-5.11E-01 (m)
F24	3.52E+02	3.44E+01	**2.89E+02+**	**3.03E+00**	-2.57E+00 (l)	2.65E+02	**7.92E+00**	**2.43E+02+**	3.30E+01	-9.22E-01 (l)
F25	2.43E+02	2.06E+01	**2.18E+02+**	**1.02E+01**	-1.51E+00 (l)	2.17E+02	5.76E+00	**2.00E+02+**	**0.00E+00**	-4.14E+00 (l)
F26	**1.93E+02**	9.77E+01	2.00E+02=	**8.89E+01**	7.02E-02 (v)	**1.55E+02**	5.01E+01	1.75E+02-	**4.39E+01**	4.12E-01 (s)
F27	1.55E+03	**1.22E+02**	**1.52E+03=**	1.40E+02	-2.97E-01 (s)	**7.02E+02**	9.12E+01	7.42E+02-	**1.91E+01**	6.17E-01 (m)
F28	**3.05E+03**	**5.86E+02**	3.37E+03-	6.24E+02	5.39E-01 (m)	**1.33E+03**	**1.60E+02**	1.35E+03=	1.94E+02	1.18E-01 (v)
F29	4.92E+07	3.35E+07	**1.47E+07+**	**3.13E+07**	-1.06E+00 (l)	1.69E+03	5.19E+02	**1.48E+03=**	**2.58E+02**	-5.22E-01 (m)
F30	1.56E+05	1.23E+05	**9.46E+04+**	**1.20E+05**	-5.02E-01 (m)	9.76E+03	9.69E+02	**9.34E+03+**	**5.18E+02**	-5.42E-01 (m)
number of			20/8/2					16/10/4		

	AWPSO		AWPSO-SEKM			EAPSO		EAPSO-SEKM		
	mean	std	mean	std	Cohen's d (effect size)	mean	std	mean	std	Cohen's d (effect size)
F1	2.86E+07	2.54E+07	**1.83E+07+**	**1.97E+07**	-4.49E-01 (s)	1.42E+06	**5.20E+05**	**1.39E+06=**	5.42E+05	-6.42E-02 (v)
F2	8.27E+09	4.18E+09	**1.06E+03+**	**3.41E+02**	-2.79E+00 (l)	**8.25E+03**	8.38E+03	1.65E+04-	**7.84E+02**	1.38E+00 (l)
F3	3.77E+03	2.54E+03	**1.47E+03+**	**2.24E+02**	-1.28E+00 (l)	4.08E+03	2.81E+03	**1.36E+03+**	**6.08E+02**	-1.34E+00 (l)
F4	4.86E+02	2.50E+02	**9.83E+01+**	**6.98E-04**	-2.19E+00 (l)	8.71E+01	2.38E+01	**1.92E+01+**	**7.16E-01**	-4.04E+00 (l)
F5	**2.10E+01**	9.45E-02	2.11E+01-	**7.05E-02**	4.98E-01 (s)	**2.00E+01**	**3.46E-02**	2.02E+01=	3.77E-01	6.00E-01 (m)
F6	2.30E+01	5.24E+00	**2.30E+01=**	**4.24E+00**	-2.04E-03 (v)	**9.62E+00**	**3.38E+00**	1.03E+01=	4.26E+00	1.66E-01 (v)
F7	6.83E+01	3.91E+01	**7.34E-03+**	**1.03E-02**	-2.47E+00 (l)	**8.70E-04**	**2.74E-03**	2.17E-03=	4.97E-03	3.25E-01 (s)
F8	1.10E+02	2.28E+01	**7.64E+01+**	**1.86E+01**	-1.63E+00 (l)	1.07E+02	3.04E+01	**6.66E+01+**	**1.64E+01**	-1.64E+00 (l)
F9	1.54E+02	3.33E+01	**9.36E+01+**	**1.84E+01**	-2.24E+00 (l)	1.16E+02	3.13E+01	**9.63E+01+**	**1.55E+01**	-8.13E-01 (l)
