

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

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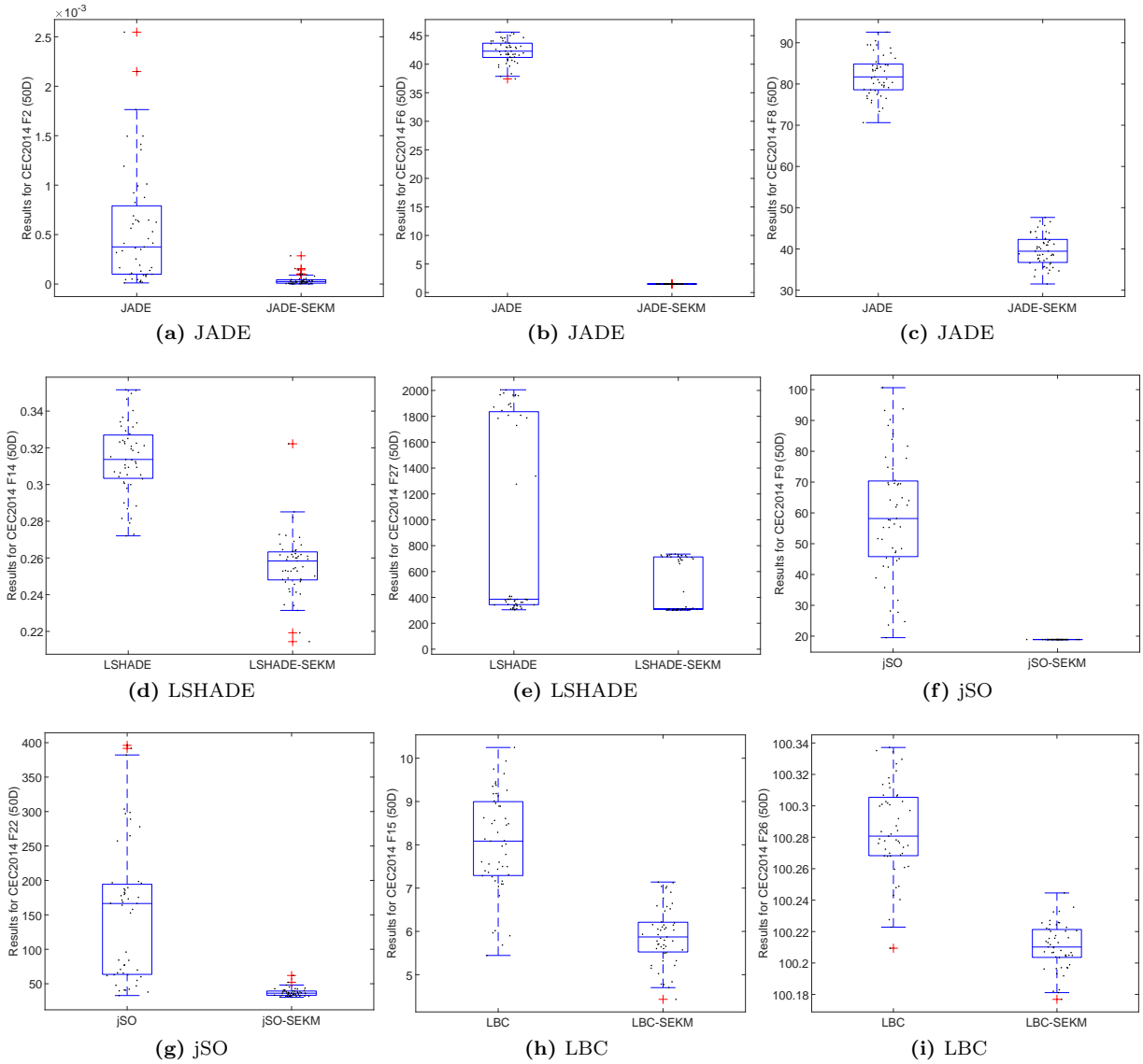


Fig. S-1. Box graph of results obtained by DE-variants and DE-variants-SEKM on CEC2014 test suite ($D = 50$)

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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	mean	std	mean	std
F1	0.00E+00	0.00E+00	0.00E+00=	0.00E+00	1.31E+06	9.36E+06	3.63E+04=	1.82E+05
F2	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	0.00E+00	0.00E+00	0.00E+00=	0.00E+00	2.99E+02	2.14E+03	3.11E+02=	1.27E+03
F4	2.80E+01	1.39E+01	9.71E+00+	1.17E+01	3.38E+01	1.46E+01	3.48E+01=	0.00E+00
F5	1.98E+01	1.42E+00	1.96E+01=	1.52E+00	1.97E+01	2.65E+00	1.41E+01+	8.80E+00
F6	3.21E-01	5.60E-01	2.19E-05+	1.54E-04	2.26E-01	8.78E-01	2.97E-01=	1.03E+00
F7	1.61E-02	1.03E-02	1.90E-02=	1.14E-02	9.17E-04	3.72E-03	2.90E-04=	1.45E-03
F8	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	4.46E+00	8.70E-01	2.09E+00+	9.30E-01	1.95E+00	8.13E-01	1.95E-02+	1.39E-01
F10	7.80E+00	4.37E+00	5.37E+00+	3.66E+00	2.38E+02	3.60E+02	1.83E+02=	2.66E+02
F11	2.11E+02	9.40E+01	1.50E+02+	7.90E+01	3.80E+02	4.69E+02	1.67E+02+	3.47E+02
F12	3.46E-01	9.13E-02	3.63E-01=	6.73E-02	5.03E-01	3.30E-01	4.03E-01=	3.09E-01
F13	1.01E-01	1.83E-02	8.49E-02+	1.78E-02	6.52E-02	1.63E-02	5.26E-02+	9.71E-03
F14	1.13E-01	3.19E-02	9.04E-02+	2.62E-02	1.07E-01	3.39E-02	6.16E-02+	1.47E-02
F15	6.45E-01	1.18E-01	5.94E-01+	8.60E-02	4.19E-01	8.34E-02	5.51E-01=	9.89E-01
F16	2.13E+00	2.25E-01	1.41E+00+	2.89E-01	1.65E+00	6.00E-01	6.29E-01+	4.98E-01
F17	1.32E+01	2.79E+01	1.24E+01=	2.09E+01	3.40E+00	4.47E+00	2.14E+03=	1.53E+04
F18	6.84E-01	5.23E-01	6.54E-01=	4.24E-01	2.19E-01	1.82E-01	3.12E-01=	5.89E-01
F19	4.25E-01	2.03E-01	3.66E-01+	1.81E-01	3.45E-01	1.00E+00	2.72E-01+	7.72E-01
F20	4.94E-01	1.51E-01	4.69E-01=	1.34E-01	2.03E-01	1.73E-01	2.44E-01=	1.80E-01
F21	1.54E+00	1.46E+00	1.28E+00=	6.18E-01	1.45E+02	1.03E+03	1.79E+02=	9.36E+02
F22	2.52E+00	1.97E+00	2.09E+00=	1.81E+00	3.56E+00	2.20E+01	1.33E+00+	6.66E+00
F23	3.29E+02	0.00E+00	3.29E+02=	0.00E+00	3.29E+02	0.00E+00	3.29E+02=	1.42E-01
F24	1.10E+02	2.11E+00	1.05E+02+	3.28E+00	1.06E+02	2.66E+00	1.05E+02=	3.38E+00
F25	1.67E+02	4.00E+01	1.14E+02+	1.85E+01	1.48E+02	3.83E+01	1.05E+02+	7.34E+00
F26	1.00E+02	2.22E-02	1.00E+02+	1.30E-02	1.00E+02	2.78E-01	1.00E+02+	5.23E-02
F27	8.62E+01	1.55E+02	7.86E+01=	1.49E+02	7.14E+01	1.46E+02	7.77E+00+	4.18E+01
F28	3.93E+02	4.29E+01	3.92E+02+	3.98E+01	3.91E+02	2.30E+01	3.73E+02+	7.03E+00
F29	2.22E+02	7.40E-01	2.23E+02=	8.30E-01	1.26E+03	4.48E+03	4.96E+02=	5.71E+02
F30	4.73E+02	2.13E+01	4.68E+02=	1.01E+01	6.18E+02	5.16E+02	4.80E+02=	7.28E+01
number of			12/18/0				14/16/0	
	jSO		jSO-SEKM		LBC		LBC-SEKM	
	mean	std	mean	std	mean	std	mean	std
