

CEC 2005 Benchmark Function Fix Dimensions

Comparison of optimization results for the CEC benchmark functions 2005 (Fix Dim)

Function		OLOA	LOA	PSO	GA	GSA	WOA
F1	Mean	<u>3.83E-75</u>	1.03E+04	6.28E+04	6.60E+04	2.64E+03	1.40E-11
	Std	1.18E-74	2.92E+03	5.24E+03	7.18E+03	7.60E+02	2.29E-11
	CPU	0.192	0.081	0.092	0.222	1.266	0.122
F2	Mean	<u>5.28E-38</u>	3.97E+01	4.12E+10	1.80E+12	1.09E+01	2.17E-08
	Std	1.34E-37	1.37E+01	1.14E+11	3.04E+12	2.07E+00	3.59E-08
	CPU	0.170	0.069	0.069	0.120	0.616	0.119
F3	Mean	<u>7.90E-72</u>	2.25E+04	9.01E+04	1.29E+05	7.70E+03	9.09E+04
	Std	2.50E-71	8.32E+03	9.21E+03	3.57E+04	3.32E+03	3.22E+04
	CPU	0.903	0.275	0.214	0.286	0.898	0.277
F4	Mean	<u>6.58E-35</u>	3.75E+01	8.76E+01	8.12E+01	2.00E+01	6.33E+01
	Std	1.40E-34	7.56E+00	2.94E+00	3.09E+00	2.77E+00	2.88E+01
	CPU	0.138	0.039	0.039	0.095	0.566	0.088
F5	Mean	2.90E+01	6.76E+06	2.29E+08	2.53E+08	3.08E+05	<u>2.88E+01</u>
	Std	2.23E-02	2.84E+06	6.37E+07	3.29E+07	2.48E+05	1.13E-01
	CPU	0.269	0.075	0.069	0.103	0.678	0.114
F6	Mean	5.77E+00	1.02E+04	5.95E+04	6.34E+04	2.61E+03	<u>1.53E+00</u>
	Std	6.54E-01	1.94E+03	5.25E+03	5.51E+03	6.92E+02	4.15E-01
	CPU	0.130	0.044	0.077	0.105	0.614	0.100
F7	Mean	3.02E-02	6.18E-01	1.09E+02	9.96E+01	3.77E-01	<u>1.87E-02</u>
	Std	3.65E-02	2.33E-01	2.09E+01	2.81E+01	1.75E-01	1.74E-02
	CPU	0.464	0.113	0.136	0.169	0.673	0.175
F8	Mean	-3.89E+03	-2.73E+03	-5.26E+03	-5.54E+03	-2.45E+03	<u>-8.59E+03</u>
	Std	4.59E+02	4.76E+02	5.35E+02	2.01E+03	4.33E+02	9.48E+02
	CPU	0.248	0.105	0.083	0.134	0.617	0.088
F9	Mean	<u>0.00E+00</u>	1.27E+02	4.08E+02	4.05E+02	6.47E+01	1.42E-03
	Std	0.00E+00	1.48E+01	2.35E+01	3.86E+01	2.27E+01	4.48E-03
	CPU	0.178	0.081	0.077	0.108	0.661	0.113
F10	Mean	<u>4.44E-16</u>	1.49E+01	2.01E+01	2.04E+01	8.25E+00	4.49E-07
	Std	0.00E+00	9.67E-01	2.11E-01	1.63E-01	8.23E-01	7.42E-07
	CPU	0.203	0.077	0.088	0.122	0.705	0.081
F11	Mean	<u>0.00E+00</u>	1.14E+02	5.60E+02	5.84E+02	4.30E+02	1.17E-01
	Std	0.00E+00	2.32E+01	5.23E+01	8.12E+01	5.29E+01	2.69E-01
	CPU	0.247	0.094	0.072	0.145	0.784	0.125
F12	Mean	3.92E-01	1.86E+06	5.68E+08	5.62E+08	1.96E+02	<u>1.65E-01</u>
	Std	9.54E-02	2.29E+06	1.80E+08	1.11E+08	4.55E+02	1.51E-01
	CPU	0.922	0.298	0.277	0.358	0.895	0.397
F13	Mean	2.88E+00	1.49E+07	9.69E+08	1.11E+09	4.68E+04	<u>1.11E+00</u>
	Std	2.57E-01	1.38E+07	2.55E+08	2.07E+08	4.26E+04	3.68E-01
	CPU	1.002	0.316	0.289	0.347	0.942	0.405
F14	Mean	9.88E+00	1.14E+01	<u>2.16E+00</u>	7.80E+01	9.13E+00	3.97E+00
	Std	3.42E+00	5.04E+00	1.50E+00	9.03E+01	5.45E+00	1.31E+00
	CPU	2.289	0.702	0.534	0.581	0.922	0.642
F15	Mean	1.65E-03	5.56E-03	5.64E-03	1.14E-01	1.94E-02	<u>8.20E-04</u>

Comparison of optimization results for the CEC benchmark functions 2005 (Fix Dim)

Function		OLOA	LOA	PSO	GA	GSA	WOA
	Std	9.18E-04	7.35E-03	5.75E-03	6.62E-02	1.26E-02	6.04E-04
	CPU	0.170	0.055	0.058	0.080	0.236	0.059
F16	Mean	-1.03E+00	-1.03E+00	-1.01E+00	8.15E-01	-1.03E+00	-1.03E+00
	Std	2.52E-03	2.32E-04	3.22E-02	1.53E+00	2.56E-16	2.22E-05
	CPU	0.150	0.039	0.039	0.084	0.159	0.048
F17	Mean	4.00E-01	3.98E-01	4.03E-01	2.04E+00	3.98E-01	3.99E-01
	Std	3.08E-03	7.87E-05	4.99E-03	9.32E-01	1.39E-05	1.20E-03
	CPU	0.125	0.034	0.042	0.073	0.156	0.053
F18	Mean	3.06E+00	3.02E+00	3.20E+00	5.43E+01	3.00E+00	3.00E+00
	Std	1.04E-01	2.28E-02	1.81E-01	3.52E+01	1.32E-14	2.05E-03
	CPU	0.114	0.063	0.048	0.075	0.116	0.050
F19	Mean	-3.78E+00	-3.83E+00	-3.85E+00	-3.77E+00	-3.84E+00	-3.82E+00
	Std	5.95E-02	2.94E-02	3.07E-03	6.44E-02	1.94E-02	7.84E-02
	CPU	0.173	0.077	0.050	0.058	0.209	0.058
F20	Mean	-2.67E+00	-3.18E+00	-2.98E+00	-2.88E+00	-3.32E+00	-3.11E+00
	Std	3.83E-01	6.69E-02	1.82E-01	3.96E-01	2.59E-03	3.03E-01
	CPU	0.181	0.052	0.070	0.083	0.238	0.045
F21	Mean	-8.57E+00	-7.84E+00	-2.86E+00	-2.09E+00	-6.41E+00	-6.44E+00
	Std	9.63E-01	3.57E+00	8.60E-01	4.41E-01	3.94E+00	2.47E+00
	CPU	0.252	0.094	0.059	0.098	0.252	0.083
F22	Mean	-8.91E+00	-5.19E+00	-2.60E+00	-2.69E+00	-9.64E+00	-6.09E+00
	Std	1.31E+00	3.52E+00	8.25E-01	8.21E-01	2.42E+00	2.72E+00
	CPU	0.306	0.086	0.080	0.109	0.250	0.103
F23	Mean	-7.89E+00	-5.93E+00	-2.34E+00	-2.01E+00	-9.87E+00	-5.60E+00
	Std	1.69E+00	3.94E+00	9.28E-01	7.14E-01	2.12E+00	2.74E+00
	CPU	0.367	0.091	0.092	0.123	0.245	0.105