F10	3.12E+03	**7.99E+02**	**2.90E+03=**	8.23E+02	-2.63E-01 (s)	**2.78E+03**	7.98E+02	2.96E+03=	**6.96E+02**	2.30E-01 (s)
F11	5.69E+03	**8.48E+02**	**5.51E+03=**	1.05E+03	-1.E-01 (v)	5.40E+03	**8.00E+02**	**5.36E+03=**	9.34E+02	-5.24E-02 (v)
F12	**5.62E-01**	**2.28E-01**	1.06E+00-	6.80E-01	9.74E-01 (l)	**4.17E-02**	**4.27E-02**	4.40E-02=	4.59E-02	5.18E-02 (v)
F13	6.63E-01	1.33E-01	**4.32E-01+**	**5.61E-02**	-2.25E+00 (l)	**5.06E-01**	9.25E-02	5.52E-01-	**5.68E-02**	5.94E-01 (m)
F14	1.12E+01	1.15E+01	**1.15E+00+**	**9.81E-02**	-1.23E+00 (l)	4.00E-01	2.18E-01	**2.91E-01+**	**1.77E-02**	-7.05E-01 (m)
F15	4.53E+02	1.41E+03	**1.34E+01+**	**2.74E+00**	-4.41E-01 (s)	**6.77E+00**	**1.53E+00**	7.66E+00-	1.91E+00	5.14E-01 (m)
F16	1.96E+01	**9.54E-01**	**1.96E+01=**	1.02E+00	-1.76E-02 (v)	2.07E+01	1.01E+00	**2.05E+01=**	**8.87E-01**	-1.61E-01 (v)
F17	2.13E+06	2.26E+06	**1.69E+06=**	**1.63E+06**	-2.24E-01 (s)	1.81E+05	9.77E+04	**1.62E+05=**	**9.00E+04**	-1.94E-01 (v)
F18	**4.72E+07**	**1.13E+08**	1.13E+08=	2.05E+08	4.01E-01 (s)	**1.92E+03**	1.40E+03	2.65E+03-	**6.93E+02**	6.64E-01 (m)
F19	5.27E+01	2.65E+01	**4.49E+01=**	**1.67E+01**	-3.50E-01 (s)	1.39E+01	5.74E+00	**1.16E+01+**	**1.95E+00**	-5.45E-01 (m)
F20	1.23E+03	5.53E+02	**8.40E+02+**	**1.E+02**	-9.33E-01 (l)	1.10E+03	**6.00E+02**	**9.33E+02+**	6.18E+02	-2.67E-01 (s)
F21	7.58E+05	1.26E+06	**5.64E+05+**	**8.09E+05**	-1.84E-01 (v)	**1.23E+05**	7.02E+04	1.24E+05=	**4.92E+04**	1.33E-02 (v)
F22	**8.83E+02**	2.99E+02	9.09E+02=	**2.98E+02**	8.68E-02 (v)	9.41E+02	3.18E+02	**9.33E+02=**	**2.92E+02**	-2.69E-02 (v)
F23	3.78E+02	4.04E+01	**3.57E+02+**	**1.43E+01**	-7.08E-01 (m)	**3.44E+02**	**0.00E+00**	**3.44E+02+**	**0.00E+00**	nan (v)
F24	2.84E+02	1.09E+01	**2.73E+02+**	**7.04E-01**	-1.37E+00 (l)	**2.70E+02**	4.55E+00	2.71E+02=	**1.31E+00**	1.87E-01 (v)
F25	2.13E+02	3.86E+00	**2.00E+02+**	**3.32E-05**	-4.64E+00 (l)	**2.09E+02**	**1.89E+00**	2.09E+02=	4.28E+00	1.37E-01 (v)
F26	**1.46E+02**	4.89E+01	1.65E+02-	**4.81E+01**	3.99E-01 (s)	1.34E+02	5.34E+01	**1.24E+02+**	**4.28E+01**	-2.17E-01 (s)
F27	1.14E+03	**9.95E+01**	**1.08E+03+**	1.28E+02	-5.21E-01 (m)	6.54E+02	1.15E+02	**6.22E+02=**	**1.12E+02**	-2.83E-01 (s)