F1	0.00E+00	0.00E+00	0.00E+00=	0.00E+00	3.73E+01	5.44E+01	8.90E+01=	1.95E+02
F2	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	0.00E+00	0.00E+00	0.00E+00=	0.00E+00	0.00E+00	0.00E+00	0.00E+00=	0.00E+00
F4	2.81E+01	1.37E+01	3.48E+01=	0.00E+00	2.91E+00	6.29E+00	5.66E-02+	5.04E-02
F5	1.91E+01	3.30E+00	4.70E-01+	2.85E+00	1.62E+01	7.50E+00	5.21E+00+	7.98E+00
F6	1.75E-02	1.25E-01	0.00E+00=	0.00E+00	9.74E-04	4.96E-03	7.47E-07+	4.85E-06
F7	1.25E-07	7.97E-07	1.45E-04=	1.04E-03	2.38E-03	3.79E-03	1.50E-03=	3.32E-03
F8	4.49E-01	6.39E-01	0.00E+00+	0.00E+00	0.00E+00	0.00E+00	0.00E+00=	0.00E+00
F9	2.17E+00	8.86E-01	9.95E-01+	0.00E+00	2.81E+00	8.36E-01	2.66E+00=	1.06E+00
F10	5.02E+01	3.69E+01	3.57E+01+	2.62E+01	0.00E+00	0.00E+00	0.00E+00=	0.00E+00
F11	1.36E+02	1.29E+02	3.35E+01+	4.83E+01	9.64E+01	7.32E+01	4.91E+01+	5.01E+01
F12	3.83E-01	2.37E-01	3.43E-01=	2.18E-01	1.15E-01	5.47E-02	9.53E-02=	4.13E-02
F13	7.35E-02	3.35E-02	7.00E-02=	2.27E-02	1.02E-01	2.70E-02	8.03E-02+	2.55E-02
F14	1.08E-01	4.82E-02	9.70E-02=	3.15E-02	1.08E-01	3.30E-02	1.19E-01=	3.19E-02
F15	4.89E-01	1.18E-01	5.04E-01=	1.23E-01	4.38E-01	9.23E-02	4.69E-01=	8.24E-02
F16	1.14E+00	4.44E-01	2.44E-01+	7.00E-02	1.61E+00	2.90E-01	1.39E+00+	2.49E-01
F17	4.00E+00	4.15E+00	5.28E+00=	6.99E+00	7.22E+00	5.44E+00	7.37E+00=	7.32E+00
F18	1.97E-01	1.67E-01	1.57E-01=	1.46E-01	2.87E-01	2.88E-01	2.96E-01=	3.23E-01
F19	1.57E-01	2.07E-01	8.10E-02+	3.84E-02	6.87E-02	3.30E-02	4.43E-02+	2.49E-02
F20	3.77E-01	2.00E-01	3.25E-01=	2.06E-01	2.24E-01	1.64E-01	1.90E-01=	1.56E-01
F21	4.27E-01	2.83E-01	5.09E-01=	3.27E-01	2.33E-01	1.71E-01	2.64E-01=	2.17E-01
F22	3.25E+00	6.69E+00	6.95E-01+	2.10E+00	2.38E-02	1.77E-02	1.95E-02=	1.61E-02
F23	3.29E+02	0.00E+00	3.29E+02=	0.00E+00	3.29E+02	0.00E+00	3.29E+02=	0.00E+00
F24	1.06E+02	2.84E+00	1.01E+02+	2.33E+00	1.09E+02	1.88E+00	1.07E+02+	3.41E+00
F25	1.38E+02	3.14E+01	1.11E+02+	3.98E+00	1.27E+02	8.39E+00	1.27E+02=	5.84E+00
F26	1.00E+02	2.56E-02	1.00E+02+	2.27E-02	1.00E+02	2.94E-02	1.00E+02+	2.83E-02
F27	4.02E+01	1.20E+02	2.06E+01=	7.98E+01	2.38E+00	3.83E-01	1.89E+00+	4.18E-01
F28	3.82E+02	3.24E+01	3.59E+02+	1.39E+00	3.40E+02	1.16E+01	3.35E+02+	1.02E+01
F29	2.22E+02	4.02E-01	2.22E+02=	3.47E-01	2.72E+02	8.66E+01	3.72E+02=	1.26E+02
F30	4.64E+02	6.58E+00	4.63E+02=	2.41E-01	4.69E+02	1.68E+01	4.70E+02=	7.67E+00
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	mean	std	mean	std
F1	6.21E+04	3.45E+04	6.74E+04=	4.01E+04	1.18E+07	8.39E+07	1.46E+05+	1.04E+06
F2	5.61E-04	5.85E-04	3.79E-05+	5.01E-05	0.00E+00	0.00E+00	0.00E+00=	0.00E+00
F3	6.69E+02	1.30E+02	9.61E+01+	3.03E+01	5.93E+04	8.56E+04	1.01E+03=	2.05E+03
F4	8.73E+01	1.38E+01	9.81E+01-	0.00E+00	2.92E+01	3.64E+01	4.02E+00+	1.48E+01
F5	2.08E+01	3.39E-02	2.08E+01=	3.98E-02	2.09E+01	3.60E-02	2.09E+01=	3.49E-02