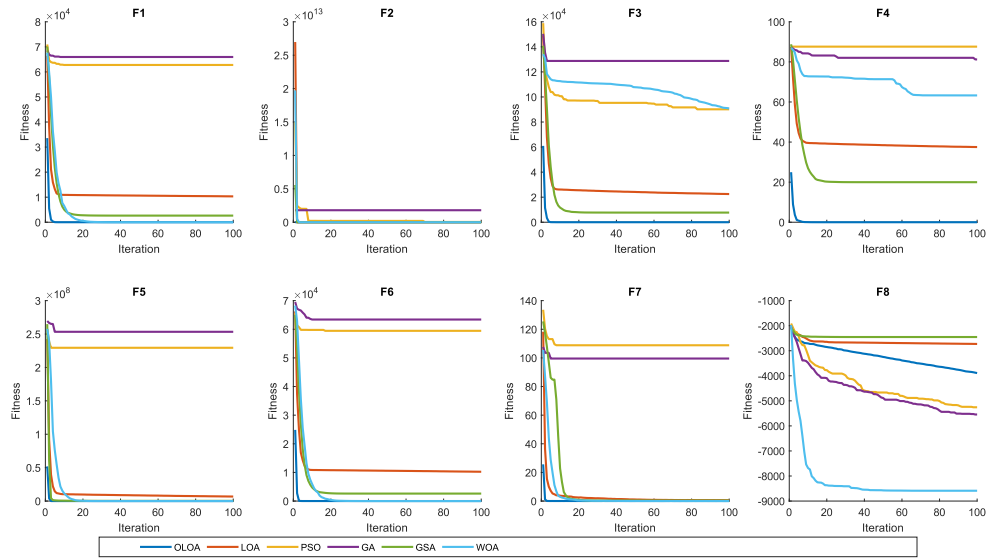
P-value of the T-test analysis for the CEC benchmark functions 2005 (Fix Dim)

Function	OLOA versus LOA	OLOA versus PSO	OLOA versus GA	OLOA versus GSA	OLOA versus WOA
F1	1.59E-09	1.30E-18	1.41E-16	2.01E-09	6.98E-02
F2	3.15E-08	2.68E-01	7.79E-02	2.38E-12	7.16E-02
F3	9.32E-08	4.62E-17	1.16E-09	8.10E-07	5.08E-08
F4	6.06E-12	1.04E-25	1.03E-24	9.84E-15	1.73E-06
F5	5.70E-07	1.15E-09	3.09E-15	1.00E-03	8.02E-06
F6	2.13E-12	3.50E-18	2.59E-18	5.82E-10	1.12E-12
F7	3.10E-07	2.63E-12	1.55E-09	8.33E-06	3.81E-01
F8	2.85E-05	8.74E-06	2.09E-02	1.04E-06	3.58E-11
F9	4.71E-16	1.62E-21	1.32E-17	4.26E-08	3.31E-01
F10	1.42E-20	8.94E-35	6.60E-37	3.02E-17	7.14E-02
F11	6.76E-12	9.24E-18	1.02E-14	1.25E-15	1.87E-01
F12	1.96E-02	9.11E-09	4.34E-12	1.90E-01	8.20E-04
F13	3.12E-03	5.01E-10	1.58E-12	2.73E-03	2.79E-10
F14	4.44E-01	3.81E-06	2.84E-02	7.18E-01	7.43E-05

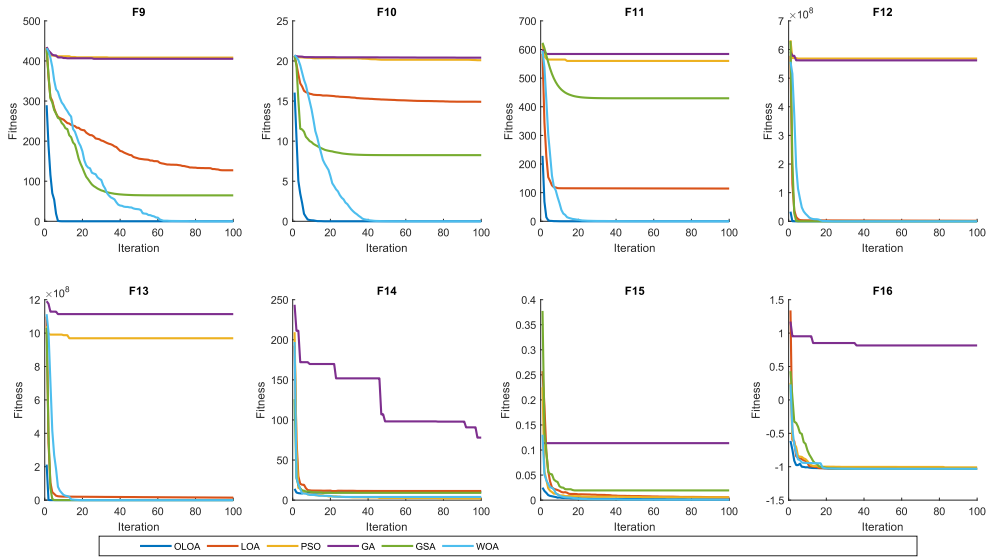
P-value of the T-test analysis for the CEC benchmark functions 2005 (Fix Dim)

Function	OLOA versus LOA	OLOA versus PSO	OLOA versus GA	OLOA versus GSA	OLOA versus WOA
F15	1.13E-01	4.39E-02	4.32E-05	3.22E-04	2.75E-02
F16	5.52E-03	7.10E-02	1.29E-03	3.42E-03	3.49E-03
F17	1.91E-02	1.93E-01	2.73E-05	1.76E-02	1.30E-01
F18	2.35E-01	5.11E-02	2.19E-04	7.72E-02	8.30E-02
F19	1.74E-02	6.09E-04	8.93E-01	5.66E-03	2.21E-01
F20	5.80E-04	3.47E-02	2.39E-01	4.30E-05	1.15E-02
F21	5.42E-01	4.19E-11	1.75E-13	1.11E-01	2.08E-02
F22	5.68E-03	1.63E-10	1.99E-10	4.16E-01	8.45E-03
F23	1.66E-01	3.78E-08	7.27E-09	3.29E-02	3.78E-02

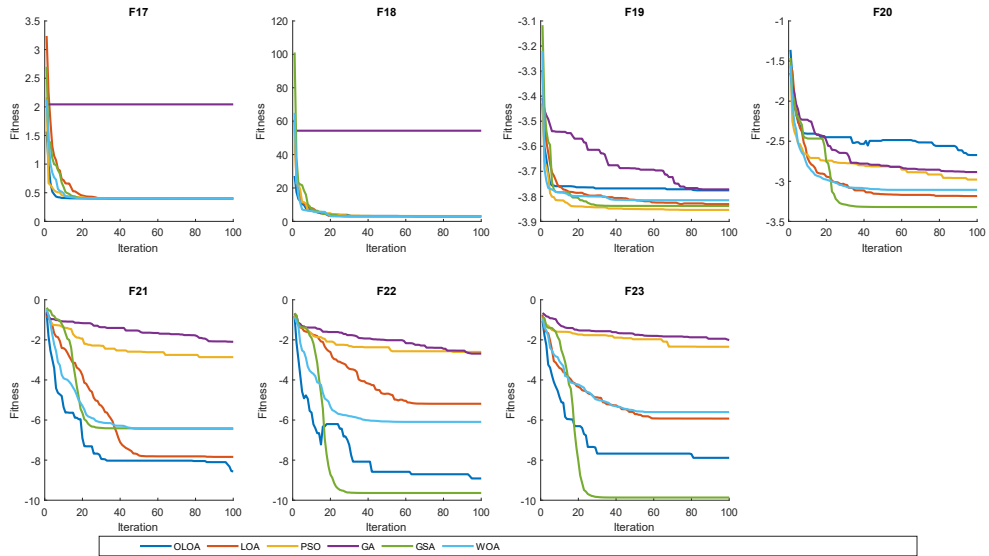
CEC Benchmark
2005



CEC Benchmark
2005



CEC Benchmark
2005



CEC 2017 Benchmark Function 10 Dimensions

Comparison of optimization results for the CEC benchmark functions 2017 (10 Dim)