F28	2.75E+03	**6.87E+02**	**2.50E+03=**	7.92E+02	-3.33E-01 (s)	1.77E+03	**5.51E+02**	**1.73E+03=**	5.71E+02	-6.77E-02 (v)
F29	1.50E+07	3.22E+07	**1.43E+07=**	**3.21E+07**	-2.31E-02 (v)	5.31E+06	1.49E+07	**9.23E+05=**	**6.57E+06**	-3.81E-01 (s)
F30	4.62E+04	**3.14E+04**	**4.19E+04+**	6.98E+04	-8.06E-02 (v)	9.72E+03	1.06E+03	**9.53E+03=**	**5.93E+02**	-2.23E-01 (s)
number of			17/10/3					9/17/4		

Table S-6
Means and standard deviations of function error values for DE, DE-SEKM, PSO and PSO-SEKM at D=10 (+/ = /−)

	DE		DE-SEKM			PSO		PSO-SEKM		
	mean	std	mean	std	Cohen's d (effect size)	mean	std	mean	std	Cohen's d (effect size)
F1	6.61E+06	5.86E+06	**1.78E+06+**	**1.64E+06**	-1.12E+00 (l)	5.80E+06	1.01E+07	**2.49E+06=**	**4.86E+06**	-4.16E-01 (s)
F2	1.11E+07	1.92E+07	**5.76E+06+**	**1.44E+07**	-3.16E-01 (s)	2.21E+08	5.81E+08	**4.54E+03+**	**5.33E+03**	-5.37E-01 (m)
F3	2.73E+04	1.13E+04	**1.37E+04+**	**8.11E+03**	-1.38E+00 (l)	1.11E+04	1.49E+04	**3.54E+03+**	**7.32E+03**	-6.41E-01 (m)
F4	4.27E+01	2.16E+01	**3.59E+01=**	**8.36E+00**	-4.15E-01 (s)	4.68E+01	3.86E+01	**3.42E+01=**	**1.32E+01**	-4.38E-01 (s)
F5	**2.01E+01**	1.10E-01	2.03E+01-	**8.54E-02**	1.91E+00 (l)	**2.00E+01**	**7.11E-02**	2.01E+01=	8.96E-02	3.40E-02 (v)
F6	4.57E+00	**1.80E+00**	**4.08E+00=**	1.81E+00	-2.72E-01 (s)	3.68E+00	2.34E+00	**2.72E+00=**	**1.68E+00**	-4.69E-01 (s)
F7	1.10E+00	9.72E-01	**5.38E-01+**	**2.46E-01**	-7.94E-01 (m)	7.57E+00	3.98E+00	**8.14E-01+**	**1.36E+00**	-2.27E+00 (l)
F8	2.69E+01	**9.56E+00**	**2.65E+01=**	1.07E+01	-4.83E-02 (v)	2.52E+01	1.53E+01	**2.49E+01=**	**1.01E+01**	-2.61E-02 (v)
F9	2.68E+01	1.17E+01	**2.34E+01=**	**8.61E+00**	-3.34E-01 (s)	2.E+01	1.12E+01	**2.40E+01+**	**1.00E+01**	-4.53E-01 (s)
F10	**8.E+02**	**3.27E+02**	9.09E+02=	3.31E+02	6.22E-02 (v)	7.56E+02	**2.79E+02**	**6.50E+02+**	3.75E+02	-3.22E-01 (s)
F11	**8.12E+02**	3.17E+02	9.62E+02-	**3.07E+02**	4.80E-01 (s)	9.98E+02	**3.11E+02**	**8.14E+02+**	3.51E+02	-5.54E-01 (m)
F12	**5.99E-01**	3.39E-01	8.09E-01-	**2.83E-01**	6.72E-01 (m)	**1.77E-01**	**9.85E-02**	2.54E-01=	2.96E-01	3.53E-01 (s)