F6	4.23E+01	1.93E+00	1.50E+00+	2.22E-05	1.69E+01	2.60E+01	2.73E+00+	5.07E+00
F7	0.00E+00	0.00E+00	0.00E+00=	0.00E+00	1.02E-03	2.88E-03	0.00E+00+	0.00E+00
F8	8.22E+01	5.00E+00	3.97E+01+	3.79E+00	1.04E+01	4.02E+00	2.19E+00+	7.18E-01
F9	1.92E+02	1.15E+01	1.79E+01+	1.32E+00	2.63E+01	3.71E+00	2.64E+01-	3.15E+01
F10	4.11E+03	2.45E+02	4.10E+03=	2.02E+02	8.92E+03	3.30E+03	9.56E+03=	2.26E+03
F11	9.27E+03	3.46E+02	9.28E+03=	4.18E+02	1.05E+04	1.06E+03	1.07E+04=	8.97E+02
F12	1.25E+00	9.78E-02	1.24E+00=	1.26E-01	1.80E+00	1.29E-01	1.80E+00=	1.59E-01
F13	3.22E-01	3.23E-02	2.35E-01+	2.03E-02	2.13E-01	2.22E-02	1.61E-01+	1.60E-02
F14	3.16E-01	2.37E-02	2.74E-01+	1.44E-02	3.14E-01	1.97E-02	2.54E-01+	1.40E-02
F15	1.87E+01	1.06E+00	1.30E+01+	9.54E-01	7.73E+00	1.16E+00	4.01E+00+	2.65E-01
F16	2.09E+01	2.61E-01	2.07E+01+	3.00E-01	2.06E+01	1.09E+00	1.99E+01+	1.29E+00
F17	1.46E+03	4.11E+02	1.50E+03=	4.24E+02	1.70E+07	4.46E+07	4.04E+04=	1.27E+05
F18	7.89E+01	2.52E+01	7.77E+01=	2.13E+01	1.03E+02	1.64E+01	9.98E+01=	8.92E+00
F19	1.28E+01	5.57E+00	1.33E+01-	3.20E-01	2.77E+01	8.93E+01	6.91E+00+	2.74E+00
F20	7.98E+02	4.77E+02	2.59E+02+	2.04E+02	2.38E+04	5.47E+04	4.10E+02=	1.40E+03
F21	5.13E+02	1.65E+02	5.16E+02=	1.68E+02	4.27E+06	1.10E+07	8.70E+05=	2.49E+06
F22	7.06E+02	1.34E+02	5.19E+02+	1.09E+02	5.26E+02	8.41E+02	2.02E+02+	4.32E+02
F23	3.44E+02	0.00E+00	3.38E+02=	2.82E+01	3.44E+02	0.00E+00	3.44E+02-	1.61E+00
F24	2.72E+02	1.83E+00	2.00E+02+	1.65E-02	2.81E+02	4.33E+01	2.18E+02+	3.19E+01
F25	2.06E+02	2.20E+00	2.00E+02+	0.00E+00	2.05E+02	4.90E-01	2.00E+02+	1.41E+00
F26	1.00E+02	2.68E-02	1.10E+02-	3.00E+01	1.02E+02	3.21E+00	1.04E+02-	1.96E+01
F27	4.29E+02	1.65E+02	3.79E+02+	2.24E-03	9.36E+02	7.40E+02	4.24E+02+	1.46E+02
F28	1.21E+03	2.98E+01	1.12E+03+	4.65E+00	1.40E+03	3.84E+02	1.19E+03+	2.22E+02
F29	6.92E+05	4.93E+06	8.14E+02+	2.95E+01	3.55E+07	4.51E-08	3.54E+07+	1.24E+05
F30	8.29E+03	3.31E+02	8.70E+03-	1.55E+00	2.78E+05	2.89E+05	9.34E+03+	4.89E+03
number of			16/10/4				15/13/2	

	jSO		jSO-SEKM		LBC		LBC-SEKM	
	mean	std	mean	std	mean	std	mean	std
F1	9.21E+04	4.83E+04	3.23E+04+	1.13E+04	2.26E+06	5.06E+05	1.83E+06+	1.17E+05
F2	1.86E-05	4.86E-05	2.29E-08+	6.15E-08	5.81E+02	4.41E+02	3.85E+02=	1.03E+01
F3	9.54E-07	2.96E-06	2.55E-08+	6.74E-08	2.23E+01	2.39E+01	1.23E+00+	1.11E+00
F4	9.58E+01	2.48E+00	8.58E+01+	5.33E-01	9.67E+01	1.50E+00	9.33E+01+	5.91E-02
F5	2.10E+01	1.62E-01	2.10E+01=	1.43E-01	2.05E+01	5.76E-02	2.05E+01=	4.62E-02
F6	8.65E-02	8.60E-02	4.89E-03+	3.23E-02	2.42E+01	2.06E+00	1.44E+01+	1.94E+00
F7	0.00E+00	0.00E+00	0.00E+00=	0.00E+00	2.86E-06	4.70E-06	8.13E-06-	3.52E-06
F8	3.69E+01	1.12E+01	1.99E+01+	0.00E+00	0.00E+00	0.00E+00	0.00E+00=	0.00E+00
F9	5.94E+01	1.96E+01	1.89E+01+	0.00E+00	8.60E+01	8.09E+00	8.88E+01=	1.25E+01