Function		OLOA	LOA	PSO	GA	GSA	WOA
F1	Mean	2.91E+09	9.45E+09	4.01E+09	2.08E+10	1.52E+10	1.36E+09
	Std	2.84E+09	3.05E+09	1.19E+09	7.19E+09	5.42E+09	1.10E+09
	CPU	0.134	0.083	0.100	0.202	0.734	0.166
F2	Mean	The Function F2 was Delete in CEC 2017					
	Std						
	CPU						
F3	Mean	<u>7.99E+03</u>	2.15E+04	3.93E+04	1.14E+06	2.01E+04	2.04E+04
	Std	3.84E+03	1.28E+04	1.37E+04	2.11E+06	5.36E+03	1.77E+04
	CPU	0.088	0.053	0.108	0.095	0.467	0.105
F4	Mean	5.77E+02	1.44E+03	6.79E+02	3.67E+03	1.89E+03	<u>5.36E+02</u>
	Std	1.22E+02	8.67E+02	1.11E+02	1.50E+03	7.60E+02	6.06E+01
	CPU	0.045	0.023	0.067	0.150	0.466	0.086
F5	Mean	<u>5.46E+02</u>	5.79E+02	5.83E+02	6.41E+02	6.19E+02	5.72E+02
	Std	1.30E+01	1.69E+01	1.43E+01	2.40E+01	1.85E+01	1.35E+01
	CPU	0.072	0.058	0.073	0.095	0.452	0.086
F6	Mean	6.40E+02	<u>6.38E+02</u>	6.54E+02	6.77E+02	6.59E+02	6.48E+02
	Std	1.15E+01	7.13E+00	9.16E+00	1.17E+01	1.07E+01	1.28E+01
	CPU	0.197	0.059	0.088	0.122	0.455	0.095
F7	Mean	<u>7.86E+02</u>	8.03E+02	9.95E+02	1.12E+03	8.02E+02	8.17E+02
	Std	3.76E+01	3.34E+01	8.31E+01	9.04E+01	3.02E+01	3.11E+01
	CPU	0.114	0.055	0.072	0.155	0.431	0.086
F8	Mean	<u>8.28E+02</u>	8.61E+02	8.90E+02	9.14E+02	8.59E+02	8.57E+02
	Std	8.57E+00	2.10E+01	1.63E+01	1.24E+01	6.34E+00	2.44E+01
	CPU	0.084	0.020	0.070	0.100	0.478	0.067
F9	Mean	1.44E+03	<u>1.37E+03</u>	2.78E+03	5.34E+03	1.81E+03	1.95E+03
	Std	2.91E+02	1.61E+02	6.03E+02	1.55E+03	2.74E+02	5.36E+02
	CPU	0.105	0.042	0.089	0.164	0.436	0.119
F10	Mean	2.56E+03	2.67E+03	2.61E+03	3.11E+03	3.36E+03	<u>2.54E+03</u>
	Std	2.47E+02	3.66E+02	2.15E+02	1.62E+02	2.77E+02	2.08E+02
	CPU	0.147	0.050	0.070	0.091	0.306	0.094
F11	Mean	<u>1.76E+03</u>	6.45E+03	2.44E+03	1.69E+04	7.65E+03	1.92E+03
	Std	9.81E+02	2.61E+03	8.75E+02	9.29E+03	4.30E+03	1.06E+03
	CPU	0.105	0.047	0.058	0.098	0.378	0.111
F12	Mean	<u>3.98E+06</u>	4.40E+08	1.30E+08	1.84E+09	9.70E+08	1.38E+07
	Std	9.26E+06	6.45E+08	9.07E+07	1.12E+09	7.55E+08	1.25E+07
	CPU	0.067	0.031	0.080	0.108	0.391	0.067
F13	Mean	<u>1.03E+04</u>	6.69E+05	1.67E+06	2.29E+08	1.03E+08	1.53E+04
	Std	5.26E+03	1.95E+06	1.40E+06	2.71E+08	1.39E+08	7.23E+03
	CPU	0.111	0.022	0.083	0.102	0.234	0.081
F14	Mean	5.30E+03	5.87E+03	9.19E+03	3.39E+05	3.31E+05	<u>4.22E+03</u>
	Std	4.37E+03	5.83E+03	8.95E+03	6.69E+05	4.49E+05	3.04E+03
	CPU	0.150	0.033	0.078	0.095	0.353	0.084
F15	Mean	2.17E+04	<u>1.79E+04</u>	2.45E+04	5.70E+05	3.17E+04	3.14E+04

Comparison of optimization results for the CEC benchmark functions 2017 (10 Dim)

Function		OLOA	LOA	PSO	GA	GSA	WOA
	Std	1.79E+04	8.89E+03	2.32E+04	6.04E+05	2.17E+04	4.53E+04
	CPU	0.066	0.034	0.050	0.100	0.345	0.055
F16	Mean	2.08E+03	2.09E+03	<u>1.98E+03</u>	2.55E+03	2.29E+03	2.02E+03
	Std	1.07E+02	1.39E+02	1.88E+02	1.86E+02	1.08E+02	1.90E+02
	CPU	0.113	0.034	0.058	0.114	0.308	0.070
F17	Mean	<u>1.80E+03</u>	1.80E+03	1.96E+03	2.42E+03	1.96E+03	1.83E+03
	Std	7.67E+01	3.57E+01	8.54E+01	2.91E+02	1.47E+02	5.94E+01
	CPU	0.183	0.075	0.092	0.128	0.322	0.097
F18	Mean	<u>1.40E+04</u>	3.40E+08	1.17E+06	6.40E+08	8.64E+08	2.61E+04
	Std	8.89E+03	7.31E+08	6.52E+05	6.98E+08	1.38E+09	2.71E+04
	CPU	0.117	0.023	0.055	0.102	0.252	0.056
F19	Mean	<u>3.26E+04</u>	2.47E+05	1.66E+05	2.38E+07	6.82E+07	3.08E+06
	Std	3.65E+04	6.72E+05	1.59E+05	2.88E+07	1.57E+08	7.99E+06
	CPU	0.503	0.134	0.125	0.147	0.267	0.103
F20	Mean	<u>2.19E+03</u>	2.25E+03	2.21E+03	2.46E+03	2.40E+03	2.24E+03
	Std	9.23E+01	1.52E+02	5.27E+01	1.28E+02	1.23E+02	1.33E+02
	CPU	0.075	0.027	0.038	0.053	0.128	0.044
F21	Mean	2.34E+03	2.35E+03	2.38E+03	2.36E+03	2.43E+03	<u>2.34E+03</u>
	Std	3.61E+01	3.39E+01	1.51E+01	6.47E+01	4.00E+01	4.42E+01
	CPU	0.066	0.022	0.042	0.058	0.127	0.036
F22	Mean	2.46E+03	3.07E+03	2.88E+03	3.49E+03	3.58E+03	<u>2.41E+03</u>
	Std	1.50E+02	2.32E+02	2.19E+02	3.83E+02	4.66E+02	4.66E+01
	CPU	0.056	0.028	0.044	0.045	0.139	0.048
F23	Mean	2.75E+03	2.80E+03	<u>2.68E+03</u>	2.84E+03	2.88E+03	2.69E+03
	Std	5.41E+01	4.35E+01	1.86E+01	6.25E+01	1.15E+02	3.35E+01
	CPU	0.080	0.036	0.039	0.063	0.138	0.050
F24	Mean	<u>2.74E+03</u>	2.90E+03	2.81E+03	2.94E+03	3.01E+03	2.80E+03
	Std	1.73E+02	9.97E+01	2.62E+01	6.60E+01	1.20E+02	6.76E+01
	CPU	0.080	0.034	0.048	0.063	0.147	0.047
F25	Mean	<u>2.98E+03</u>	3.67E+03	3.19E+03	4.46E+03	3.70E+03	3.07E+03
	Std	2.31E+01	2.53E+02	2.05E+02	5.65E+02	2.49E+02	2.10E+02
	CPU	0.058	0.038	0.030	0.070	0.148	0.063
F26	Mean	3.94E+03	4.15E+03	<u>3.46E+03</u>	4.51E+03	4.51E+03	3.96E+03
	Std	5.81E+02	3.40E+02	4.66E+02	4.25E+02	4.38E+02	6.44E+02
	CPU	0.102	0.039	0.045	0.064	0.144	0.055
F27	Mean	3.28E+03	3.33E+03	<u>3.14E+03</u>	3.35E+03	3.47E+03	3.17E+03
	Std	5.29E+01	8.73E+01	3.15E+01	6.20E+01	1.07E+02	3.11E+01
	CPU	0.102	0.039	0.052	0.072	0.136	0.050
F28	Mean	3.59E+03	3.86E+03	<u>3.48E+03</u>	3.89E+03	3.90E+03	3.56E+03
	Std	1.76E+02	1.58E+02	2.11E+02	2.24E+02	1.44E+02	1.48E+02
	CPU	0.089	0.034	0.044	0.064	0.139	0.056
F29	Mean	3.40E+03	3.49E+03	<u>3.37E+03</u>	4.04E+03	3.85E+03	3.49E+03
	Std	1.06E+02	1.85E+02	6.11E+01	1.87E+02	1.73E+02	2.21E+02
	CPU	0.123	0.048	0.047	0.070	0.147	0.052