F13	2.77E-01	1.46E-01	**1.85E-01+**	**9.78E-02**	-7.37E-01 (m)	4.84E-01	1.13E-01	**3.07E-01+**	**1.12E-01**	-1.57E+00 (l)
F14	3.49E-01	1.80E-01	**2.59E-01+**	**1.50E-01**	-5.42E-01 (m)	1.08E+00	7.74E-01	**3.13E-01+**	**1.16E-01**	-1.38E+00 (l)
F15	3.28E+00	2.75E+00	**2.12E+00+**	**1.19E+00**	-5.44E-01 (m)	5.27E+00	1.34E+01	**1.33E+00=**	**6.11E-01**	-4.14E-01 (s)
F16	3.40E+00	4.25E-01	**3.10E+00+**	**3.82E-01**	-7.49E-01 (m)	3.34E+00	**3.31E-01**	**3.16E+00+**	3.72E-01	-5.26E-01 (m)
F17	3.94E+04	9.50E+04	**1.09E+04+**	**4.48E+04**	-3.84E-01 (s)	2.84E+05	7.86E+05	**9.81E+03+**	**1.73E+04**	-4.93E-01 (s)
F18	7.38E+03	8.02E+03	**6.15E+03=**	**7.61E+03**	-1.57E-01 (v)	9.86E+03	**1.21E+04**	**8.12E+03=**	1.22E+04	-1.43E-01 (v)
F19	4.37E+00	1.46E+00	**4.11E+00=**	**1.02E+00**	-2.05E-01 (s)	5.41E+00	2.08E+00	**4.78E+00=**	**1.83E+00**	-3.21E-01 (s)
F20	6.26E+03	8.11E+03	**3.21E+03+**	**3.92E+03**	-4.79E-01 (s)	**1.12E+04**	**1.46E+04**	1.35E+04=	6.83E+04	4.62E-02 (v)
F21	7.94E+03	7.81E+03	**6.47E+03=**	**6.59E+03**	-2.03E-01 (s)	4.62E+03	8.20E+03	**3.16E+03+**	**8.01E+03**	-1.80E-01 (v)
F22	1.02E+02	8.35E+01	**8.94E+01=**	**5.54E+01**	-1.81E-01 (v)	2.08E+02	**7.43E+01**	**1.31E+02+**	8.54E+01	-9.65E-01 (l)
F23	3.39E+02	1.12E+01	**3.33E+02+**	**5.80E+00**	-7.18E-01 (m)	3.43E+02	1.64E+01	**3.37E+02+**	**1.32E+01**	-4.44E-01 (s)
F24	1.44E+02	2.16E+01	**1.31E+02+**	**1.23E+01**	-7.37E-01 (m)	1.37E+02	**8.72E+00**	**1.30E+02+**	9.24E+00	-8.13E-01 (l)
F25	1.94E+02	**1.89E+01**	**1.86E+02+**	2.66E+01	-3.58E-01 (s)	1.98E+02	**1.44E+01**	**1.91E+02+**	2.23E+01	-3.78E-01 (s)
F26	**1.00E+02**	**1.29E-01**	1.00E+02=	1.34E-01	2.59E-01 (s)	**1.00E+02**	1.86E-01	1.00E+02=	**1.77E-01**	1.17E-01 (v)
F27	3.64E+02	**9.69E+01**	**3.07E+02=**	1.61E+02	-4.32E-01 (s)	3.31E+02	1.76E+02	**3.04E+02+**	**1.70E+02**	-1.54E-01 (v)
F28	**5.16E+02**	**9.43E+01**	5.43E+02=	1.54E+02	2.09E-01 (s)	5.78E+02	**9.77E+01**	**5.01E+02+**	1.27E+02	-6.81E-01 (m)
F29	**1.31E+05**	9.31E+05	1.91E+05=	**6.69E+05**	7.39E-02 (v)	**1.45E+03**	**8.38E+02**	1.77E+05-	6.33E+05	3.93E-01 (s)
F30	2.40E+03	8.48E+02	**2.02E+03+**	**7.79E+02**	-4.68E-01 (s)	1.13E+03	**2.69E+02**	**1.12E+03=**	3.87E+02	-3.71E-02 (v)