F10	3.81E+03	6.80E+02	3.48E+03+	6.64E+02	2.20E+00	2.15E+00	2.11E+00=	1.42E+00
F11	7.44E+03	9.16E+02	7.26E+03=	8.73E+02	3.74E+03	3.82E+02	3.64E+03=	3.78E+02
F12	1.62E+00	7.10E-01	1.48E+00=	5.92E-01	4.62E-01	6.29E-02	4.17E-01+	7.26E-02
F13	3.04E-01	3.94E-02	2.35E-01+	2.72E-02	3.43E-01	3.76E-02	3.00E-01+	2.31E-02
F14	3.23E-01	2.95E-02	3.30E-01=	1.51E-02	2.81E-01	1.76E-02	3.00E-01-	1.22E-02
F15	1.19E+01	1.75E+00	9.10E+00+	1.54E+00	8.05E+00	1.16E+00	5.90E+00+	6.69E-01
F16	1.95E+01	7.40E-01	1.82E+01+	8.95E-01	1.82E+01	4.25E-01	1.78E+01+	5.03E-01
F17	6.32E+02	2.73E+02	4.86E+02+	1.86E+02	1.27E+05	6.61E+04	6.87E+04+	2.45E+04
F18	2.43E+01	6.59E+00	5.08E+01-	1.05E+01	3.34E+01	1.51E+01	9.46E+01-	2.04E+01
F19	1.11E+01	5.85E-01	1.04E+01+	1.32E-01	2.25E+01	1.11E+01	1.01E+01+	5.44E-01
F20	1.22E+01	3.33E+00	1.18E+01=	3.20E+00	5.83E+02	3.78E+02	2.93E+02+	1.53E+02
F21	4.08E+02	1.67E+02	3.89E+02=	1.16E+02	8.06E+04	3.96E+04	7.86E+04=	3.85E+04
F22	1.54E+02	1.00E+02	3.72E+01+	5.73E+00	3.57E+02	1.20E+02	2.32E+02+	1.05E+02
F23	3.44E+02	0.00E+00	3.44E+02=	0.00E+00	3.44E+02	3.82E-02	3.44E+02+	7.75E-02
F24	2.70E+02	2.01E+00	2.03E+02+	1.04E+01	2.65E+02	1.69E+00	2.05E+02+	8.33E-01
F25	2.05E+02	3.03E-01	2.00E+02+	0.00E+00	2.12E+02	1.04E+00	2.00E+02+	0.00E+00
F26	1.00E+02	4.26E-02	1.08E+02-	2.71E+01	1.00E+02	2.93E-02	1.00E+02+	1.46E-02
F27	3.10E+02	1.92E+01	3.32E+02-	8.23E-01	8.49E+02	2.08E+02	5.27E+02+	2.96E+01
F28	1.14E+03	5.63E+01	1.12E+03=	6.63E-01	1.21E+03	3.29E+01	1.13E+03+	5.24E+00
F29	8.23E+02	4.19E+01	8.17E+02=	3.64E+01	4.75E+03	6.58E+03	2.93E+03+	3.83E+03
F30	8.30E+03	3.38E+02	8.05E+03+	5.92E-01	7.95E+03	1.10E+03	7.91E+03+	4.18E+02
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	mean	std	mean	std
F1	1.43E+07	3.21E+07	1.62E+05+	1.21E+05	1.10E+03	9.72E+02	1.29E+03=	9.12E+02
F2	2.38E+08	6.19E+08	9.67E+03+	1.79E+03	5.07E+02	5.89E+02	4.20E+02=	4.12E+02
F3	1.34E+04	2.18E+04	2.85E+02+	1.71E+02	1.75E+02	2.54E+02	1.60E+02=	3.28E+02
F4	5.65E+01	4.53E+01	3.41E+01+	4.79E+00	2.44E+01	1.56E+01	3.00E+01-	4.35E+00
F5	2.03E+01	1.04E-01	1.99E+01=	2.85E+00	1.81E+01	6.01E+00	1.42E+01=	9.25E+00
F6	3.09E+00	2.18E+00	1.76E+00+	2.02E+00	2.02E-01	4.78E-01	1.22E-01=	3.69E-01
F7	4.63E+00	3.71E+00	3.70E-01+	2.10E-01	4.66E-02	3.26E-02	4.14E-02=	2.56E-02
F8	8.97E+00	5.94E+00	4.88E+00+	1.99E+00	0.00E+00	0.00E+00	0.00E+00=	0.00E+00
F9	1.59E+01	7.09E+00	1.07E+01+	5.87E+00	5.76E+00	2.39E+00	5.36E+00=	2.01E+00
F10	3.83E+02	2.43E+02	3.17E+02=	2.06E+02	3.51E-01	6.66E-01	2.41E-01=	1.01E-01
F11	5.12E+02	2.50E+02	3.59E+02+	2.85E+02	1.24E+02	1.13E+02	8.54E+01+	1.11E+02
F12	5.61E-01	4.34E-01	7.64E-01-	4.21E-01	7.46E-02	7.40E-02	4.61E-02=	3.54E-02
F13	2.95E-01	5.93E-02	2.02E-01+	4.01E-02	6.02E-02	1.61E-02	4.93E-02+	1.27E-02
F14	5.31E-01	1.31E+00	1.61E-01=	4.58E-02	8.19E-02	3.96E-02	2.97E-02+	1.30E-02