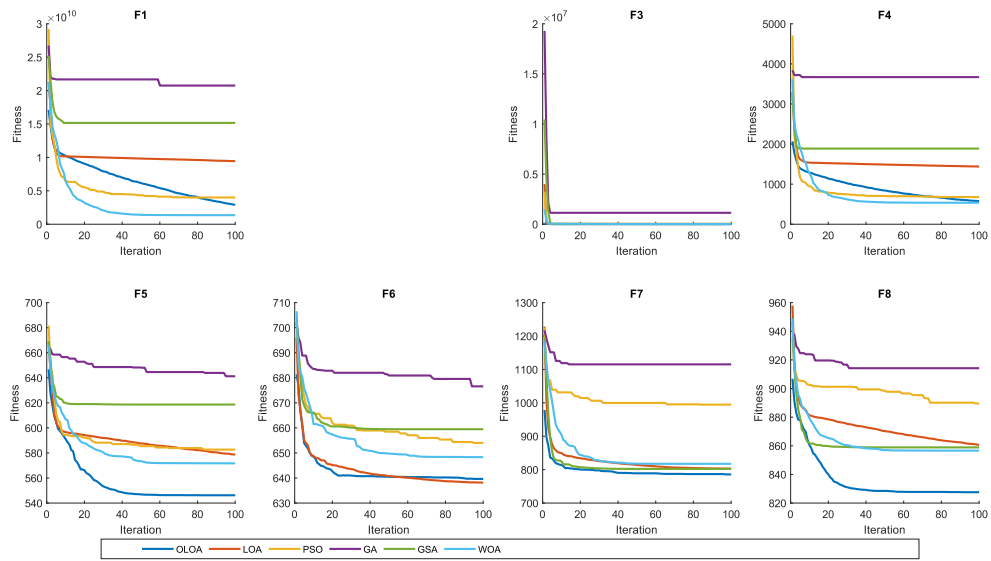
Comparison of optimization results for the CEC benchmark functions 2017 (10 Dim)

Function		OLOA	LOA	PSO	GA	GSA	WOA
F30	Mean	1.91E+07	7.47E+07	<u>1.11E+06</u>	8.43E+07	1.07E+08	2.97E+06
	Std	2.21E+07	6.93E+07	6.28E+05	6.50E+07	6.53E+07	3.41E+06
	CPU	0.277	0.088	0.092	0.105	0.192	0.102

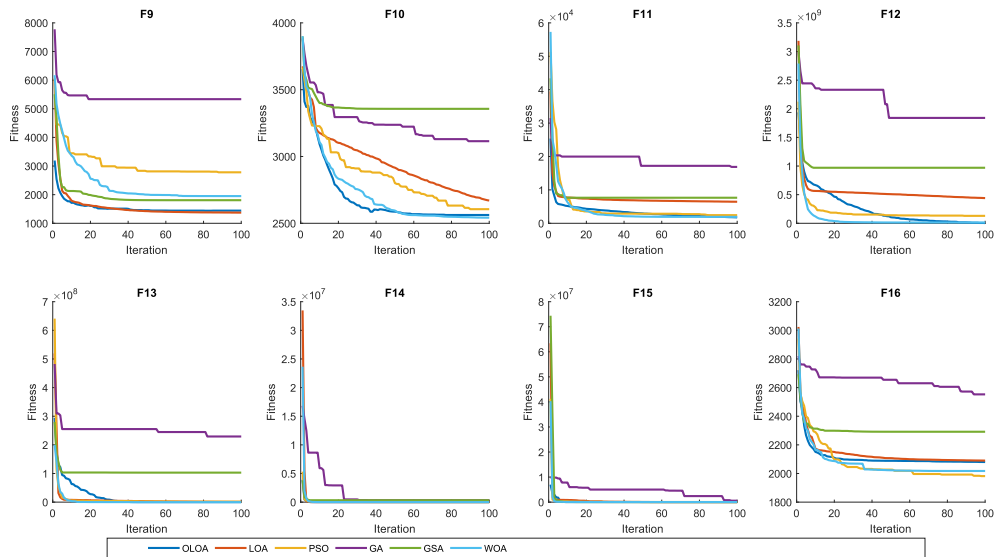
P-value of the T-test analysis for the CEC benchmark functions 2017 (10 Dim)

Function	OLOA versus LOA	OLOA versus PSO	OLOA versus GA	OLOA versus GSA	OLOA versus WOA
F1	1.01E-04	2.75E-01	8.81E-07	5.74E-06	1.23E-01
F2			Deleted		
F3	5.19E-03	1.69E-06	1.07E-01	1.77E-05	4.38E-02
F4	5.97E-03	6.56E-02	3.95E-06	4.07E-05	3.58E-01
F5	1.39E-04	1.25E-05	1.98E-09	7.42E-09	4.30E-04
F6	7.30E-01	6.34E-03	1.24E-06	8.62E-04	1.27E-01
F7	2.93E-01	9.78E-07	3.43E-09	2.94E-01	5.44E-02
F8	2.22E-04	3.32E-09	4.96E-13	2.75E-08	2.26E-03
F9	5.15E-01	5.87E-06	3.36E-07	1.00E-02	1.69E-02
F10	4.49E-01	6.80E-01	1.35E-05	2.45E-06	8.46E-01
F11	4.64E-05	1.21E-01	7.22E-05	5.13E-04	7.25E-01
F12	4.64E-02	3.68E-04	6.47E-05	7.59E-04	6.22E-02
F13	3.01E-01	1.49E-03	1.56E-02	3.08E-02	9.40E-02
F14	8.05E-01	2.32E-01	1.32E-01	3.39E-02	5.29E-01
F15	5.51E-01	7.69E-01	1.01E-02	2.75E-01	5.38E-01
F16	8.60E-01	1.68E-01	1.71E-06	3.45E-04	3.76E-01
F17	9.84E-01	3.18E-04	4.37E-06	7.96E-03	3.51E-01
F18	1.59E-01	2.61E-05	9.49E-03	6.34E-02	1.97E-01
F19	3.28E-01	1.83E-02	1.79E-02	1.86E-01	2.43E-01
F20	3.16E-01	6.98E-01	3.61E-05	4.23E-04	3.84E-01
F21	5.60E-01	2.06E-02	4.29E-01	7.77E-05	8.60E-01
F22	1.87E-06	9.11E-05	3.24E-07	1.07E-06	3.01E-01
F23	4.27E-02	7.55E-04	2.20E-03	3.80E-03	1.06E-02
F24	1.80E-02	2.51E-01	2.66E-03	8.05E-04	3.47E-01
F25	8.03E-08	5.45E-03	1.53E-07	3.41E-08	1.82E-01
F26	3.25E-01	6.06E-02	2.20E-02	2.35E-02	9.22E-01
F27	1.60E-01	5.65E-07	2.27E-02	1.30E-04	9.93E-06
F28	1.87E-03	2.31E-01	3.90E-03	3.75E-04	7.11E-01
F29	2.05E-01	4.72E-01	2.14E-08	1.18E-06	2.62E-01
F30	2.66E-02	1.92E-02	7.65E-03	7.42E-04	3.50E-02