number of			14/13/3			number of		17/12/1		

Table S-7
Means and standard deviations of function error values for comparison of LSHADE-SEKM and LSHADE-WOR on the CEC2014 benchmark suite (D=10) (+/ = /−)

	LSHADE-WOR		LSHADE-SEKM		
	mean	std	mean	std	Cohen's d (effect size)
F1	4.35E+04	3.11E+05	**3.63E+04=**	**1.82E+05**	-2.83E-02 (v)
F2	**0.00E+00**	**0.00E+00**	**0.00E+00=**	**0.00E+00**	nan (v)
F3	**8.75E+01**	**6.25E+02**	3.11E+02=	1.27E+03	2.24E-01 (s)
F4	**3.48E+01**	**0.00E+00**	**3.48E+01=**	**0.00E+00**	nan (v)
F5	1.63E+01	**7.42E+00**	**1.41E+01=**	8.80E+00	-2.72E-01 (s)
F6	**2.35E-01**	**7.71E-01**	2.97E-01=	1.03E+00	6.84E-02 (v)
F7	3.61E-02	2.54E-01	**2.90E-04=**	**1.45E-03**	-1.99E-01 (v)
F8	**0.00E+00**	**0.00E+00**	**0.00E+00=**	**0.00E+00**	nan (v)
F9	9.97E-01	2.43E+00	**1.95E-02+**	**1.39E-01**	-5.67E-01 (m)
F10	2.09E+02	**2.66E+02**	**1.83E+02=**	2.66E+02	-9.52E-02 (v)
F11	2.33E+02	4.17E+02	**1.67E+02=**	**3.47E+02**	-1.73E-01 (v)
F12	**3.87E-01**	**2.78E-01**	4.03E-01=	3.09E-01	5.37E-02 (v)
F13	6.34E-02	5.13E-02	**5.26E-02+**	**9.71E-03**	-2.95E-01 (s)
F14	**5.25E-02**	**1.18E-02**	6.16E-02-	1.47E-02	6.82E-01 (m)
F15	**4.29E-01**	**7.46E-02**	5.51E-01=	9.89E-01	1.75E-01 (v)
F16	1.33E+00	7.19E-01	**6.29E-01+**	**4.98E-01**	-1.13E+00 (l)
F17	**1.15E+03**	**8.23E+03**	2.14E+03=	1.53E+04	8.06E-02 (v)
F18	**2.04E-01**	**1.62E-01**	3.12E-01=	5.89E-01	2.48E-01 (s)
F19	**1.45E-01**	**4.81E-01**	2.72E-01=	7.72E-01	1.97E-01 (v)
F20	**2.17E-01**	1.83E-01	2.44E-01=	**1.80E-01**	1.49E-01 (v)
F21	**1.31E+01**	**9.06E+01**	1.79E+02=	9.36E+02	2.50E-01 (s)
F22	2.40E+00	1.00E+01	**1.33E+00+**	**6.66E+00**	-1.27E-01 (v)
F23	**3.29E+02**	**0.00E+00**	3.29E+02=	1.42E-01	1.98E-01 (v)
F24	**1.00E+02**	**3.29E+00**	1.05E+02-	3.38E+00	1.45E+00 (l)
F25	1.11E+02	9.94E+00	**1.05E+02+**	**7.34E+00**	-6.21E-01 (m)
F26	1.00E+02	7.08E-02	**1.00E+02=**	**5.23E-02**	-1.66E-01 (v)
F27	**1.45E+00**	**1.33E+00**	7.77E+00-	4.18E+01	2.13E-01 (s)
F28	**3.70E+02**	**2.73E+00**	3.73E+02-	7.03E+00	6.00E-01 (m)
F29	**2.94E+02**	**2.54E+02**	4.96E+02=	5.71E+02	4.56E-01 (s)
F30	**4.75E+02**	**3.46E+01**	4.80E+02=	7.28E+01	1.01E-01 (v)