F15	5.55E+00	1.17E+01	2.03E+00=	5.64E-01	7.42E-01	2.32E-01	7.00E-01=	2.23E-01
F16	2.47E+00	5.01E-01	2.24E+00+	3.57E-01	1.06E+00	6.03E-01	5.93E-01+	5.40E-01
F17	1.16E+04	1.13E+04	9.87E+03=	9.92E+03	1.51E+03	1.85E+03	1.08E+03=	1.37E+03
F18	6.13E+03	9.61E+03	7.02E+03=	1.04E+04	5.62E+03	5.61E+03	5.62E+03=	3.50E+03
F19	4.56E+00	1.19E+00	3.19E+00+	1.35E+00	5.75E-01	5.14E-01	6.16E-01=	4.95E-01
F20	1.18E+03	1.72E+03	1.02E+02+	1.24E+02	5.26E+02	8.69E+02	2.54E+01+	3.42E+01
F21	3.33E+03	8.85E+03	3.00E+02+	3.22E+02	3.56E+01	4.75E+01	2.83E+01=	4.17E+01
F22	6.03E+01	8.08E+01	2.71E+01+	3.63E+01	9.90E-01	2.82E+00	6.45E+00=	2.38E+01
F23	3.47E+02	1.67E+01	3.29E+02+	4.06E-08	3.29E+02	0.00E+00	3.29E+02=	0.00E+00
F24	1.21E+02	6.83E+00	1.14E+02+	5.00E+00	1.14E+02	4.74E+00	1.13E+02+	3.87E+00
F25	1.97E+02	1.94E+01	1.95E+02=	2.36E+01	1.74E+02	3.52E+01	1.57E+02+	3.66E+01
F26	1.00E+02	1.72E-01	1.00E+02+	2.72E-02	1.00E+02	2.11E-02	1.00E+02+	9.55E-03
F27	3.20E+02	1.66E+02	2.01E+02+	1.98E+02	1.87E+02	1.87E+02	1.47E+02+	1.86E+02
F28	5.14E+02	9.93E+01	4.90E+02=	1.20E+02	4.24E+02	5.80E+01	4.13E+02=	4.91E+01
F29	4.19E+04	2.86E+05	1.85E+05=	6.39E+05	1.09E+05	4.42E+05	3.41E+04=	2.41E+05
F30	9.37E+02	4.08E+02	8.14E+02=	2.64E+02	6.68E+02	1.66E+02	6.63E+02=	1.48E+02
number of			19/10/1			9/20/1		

	AWPSO		AWPSO-SEKM		EAPSO		EAPSO-SEKM	
	mean	std	mean	std	mean	std	mean	std
F1	2.11E+05	4.54E+05	2.49E+05-	6.26E+05	1.54E+03	7.37E+02	1.66E+03=	8.96E+02
F2	2.95E+03	4.00E+03	1.63E+03=	6.09E+02	1.51E+03	1.15E+03	7.82E+02+	8.80E+02
F3	1.65E+02	3.26E+02	4.58E+01+	5.88E+01	1.69E+03	1.85E+03	8.27E+02+	1.32E+03
F4	2.98E+01	1.21E+01	3.38E+01-	3.53E+00	2.52E+01	1.57E+01	9.36E+00+	1.17E+01
F5	2.02E+01	1.16E-01	1.71E+01+	7.45E+00	2.00E+01	1.63E-04	1.96E+01=	2.80E+00
F6	8.57E-01	8.70E-01	1.12E+00=	1.16E+00	1.51E+00	1.44E+00	1.04E+00=	1.27E+00
F7	8.99E-01	1.61E+00	1.49E-01=	6.64E-02	9.20E-02	6.36E-02	1.09E-01=	7.32E-02
F8	3.99E+00	2.30E+00	2.13E+00+	1.46E+00	5.87E+00	3.88E+00	5.24E+00=	2.92E+00
F9	8.85E+00	3.70E+00	6.67E+00+	3.23E+00	1.52E+01	7.08E+00	1.11E+01+	5.33E+00
F10	1.90E+02	1.07E+02	1.78E+02=	9.22E+01	1.85E+02	1.60E+02	1.98E+02=	1.30E+02
F11	2.93E+02	1.58E+02	2.75E+02=	2.11E+02	6.54E+02	3.33E+02	5.57E+02=	2.41E+02
F12	9.00E-02	6.92E-02	3.11E-01-	2.98E-01	8.58E-02	1.11E-01	8.54E-02=	1.10E-01
F13	1.79E-01	8.77E-02	1.18E-01+	5.63E-02	1.59E-01	8.02E-02	1.44E-01=	6.34E-02
F14	1.45E-01	1.50E-01	5.89E-02+	2.67E-02	2.64E-01	1.10E-01	2.23E-01=	7.33E-02
F15	9.40E-01	3.11E-01	7.74E-01+	3.22E-01	9.29E-01	3.85E-01	9.31E-01=	3.04E-01
F16	2.01E+00	4.76E-01	1.96E+00=	3.96E-01	2.80E+00	5.47E-01	2.63E+00=	5.79E-01
F17	2.52E+03	3.03E+03	1.64E+03+	1.57E+03	3.13E+03	2.55E+03	2.75E+03=	1.98E+03
F18	6.62E+03	7.40E+03	2.70E+03+	2.75E+03	7.62E+03	8.10E+03	9.27E+03=	9.05E+03