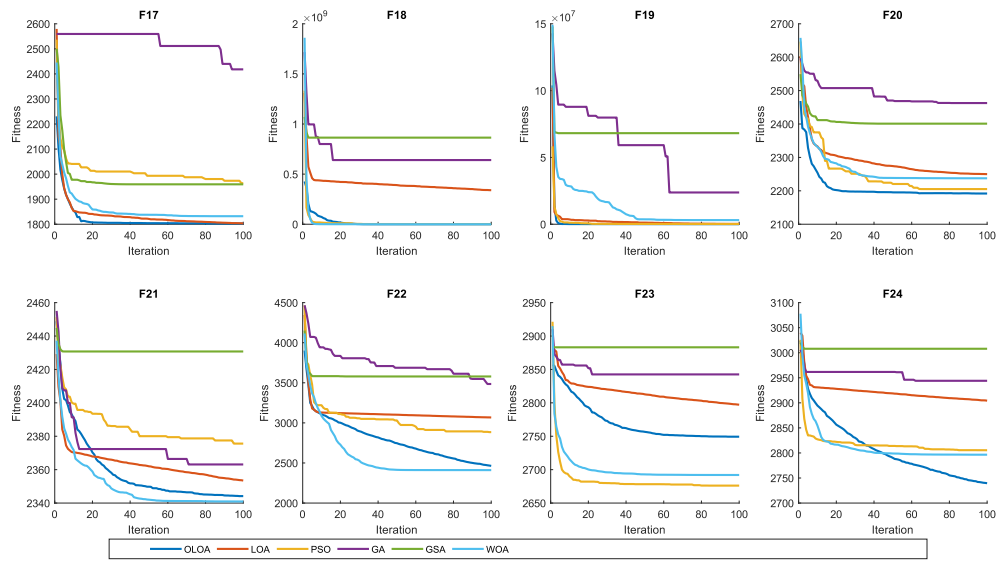
CEC Benchmark
2017



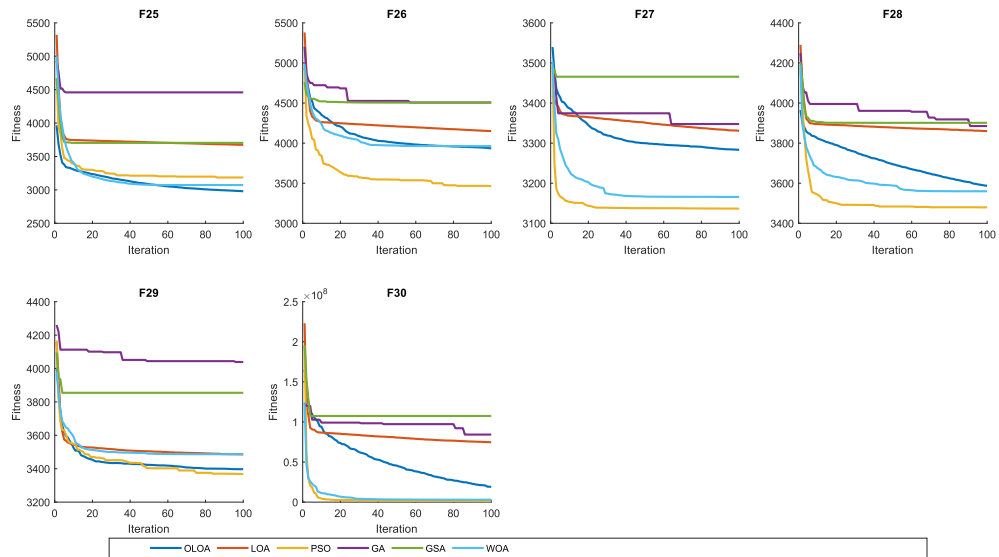
CEC Benchmark
2017



CEC Benchmark
2017



CEC Benchmark
2017



CEC 2017 Benchmark Function 30 Dimensions

Comparison of optimization results for the CEC benchmark functions 2017 (30 Dim)

Function		OLOA	LOA	PSO	GA	GSA	WOA
F1	Mean	3.57E+10	5.67E+10	7.84E+10	1.20E+11	5.91E+10	<u>2.64E+10</u>
	Std	6.86E+09	1.13E+10	9.63E+09	1.72E+10	8.93E+09	6.98E+09
	CPU	0.034	0.020	0.033	0.042	0.253	0.033
F2	Mean	The Function F2 was Delete in CEC 2017					
	Std						
	CPU						
F3	Mean	<u>8.55E+04</u>	1.27E+05	3.59E+05	1.81E+08	1.15E+05	3.13E+05
	Std	1.51E+04	3.56E+04	5.66E+04	2.98E+08	2.75E+04	6.41E+04
	CPU	0.039	0.023	0.034	0.058	0.227	0.028
F4	Mean	8.21E+03	1.72E+04	1.43E+04	4.42E+04	2.47E+04	<u>6.10E+03</u>
	Std	2.51E+03	4.25E+03	7.39E+03	1.44E+04	4.41E+03	2.00E+03
	CPU	0.064	0.023	0.027	0.047	0.208	0.047
F5	Mean	<u>7.80E+02</u>	8.77E+02	1.00E+03	1.13E+03	9.68E+02	9.26E+02
	Std	4.42E+01	3.35E+01	5.36E+01	6.69E+01	3.03E+01	5.12E+01
	CPU	0.058	0.031	0.045	0.094	0.278	0.050
F6	Mean	<u>6.74E+02</u>	6.75E+02	7.00E+02	7.21E+02	7.04E+02	6.94E+02
	Std	4.97E+00	7.75E+00	1.29E+01	1.07E+01	5.34E+00	1.01E+01
	CPU	0.142	0.077	0.063	0.108	0.319	0.077
F7	Mean	<u>1.38E+03</u>	1.49E+03	3.00E+03	3.29E+03	1.49E+03	1.39E+03
	Std	8.92E+01	1.83E+02	3.29E+02	2.86E+02	1.22E+02	7.79E+01
	CPU	0.066	0.052	0.092	0.089	0.273	0.075
F8	Mean	<u>1.00E+03</u>	1.12E+03	1.31E+03	1.36E+03	1.17E+03	1.16E+03
	Std	3.88E+01	4.10E+01	3.71E+01	5.51E+01	2.44E+01	7.35E+01
	CPU	0.095	0.044	0.052	0.095	0.322	0.097
F9	Mean	1.02E+04	<u>7.66E+03</u>	2.64E+04	3.53E+04	1.31E+04	1.35E+04
	Std	1.44E+03	1.49E+03	4.32E+03	4.15E+03	1.30E+03	2.73E+03
	CPU	0.086	0.038	0.059	0.075	0.277	0.047
F10	Mean	<u>6.44E+03</u>	8.77E+03	9.30E+03	9.42E+03	9.51E+03	8.89E+03
	Std	5.58E+02	3.73E+02	3.62E+02	3.50E+02	5.34E+02	5.95E+02
	CPU	0.088	0.047	0.056	0.078	0.259	0.061
F11	Mean	<u>6.01E+03</u>	1.52E+04	2.69E+04	2.07E+05	1.21E+04	2.49E+04
	Std	2.14E+03	5.32E+03	8.41E+03	3.06E+05	1.49E+03	8.79E+03
	CPU	0.077	0.023	0.041	0.059	0.256	0.047
F12	Mean	6.42E+09	1.43E+10	6.73E+09	2.56E+10	1.94E+10	<u>3.13E+09</u>
	Std	3.43E+09	2.51E+09	2.34E+09	5.37E+09	2.70E+09	1.49E+09
	CPU	0.081	0.036	0.047	0.073	0.264	0.058
F13	Mean	2.72E+09	1.49E+10	3.88E+09	2.91E+10	2.25E+10	<u>5.90E+08</u>
	Std	1.69E+09	8.49E+09	1.47E+09	8.60E+09	8.08E+09	5.26E+08
	CPU	0.088	0.039	0.033	0.064	0.250	0.053
F14	Mean	<u>2.97E+06</u>	1.27E+07	3.38E+06	6.17E+07	2.73E+07	6.41E+06
	Std	3.65E+06	1.27E+07	3.39E+06	4.31E+07	3.42E+07	7.44E+06
	CPU	0.097	0.047	0.042	0.077	0.286	0.056
F15	Mean	<u>2.90E+06</u>	8.55E+08	7.37E+08	7.34E+09	1.33E+09	1.54E+08