number of +/=/-			5/21/4		

Table S-8
Means and standard deviations of function error values for comparison of LSHADE-SEKM and LSHADE-ReLU on the CEC2014 benchmark suite (D=10) (+/ = /−)

	LSHADE-ReLU		LSHADE-SEKM		
	mean	std	mean	std	Cohen's d (effect size)
F1	**2.66E+04**	1.90E+05	3.63E+04=	**1.82E+05**	5.19E-02 (v)
F2	**0.00E+00**	**0.00E+00**	**0.00E+00=**	**0.00E+00**	nan (v)
F3	**0.00E+00**	**0.00E+00**	3.11E+02=	1.27E+03	3.47E-01 (s)
F4	3.48E+01	3.10E-01	**3.48E+01=**	**0.00E+00**	-2.81E-01 (s)
F5	1.77E+01	**6.15E+00**	**1.41E+01=**	8.80E+00	-4.78E-01 (s)
F6	**1.15E-01**	**8.19E-01**	2.97E-01=	1.03E+00	1.96E-01 (v)
F7	6.03E-02	3.01E-01	**2.90E-04=**	**1.45E-03**	-2.82E-01 (s)
F8	**0.00E+00**	**0.00E+00**	**0.00E+00=**	**0.00E+00**	nan (v)
F9	**1.38E-07**	**6.84E-07**	1.95E-02=	1.39E-01	1.98E-01 (v)
F10	2.00E+02	2.93E+02	**1.83E+02=**	**2.66E+02**	-5.87E-02 (v)
F11	1.98E+02	**3.45E+02**	**1.67E+02+**	3.47E+02	-9.13E-02 (v)
F12	4.16E-01	**2.81E-01**	**4.03E-01=**	3.09E-01	-4.53E-02 (v)
F13	6.76E-02	5.85E-02	**5.26E-02+**	**9.71E-03**	-3.60E-01 (s)
F14	8.18E-02	4.49E-02	**6.16E-02+**	**1.47E-02**	-6.06E-01 (m)
F15	**4.41E-01**	**8.23E-02**	5.51E-01-	9.89E-01	1.56E-01 (v)
F16	**4.48E-01**	**4.59E-01**	6.29E-01-	4.98E-01	3.78E-01 (s)
F17	**3.06E+00**	**4.05E+00**	2.14E+03=	1.53E+04	1.98E-01 (v)
F18	**2.26E-01**	**1.84E-01**	3.12E-01=	5.89E-01	1.95E-01 (v)
F19	3.48E-01	1.13E+00	**2.72E-01+**	**7.72E-01**	-7.83E-02 (v)
F20	**2.04E-01**	**1.72E-01**	2.44E-01=	1.80E-01	2.25E-01 (s)
F21	7.74E+02	4.07E+03	**1.79E+02+**	**9.36E+02**	-2.01E-01 (s)
F22	**1.10E-01**	**7.69E-02**	1.33E+00=	6.66E+00	2.59E-01 (s)
F23	3.30E+02	5.79E-01	**3.29E+02=**	**1.42E-01**	-2.21E-01 (s)
F24	**1.03E+02**	8.02E+00	1.05E+02-	**3.38E+00**	3.84E-01 (s)
F25	1.22E+02	**5.93E+00**	**1.05E+02+**	7.34E+00	-2.57E+00 (l)
F26	1.00E+02	5.81E-02	**1.00E+02+**	**5.23E-02**	-3.08E-01 (s)
F27	**2.54E+00**	**7.78E+00**	7.77E+00-	4.18E+01	1.74E-01 (v)
F28	3.75E+02	2.18E+01	**3.73E+02+**	**7.03E+00**	-1.20E-01 (v)
F29	**4.48E+02**	**5.64E+02**	4.96E+02=	5.71E+02	8.48E-02 (v)
F30	**4.80E+02**	**5.22E+01**	4.80E+02=	7.28E+01	4.34E-04 (v)