F19	2.36E+00	1.47E+00	1.77E+00=	6.68E-01	1.17E+00	8.48E-01	1.30E+00=	8.31E-01
F20	2.67E+02	4.78E+02	4.16E+01+	2.99E+01	4.46E+03	4.64E+03	1.81E+03+	2.28E+03
F21	1.68E+02	1.45E+02	1.20E+02+	1.56E+02	1.90E+02	1.75E+02	1.80E+02=	1.57E+02
F22	3.50E+01	4.09E+01	2.62E+01=	1.61E+01	8.93E+01	6.96E+01	8.06E+01=	6.61E+01
F23	3.30E+02	1.81E+00	3.29E+02=	0.00E+00	3.27E+02	1.81E+01	3.27E+02=	1.81E+01
F24	1.16E+02	5.05E+00	1.14E+02+	3.95E+00	1.25E+02	1.49E+01	1.18E+02+	7.00E+00
F25	1.73E+02	3.71E+01	1.44E+02+	3.26E+01	1.83E+02	2.88E+01	1.71E+02+	3.40E+01
F26	1.00E+02	3.98E-02	1.00E+02+	2.07E-02	1.00E+02	1.16E-01	1.00E+02+	6.88E-02
F27	3.03E+02	1.62E+02	2.93E+02=	1.66E+02	2.66E+02	1.60E+02	2.55E+02=	1.62E+02
F28	5.02E+02	8.34E+01	4.74E+02=	6.43E+01	4.36E+02	6.76E+01	4.21E+02=	6.07E+01
F29	2.87E+05	8.54E+05	1.36E+05+	4.68E+05	6.82E+04	3.38E+05	1.48E+05=	5.12E+05
F30	8.50E+02	3.47E+02	1.03E+03-	4.27E+02	1.08E+03	4.05E+02	1.13E+03=	5.13E+02
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) (+/ = /-)

0	CLPSO		CLPSO-SEKM		GLPSO		GLPSO-SEKM	
	mean	std	mean	std	mean	std	mean	std
F1	1.34E+08	1.25E+08	8.97E+07=	8.97E+07	2.96E+05	2.00E+05	2.17E+05+	1.70E+05
F2	1.07E+10	6.26E+09	2.96E+07+	6.95E+06	3.67E+01	8.12E+01	9.95E+00+	1.80E+01
F3	1.91E+04	1.40E+04	5.88E+03+	1.22E+03	1.02E+02	1.79E+02	3.30E+01+	3.88E+01
F4	7.65E+02	5.47E+02	1.33E+02+	2.15E+00	2.74E+01	3.65E+01	1.70E+01+	2.81E+01
F5	2.09E+01	6.53E-02	2.09E+01=	7.65E-02	2.09E+01	1.62E-01	2.09E+01=	1.46E-01
F6	1.82E+01	3.39E+00	1.67E+01=	4.07E+00	4.65E+00	1.87E+00	4.87E+00=	1.79E+00
F7	9.43E+01	7.32E+01	1.31E+00+	9.52E-02	4.97E-03	7.49E-03	7.92E-03-	8.16E-03
F8	9.11E+01	2.08E+01	6.68E+01+	1.91E+01	7.17E+01	6.39E+01	0.00E+00+	0.00E+00
F9	1.91E+02	2.21E+01	1.33E+02+	3.05E+01	4.29E+01	3.94E+01	2.25E+01+	4.62E+00
F10	2.30E+03	5.79E+02	2.23E+03=	6.48E+02	1.90E+03	1.87E+03	2.42E+02+	8.45E+02
F11	4.90E+03	1.36E+03	5.74E+03-	1.49E+03	1.65E+03	1.10E+03	1.92E+03=	1.43E+03
F12	2.27E+00	4.57E-01	2.40E+00=	3.23E-01	1.73E+00	9.08E-01	1.63E+00=	8.96E-01
F13	2.80E+00	9.75E-01	5.71E-01+	6.62E-02	2.94E-01	3.92E-02	1.87E-01+	3.17E-02
F14	4.33E+01	3.02E+01	1.07E+00+	8.18E-02	3.08E-01	7.79E-02	2.98E-01=	2.93E-02
F15	1.21E+04	2.84E+04	1.98E+01+	1.77E+00	1.30E+01	3.62E+00	1.10E+01+	4.51E+00
F16	1.17E+01	3.33E-01	1.16E+01+	3.38E-01	1.09E+01	3.89E-01	1.06E+01+	4.61E-01
F17	3.69E+06	4.57E+06	2.43E+06+	3.09E+06	3.81E+04	2.61E+04	3.73E+04=	3.03E+04
F18	6.19E+07	1.44E+08	2.56E+07=	1.03E+08	2.43E+03	3.05E+03	3.24E+03=	3.55E+03
F19	4.72E+01	3.93E+01	1.44E+01+	1.38E+01	6.56E+00	1.58E+00	6.43E+00=	1.41E+00
F20	1.75E+04	1.99E+04	3.43E+03+	1.04E+04	2.38E+02	5.97E+01	1.66E+02+	2.91E+01
F21	5.79E+05	1.04E+06	2.35E+05+	2.19E+05	1.78E+04	1.29E+04	1.75E+04=	1.24E+04
F22	6.12E+02	2.25E+02	4.69E+02+	1.91E+02	2.40E+02	1.01E+02	1.88E+02+	1.06E+02