Comparison of optimization results for the CEC benchmark functions 2017 (30 Dim)

Function		OLOA	LOA	PSO	GA	GSA	WOA
	Std	7.25E+06	9.46E+08	3.39E+08	3.40E+09	7.93E+08	2.22E+08
	CPU	0.064	0.030	0.041	0.059	0.245	0.047
F16	Mean	5.11E+03	6.30E+03	4.78E+03	1.12E+04	9.96E+03	4.76E+03
	Std	1.02E+03	2.99E+03	3.83E+02	2.88E+03	3.22E+03	6.12E+02
	CPU	0.072	0.036	0.036	0.066	0.273	0.053
F17	Mean	2.87E+03	4.17E+03	3.55E+03	4.78E+04	1.90E+04	3.26E+03
	Std	4.57E+02	1.20E+03	2.55E+02	3.84E+04	1.40E+04	3.37E+02
	CPU	0.197	0.080	0.070	0.102	0.277	0.072
F18	Mean	1.38E+07	2.12E+08	3.91E+07	9.57E+08	3.39E+08	1.93E+07
	Std	1.21E+07	2.12E+08	2.19E+07	5.73E+08	4.35E+08	1.45E+07
	CPU	0.073	0.036	0.039	0.064	0.253	0.055
F19	Mean	2.19E+07	1.04E+09	1.19E+09	9.27E+09	2.01E+09	1.59E+08
	Std	3.87E+07	8.67E+08	6.67E+08	4.08E+09	1.23E+09	1.14E+08
	CPU	0.667	0.238	0.184	0.217	0.436	0.213
F20	Mean	2.88E+03	3.13E+03	3.20E+03	3.29E+03	3.36E+03	3.11E+03
	Std	2.53E+02	3.18E+02	1.64E+02	1.38E+02	2.81E+02	1.85E+02
	CPU	0.241	0.075	0.063	0.083	0.292	0.069
F21	Mean	2.55E+03	2.72E+03	2.76E+03	2.91E+03	2.83E+03	2.70E+03
	Std	3.69E+01	5.20E+01	3.01E+01	6.14E+01	6.61E+01	6.88E+01
	CPU	0.208	0.095	0.083	0.100	0.278	0.083
F22	Mean	7.96E+03	9.75E+03	9.94E+03	1.09E+04	1.01E+04	9.17E+03
	Std	8.33E+02	6.14E+02	1.12E+03	5.52E+02	6.92E+02	1.79E+03
	CPU	0.253	0.075	0.080	0.103	0.272	0.091
F23	Mean	3.67E+03	3.81E+03	3.25E+03	4.03E+03	4.06E+03	3.23E+03
	Std	1.22E+02	1.92E+02	1.20E+02	3.66E+02	4.37E+02	1.28E+02
	CPU	0.275	0.100	0.094	0.106	0.305	0.116
F24	Mean	3.91E+03	4.56E+03	3.29E+03	4.27E+03	4.61E+03	3.37E+03
	Std	1.60E+02	2.35E+02	9.68E+01	2.34E+02	2.49E+02	1.45E+02
	CPU	0.291	0.094	0.088	0.130	0.311	0.113
F25	Mean	3.81E+03	5.63E+03	1.35E+04	1.87E+04	6.24E+03	3.83E+03
	Std	3.29E+02	8.69E+02	3.61E+03	4.42E+03	8.89E+02	1.99E+02
	CPU	0.259	0.097	0.092	0.114	0.298	0.092
F26	Mean	9.45E+03	1.16E+04	9.28E+03	1.74E+04	1.30E+04	9.14E+03
	Std	8.62E+02	1.51E+03	9.04E+02	1.57E+03	7.99E+02	1.05E+03
	CPU	0.334	0.105	0.113	0.130	0.291	0.144
F27	Mean	4.49E+03	5.34E+03	3.45E+03	5.37E+03	5.81E+03	3.65E+03
	Std	2.71E+02	3.56E+02	9.68E+01	6.83E+02	6.67E+02	1.63E+02
	CPU	0.403	0.172	0.134	0.145	0.334	0.141
F28	Mean	5.31E+03	8.00E+03	7.35E+03	1.34E+04	8.94E+03	5.20E+03
	Std	7.27E+02	1.25E+03	1.17E+03	2.53E+03	6.92E+02	5.03E+02
	CPU	0.339	0.123	0.100	0.125	0.317	0.138
F29	Mean	6.60E+03	9.43E+03	5.77E+03	2.84E+04	1.24E+04	6.10E+03
	Std	1.59E+03	4.22E+03	5.57E+02	2.86E+04	5.69E+03	7.48E+02
	CPU	0.272	0.113	0.100	0.128	0.330	0.114