number of (+/=/-)			8/18/4		

Table S-9
Means and standard deviations of function error values for comparison of LSHADE-SEKM and LSHADE-ML on the CEC2014 benchmark suite (D=10) (+/ = /−)

	LSHADE-ML		LSHADE-SEKM		
	mean	std	mean	std	Cohen's d (effect size)
F1	**1.15E+04**	**8.20E+04**	3.63E+04=	1.82E+05	1.76E-01 (v)
F2	**0.00E+00**	**0.00E+00**	**0.00E+00=**	**0.00E+00**	nan (v)
F3	**0.00E+00**	**0.00E+00**	3.11E+02=	1.27E+03	3.47E-01 (s)
F4	**3.48E+01**	**0.00E+00**	**3.48E+01=**	**0.00E+00**	nan (v)
F5	1.91E+01	**4.47E+00**	**1.41E+01+**	8.80E+00	-7.10E-01 (m)
F6	**6.15E-02**	**4.39E-01**	2.97E-01=	1.03E+00	2.98E-01 (s)
F7	3.51E-02	2.48E-01	**2.90E-04=**	**1.45E-03**	-1.98E-01 (v)
F8	1.64E-01	1.17E+00	**0.00E+00=**	**0.00E+00**	-1.98E-01 (v)
F9	6.45E-01	6.55E-01	**1.95E-02+**	**1.39E-01**	-1.32E+00 (l)
F10	**1.61E+02**	**2.39E+02**	1.83E+02=	2.66E+02	8.72E-02 (v)
F11	**1.42E+02**	**2.E+02**	1.67E+02=	3.47E+02	7.65E-02 (v)
F12	**3.92E-01**	**2.64E-01**	4.03E-01=	3.09E-01	3.66E-02 (v)
F13	**5.02E-02**	2.99E-02	5.26E-02-	**9.71E-03**	1.06E-01 (v)
F14	**5.28E-02**	1.49E-02	6.16E-02-	**1.47E-02**	5.98E-01 (m)
F15	**4.07E-01**	**6.41E-02**	5.51E-01=	9.89E-01	2.05E-01 (s)
F16	**6.15E-01**	**4.91E-01**	6.29E-01=	4.98E-01	2.91E-02 (v)
F17	**2.17E+00**	**2.56E+00**	2.14E+03=	1.53E+04	1.98E-01 (v)
F18	**2.06E-01**	**1.86E-01**	3.12E-01=	5.89E-01	2.42E-01 (s)
F19	**5.77E-02**	**1.30E-01**	2.72E-01=	7.72E-01	3.87E-01 (s)
F20	**2.27E-01**	**1.75E-01**	2.44E-01=	1.80E-01	9.36E-02 (v)
F21	4.71E+02	1.72E+03	**1.79E+02=**	**9.36E+02**	-2.10E-01 (s)
F22	**1.15E-01**	**6.21E-02**	1.33E+00-	6.66E+00	2.58E-01 (s)
F23	3.30E+02	5.29E-01	**3.29E+02=**	**1.42E-01**	-1.40E-01 (v)
F24	**1.03E+02**	5.50E+00	1.05E+02-	**3.38E+00**	5.82E-01 (m)
F25	1.17E+02	**0.00E+00**	**1.05E+02+**	7.34E+00	-2.26E+00 (l)
F26	**1.00E+02**	**3.86E-02**	1.00E+02=	5.23E-02	4.16E-02 (v)
F27	**1.56E+00**	**1.39E+00**	7.77E+00-	4.18E+01	2.10E-01 (s)
F28	3.75E+02	2.09E+01	**3.73E+02=**	**7.03E+00**	-8.37E-02 (v)
F29	**4.84E+02**	5.99E+02	4.96E+02=	**5.71E+02**	2.01E-02 (v)
F30	**4.72E+02**	**3.44E+01**	4.80E+02=	7.28E+01	1.56E-01 (v)
number of +/=/-			3/22/5		