F23	3.63E+02	2.96E+01	3.27E+02+	1.21E+01	3.15E+02	0.00E+00	3.15E+02=	0.00E+00
F24	2.54E+02	1.74E+01	2.40E+02+	2.92E+00	2.25E+02	2.22E+00	2.00E+02+	3.84E-02
F25	2.15E+02	8.14E+00	2.11E+02+	5.36E+00	2.06E+02	2.89E+00	2.03E+02+	3.34E+00
F26	1.08E+02	2.11E+01	1.02E+02+	1.46E+01	1.06E+02	2.37E+01	1.02E+02+	1.40E+01
F27	8.06E+02	2.31E+02	6.89E+02+	2.24E+02	4.28E+02	6.44E+01	4.23E+02=	5.79E+01
F28	1.54E+03	3.73E+02	1.52E+03=	3.12E+02	8.66E+02	5.66E+01	8.45E+02+	3.11E+01
F29	7.18E+06	7.73E+06	4.46E+06+	6.71E+06	1.43E+03	4.46E+02	1.36E+03=	3.65E+02
F30	8.14E+04	7.62E+04	9.70E+04=	9.57E+04	1.86E+03	5.16E+02	1.93E+03=	6.92E+02
number of			21/8/1				16/13/1	

	AWPSO		AWPSO-SEKM		EAPSO		EAPSO-SEKM	
	mean	std	mean	std	mean	std	mean	std
F1	1.31E+07	1.36E+07	4.36E+06+	3.19E+06	3.92E+05	2.64E+05	3.60E+05=	2.75E+05
F2	1.34E+09	1.19E+09	5.39E+01+	5.33E+01	4.69E+01	6.57E+01	3.64E+01=	6.48E+01
F3	2.07E+02	5.06E+02	2.65E+01+	2.46E+01	2.63E+02	2.97E+02	7.07E+01+	8.78E+01
F4	1.45E+02	6.58E+01	1.01E+02+	2.72E+01	2.93E-01	1.88E-01	1.77E-01+	2.40E-01
F5	2.09E+01	9.30E-02	2.09E+01=	5.12E-02	2.00E+01	2.60E-02	2.00E+01+	2.71E-02
F6	1.01E+01	3.69E+00	9.53E+00=	3.68E+00	5.17E+00	2.48E+00	3.47E+00+	2.79E+00
F7	1.90E+01	1.37E+01	1.24E-02+	1.11E-02	5.85E-03	6.09E-03	5.22E-03=	8.83E-03
F8	3.77E+01	1.10E+01	3.52E+01=	7.59E+00	4.88E+01	1.44E+01	4.26E+01+	1.74E+01
F9	6.15E+01	1.55E+01	4.75E+01+	1.26E+01	7.19E+01	2.08E+01	5.84E+01+	1.67E+01
F10	1.16E+03	5.54E+02	1.30E+03=	5.02E+02	1.45E+03	4.68E+02	1.38E+03=	4.92E+02
F11	2.66E+03	6.12E+02	2.53E+03=	6.97E+02	2.92E+03	7.11E+02	2.81E+03=	6.16E+02
F12	4.09E-01	2.65E-01	7.89E-01-	5.22E-01	4.18E-02	3.59E-02	7.29E-02-	8.13E-02
F13	5.43E-01	1.26E-01	3.44E-01+	8.71E-02	3.38E-01	8.85E-02	2.93E-01+	7.21E-02
F14	5.30E+00	7.60E+00	2.70E-01+	2.19E-02	3.12E-01	1.14E-01	2.73E-01+	4.09E-02
F15	2.61E+01	7.88E+01	4.53E+00+	1.22E+00	3.54E+00	1.01E+00	3.74E+00=	1.15E+00
F16	1.07E+01	7.98E-01	1.07E+01=	6.31E-01	1.17E+01	8.10E-01	1.13E+01+	8.98E-01
F17	4.12E+05	4.12E+05	4.93E+05=	4.93E+05	6.27E+04	3.71E+04	5.84E+04=	3.73E+04
F18	1.67E+05	4.07E+05	5.95E+03=	7.12E+03	5.33E+03	5.86E+03	6.17E+03=	6.65E+03
F19	1.27E+01	1.22E+01	9.86E+00=	2.24E+00	6.37E+00	1.17E+01	3.96E+00=	1.27E+00
F20	5.70E+02	3.42E+02	4.42E+02=	1.94E+02	9.02E+02	8.99E+02	5.93E+02+	4.47E+02
F21	2.00E+05	3.05E+05	1.81E+05=	1.62E+05	3.95E+04	3.44E+04	2.54E+04+	1.83E+04
F22	3.39E+02	1.25E+02	3.37E+02=	1.44E+02	4.45E+02	1.74E+02	3.60E+02+	1.83E+02
F23	3.23E+02	6.59E+00	3.19E+02+	4.68E+00	3.15E+02	0.00E+00	3.15E+02=	0.00E+00
F24	2.30E+02	7.18E+00	2.17E+02+	9.40E+00	2.23E+02	5.27E+00	2.18E+02+	9.04E+00
F25	2.05E+02	1.98E+00	2.06E+02=	2.76E+00	2.04E+02	1.47E+00	2.05E+02=	2.40E+00
F26	1.05E+02	1.96E+01	1.14E+02-	3.47E+01	1.00E+02	7.97E-02	1.06E+02-	2.37E+01