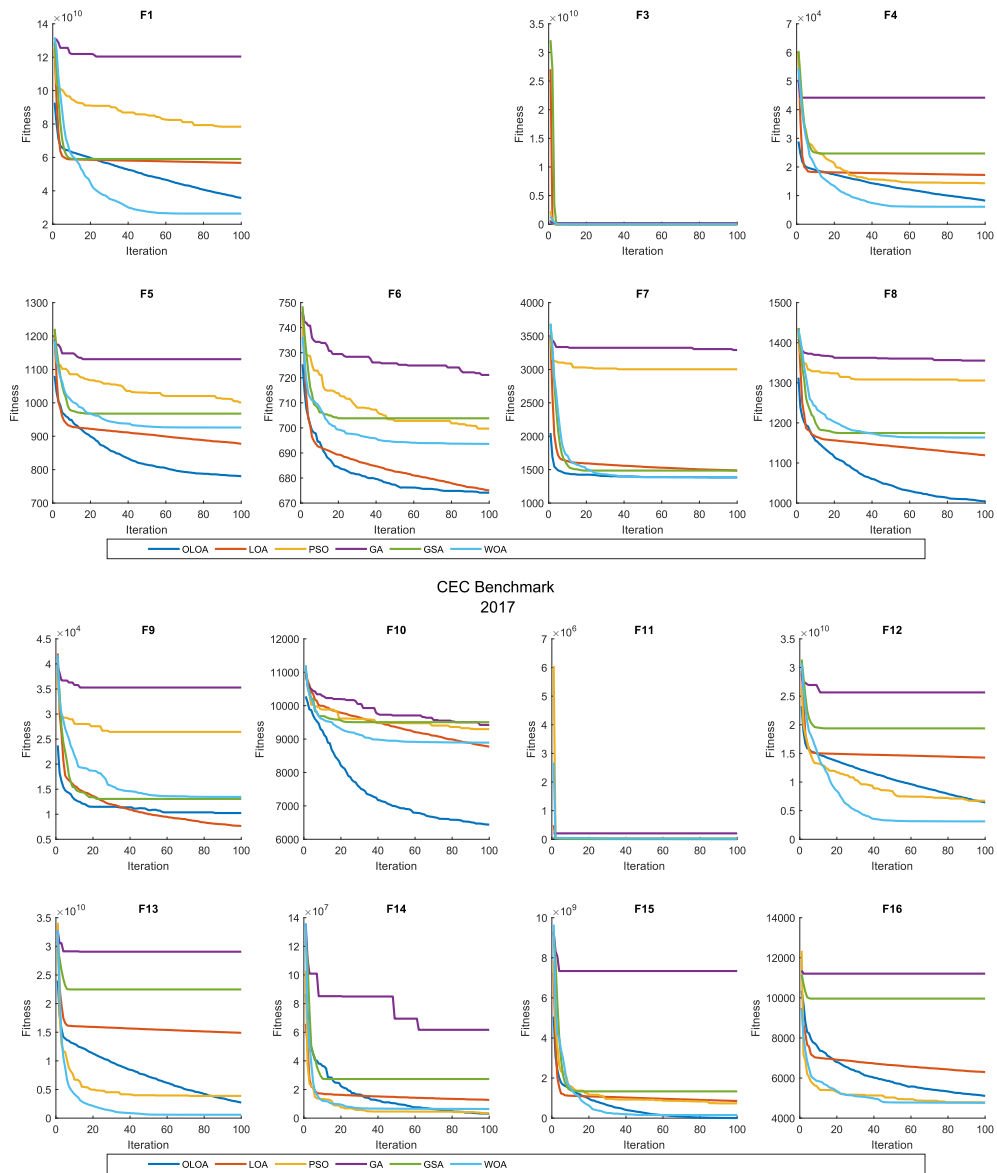
Comparison of optimization results for the CEC benchmark functions 2017 (30 Dim)

Function		OLOA	LOA	PSO	GA	GSA	WOA
F30	Mean	2.88E+08	2.59E+09	5.26E+08	4.03E+09	3.20E+09	2.96E+08
	Std	2.72E+08	1.40E+09	3.84E+08	1.56E+09	1.68E+09	1.67E+08
	CPU	0.752	0.259	0.256	0.284	0.414	0.208

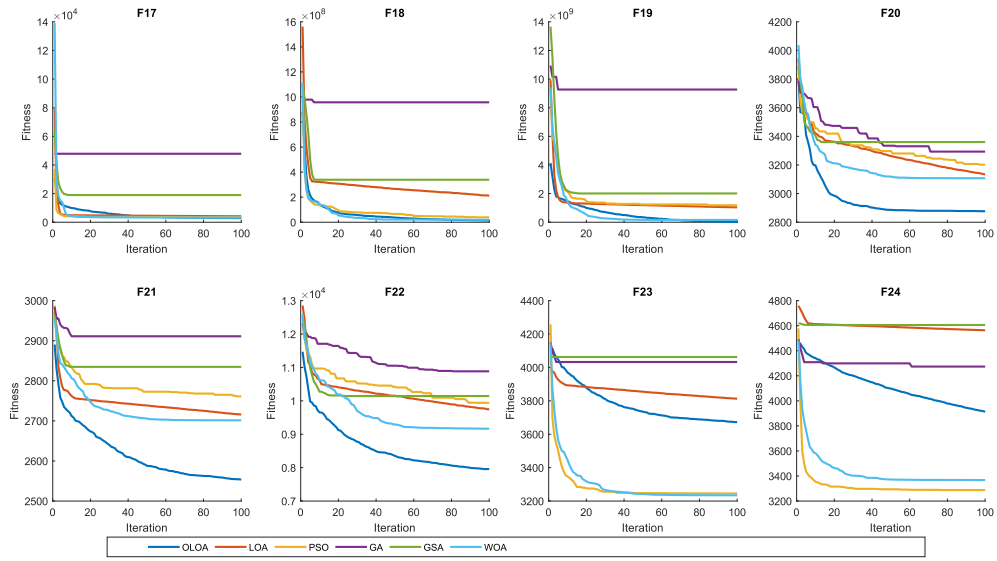
P-value of the T-test analysis for the CEC benchmark functions 2017 (30 Dim)

Function	OLOA versus LOA	OLOA versus PSO	OLOA versus GA	OLOA versus GSA	OLOA versus WOA
F1	8.98E-05	1.14E-09	2.46E-11	3.72E-06	7.29E-03
F2			Deleted		
F3	3.07E-03	1.65E-11	7.11E-02	7.27E-03	2.23E-09
F4	1.83E-05	2.34E-02	3.60E-07	5.91E-09	5.22E-02
F5	2.87E-05	8.06E-09	4.99E-11	1.82E-09	2.15E-06
F6	7.67E-01	1.48E-05	2.36E-10	1.63E-10	3.55E-05
F7	1.29E-01	1.24E-11	8.60E-14	4.59E-02	9.21E-01
F8	4.96E-06	7.71E-13	2.74E-12	7.38E-10	1.03E-05
F9	9.49E-04	1.44E-09	5.60E-13	2.21E-04	3.92E-03
F10	2.09E-09	6.70E-11	2.76E-11	2.45E-10	1.91E-08
F11	7.75E-05	4.98E-07	5.20E-02	7.06E-07	3.39E-06
F12	1.56E-05	8.11E-01	1.82E-08	2.34E-08	1.22E-02
F13	3.15E-04	1.20E-01	1.93E-08	5.36E-07	1.28E-03
F14	3.11E-02	7.96E-01	4.41E-04	3.83E-02	2.06E-01
F15	1.07E-02	2.09E-06	2.16E-06	4.76E-05	4.51E-02
F16	2.50E-01	3.55E-01	6.01E-06	2.48E-04	3.66E-01
F17	5.06E-03	6.49E-04	1.64E-03	1.86E-03	4.42E-02
F18	8.67E-03	4.87E-03	5.95E-05	2.94E-02	3.63E-01
F19	1.62E-03	3.10E-05	1.13E-06	7.08E-05	2.13E-03
F20	6.05E-02	3.11E-03	2.38E-04	7.68E-04	3.20E-02
F21	2.32E-07	5.47E-11	5.57E-12	7.16E-10	1.18E-05
F22	3.36E-05	2.87E-04	2.86E-08	5.15E-06	6.85E-02
F23	6.79E-02	2.95E-07	8.52E-03	1.42E-02	3.31E-07
F24	9.97E-07	3.78E-09	8.11E-04	7.56E-07	2.52E-07
F25	7.46E-06	1.14E-07	3.67E-09	1.98E-07	8.53E-01
F26	1.14E-03	6.62E-01	3.68E-11	1.87E-08	4.70E-01
F27	1.09E-05	1.10E-09	1.37E-03	1.70E-05	1.24E-07
F28	1.48E-05	1.87E-04	1.40E-08	1.11E-09	6.90E-01
F29	6.25E-02	1.40E-01	2.69E-02	6.20E-03	3.79E-01
F30	7.36E-05	1.27E-01	6.26E-07	3.72E-05	9.32E-01