F27	5.67E+02	1.64E+02	5.05E+02=	1.54E+02	4.21E+02	7.77E+01	4.35E+02=	7.76E+01
F28	1.39E+03	3.11E+02	1.16E+03+	1.55E+02	1.03E+03	2.98E+02	9.24E+02=	1.58E+02
F29	1.47E+06	3.49E+06	5.18E+06-	7.64E+06	7.61E+05	2.63E+06	5.48E+05=	2.21E+06
F30	1.46E+04	1.30E+04	1.01E+04+	1.10E+04	1.94E+03	6.82E+02	1.85E+03=	8.11E+02
number of			13/14/3				13/15/2	

Table S-5

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	mean	std	mean	std
F1	6.61E+06	5.86E+06	1.78E+06+	1.64E+06	5.80E+06	1.01E+07	2.49E+06=	4.86E+06
F2	1.11E+07	1.92E+07	5.76E+06+	1.44E+07	2.21E+08	5.81E+08	4.54E+03+	5.33E+03
F3	2.73E+04	1.13E+04	1.37E+04+	8.11E+03	1.11E+04	1.49E+04	3.54E+03+	7.32E+03
F4	4.27E+01	2.16E+01	3.59E+01=	8.36E+00	4.68E+01	3.86E+01	3.42E+01=	1.32E+01
F5	2.01E+01	1.10E-01	2.03E+01-	8.54E-02	2.00E+01	7.11E-02	2.01E+01=	8.96E-02
F6	4.57E+00	1.80E+00	4.08E+00=	1.81E+00	3.68E+00	2.34E+00	2.72E+00=	1.68E+00
F7	1.10E+00	9.72E-01	5.38E-01+	2.46E-01	7.57E+00	3.98E+00	8.14E-01+	1.36E+00
F8	2.69E+01	9.56E+00	2.65E+01=	1.07E+01	2.52E+01	1.53E+01	2.49E+01=	1.01E+01
F9	2.68E+01	1.17E+01	2.34E+01=	8.61E+00	2.88E+01	1.12E+01	2.40E+01+	1.00E+01
F10	8.88E+02	3.27E+02	9.09E+02=	3.31E+02	7.56E+02	2.79E+02	6.50E+02+	3.75E+02
F11	8.12E+02	3.17E+02	9.62E+02-	3.07E+02	9.98E+02	3.11E+02	8.14E+02+	3.51E+02
F12	5.99E-01	3.39E-01	8.09E-01-	2.83E-01	1.77E-01	9.85E-02	2.54E-01=	2.96E-01
F13	2.77E-01	1.46E-01	1.85E-01+	9.78E-02	4.84E-01	1.13E-01	3.07E-01+	1.12E-01
F14	3.49E-01	1.80E-01	2.59E-01+	1.50E-01	1.08E+00	7.74E-01	3.13E-01+	1.16E-01
F15	3.28E+00	2.75E+00	2.12E+00+	1.19E+00	5.27E+00	1.34E+01	1.33E+00=	6.11E-01
F16	3.40E+00	4.25E-01	3.10E+00+	3.82E-01	3.34E+00	3.31E-01	3.16E+00+	3.72E-01
F17	3.94E+04	9.50E+04	1.09E+04+	4.48E+04	2.84E+05	7.86E+05	9.81E+03+	1.73E+04
F18	7.38E+03	8.02E+03	6.15E+03=	7.61E+03	9.86E+03	1.21E+04	8.12E+03=	1.22E+04
F19	4.37E+00	1.46E+00	4.11E+00=	1.02E+00	5.41E+00	2.08E+00	4.78E+00=	1.83E+00
F20	6.26E+03	8.11E+03	3.21E+03+	3.92E+03	1.12E+04	1.46E+04	1.35E+04=	6.83E+04
F21	7.94E+03	7.81E+03	6.47E+03=	6.59E+03	4.62E+03	8.20E+03	3.16E+03+	8.01E+03
F22	1.02E+02	8.35E+01	8.94E+01=	5.54E+01	2.08E+02	7.43E+01	1.31E+02+	8.54E+01
F23	3.39E+02	1.12E+01	3.33E+02+	5.80E+00	3.43E+02	1.64E+01	3.37E+02+	1.32E+01
F24	1.44E+02	2.16E+01	1.31E+02+	1.23E+01	1.37E+02	8.72E+00	1.30E+02+	9.24E+00
F25	1.94E+02	1.89E+01	1.86E+02+	2.66E+01	1.98E+02	1.44E+01	1.91E+02+	2.23E+01
F26	1.00E+02	1.29E-01	1.00E+02=	1.34E-01	1.00E+02	1.86E-01	1.00E+02=	1.77E-01
F27	3.64E+02	9.69E+01	3.07E+02=	1.61E+02	3.31E+02	1.76E+02	3.04E+02+	1.70E+02
F28	5.16E+02	9.43E+01	5.43E+02=	1.54E+02	5.78E+02	9.77E+01	5.01E+02+	1.27E+02
F29	1.31E+05	9.31E+05	1.91E+05=	6.69E+05	1.45E+03	8.38E+02	1.77E+05-	6.33E+05
F30	2.40E+03	8.48E+02	2.02E+03+	7.79E+02	1.13E+03	2.69E+02	1.12E+03=	3.87E+02
number of			14/13/3		number of		17/12/1	