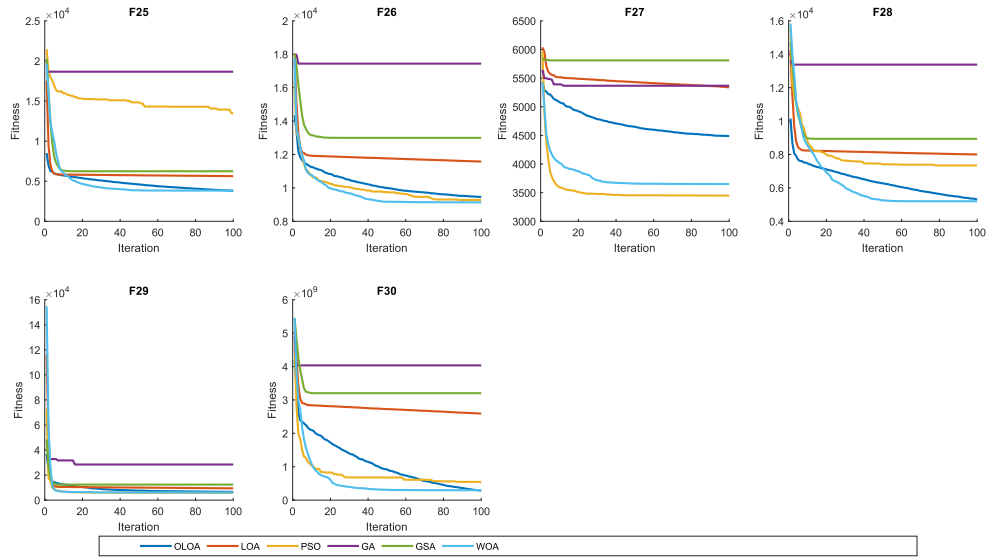
CEC Benchmark 2017



CEC Benchmark
2017



CEC Benchmark
2017



CEC 2017 Benchmark Function 50 Dimensions

Comparison of optimization results for the CEC benchmark functions 2017 (50 Dim)

Function		OLOA	LOA	PSO	GA	GSA	WOA
F1	Mean	8.09E+10	1.16E+11	2.15E+11	2.39E+11	1.20E+11	<u>6.96E+10</u>
	Std	7.01E+09	2.36E+10	2.39E+10	1.51E+10	1.27E+10	7.30E+09
	CPU	0.088	0.038	0.059	0.092	0.392	0.091
F2	Mean	The Function F2 was Delete in CEC 2017					
	Std						
	CPU						
F3	Mean	<u>2.03E+05</u>	2.39E+05	6.14E+05	8.18E+11	2.52E+06	3.52E+05
	Std	2.39E+04	4.08E+04	1.17E+05	2.11E+12	7.11E+06	6.26E+04
	CPU	0.192	0.050	0.106	0.094	0.359	0.063
F4	Mean	2.31E+04	4.57E+04	5.10E+04	1.07E+05	4.54E+04	<u>1.80E+04</u>
	Std	4.02E+03	7.43E+03	2.16E+04	1.43E+04	6.93E+03	1.95E+03
	CPU	0.122	0.061	0.055	0.116	0.447	0.095
F5	Mean	<u>9.79E+02</u>	1.17E+03	1.59E+03	1.61E+03	1.26E+03	1.22E+03
	Std	4.49E+01	4.14E+01	4.66E+01	6.00E+01	2.35E+01	4.36E+01
	CPU	0.216	0.064	0.100	0.123	0.413	0.106
F6	Mean	<u>6.84E+02</u>	6.89E+02	7.33E+02	7.39E+02	7.11E+02	7.08E+02
	Std	4.89E+00	1.00E+01	1.28E+01	8.16E+00	7.40E+00	1.10E+01
	CPU	0.320	0.122	0.152	0.133	0.456	0.116
F7	Mean	<u>1.98E+03</u>	2.33E+03	5.90E+03	5.94E+03	2.38E+03	2.00E+03
	Std	8.13E+01	2.26E+02	3.73E+02	3.91E+02	1.38E+02	8.04E+01
	CPU	0.170	0.055	0.109	0.133	0.384	0.072
F8	Mean	<u>1.27E+03</u>	1.49E+03	1.80E+03	1.92E+03	1.57E+03	1.47E+03
	Std	4.23E+01	3.00E+01	9.19E+01	4.46E+01	4.39E+01	5.81E+01
	CPU	0.170	0.069	0.061	0.088	0.409	0.072
F9	Mean	3.82E+04	<u>2.27E+04</u>	8.54E+04	9.54E+04	4.57E+04	4.27E+04
	Std	6.95E+03	2.67E+03	9.97E+03	1.00E+04	5.16E+03	1.01E+04
	CPU	0.166	0.073	0.058	0.091	0.395	0.072
F10	Mean	<u>1.12E+04</u>	1.52E+04	1.59E+04	1.59E+04	1.66E+04	1.54E+04
	Std	6.53E+02	5.29E+02	7.49E+02	6.55E+02	3.24E+02	6.07E+02
	CPU	0.163	0.070	0.088	0.109	0.428	0.084
F11	Mean	2.13E+04	3.45E+04	8.08E+04	1.34E+05	3.39E+04	<u>2.09E+04</u>
	Std	5.65E+03	8.17E+03	2.46E+04	1.19E+05	5.58E+03	4.55E+03
	CPU	0.128	0.048	0.063	0.083	0.388	0.077
F12	Mean	5.55E+10	8.71E+10	4.57E+10	1.34E+11	9.36E+10	<u>2.21E+10</u>
	Std	1.40E+10	1.91E+10	6.04E+09	3.00E+10	1.33E+10	7.65E+09
	CPU	0.153	0.064	0.072	0.081	0.414	0.092
F13	Mean	1.79E+10	4.94E+10	1.90E+10	7.81E+10	6.95E+10	<u>6.17E+09</u>
	Std	2.86E+09	1.06E+10	6.50E+09	1.89E+10	1.70E+10	2.45E+09
	CPU	0.164	0.059	0.061	0.089	0.398	0.075
F14	Mean	3.05E+07	2.01E+08	2.41E+07	3.78E+08	3.01E+08	<u>1.05E+07</u>
	Std	1.74E+07	1.05E+08	1.56E+07	1.98E+08	5.84E+07	7.99E+06
	CPU	0.209	0.072	0.067	0.105	0.395	0.091
F15	Mean	1.58E+09	1.09E+10	5.63E+09	3.20E+10	1.29E+10	<u>8.12E+08</u>

Comparison of optimization results for the CEC benchmark functions 2017 (50 Dim)

Function		OLOA	LOA	PSO	GA	GSA	WOA
	Std	1.31E+09	3.64E+09	4.25E+09	6.46E+09	4.03E+09	4.53E+08
	CPU	0.141	0.050	0.050	0.088	0.400	0.077
F16	Mean	<u>6.51E+03</u>	9.66E+03	7.84E+03	1.63E+04	1.24E+04	7.77E+03
	Std	1.11E+03	1.56E+03	5.09E+02	2.60E+03	2.14E+03	1.42E+03
	CPU	0.163	0.064	0.069	0.102	0.391	0.080
F17	Mean	<u>4.25E+03</u>	6.84E+03	1.87E+05	1.97E+06	2.35E+04	6.11E+03
	Std	3.77E+02	1.67E+03	3.67E+05	1.87E+06	1.32E+04	1.60E+03
	CPU	0.323	0.114	0.117	0.138	0.502	0.134
F18	Mean	<u>6.70E+07</u>	2.23E+08	1.39E+08	1.09E+09	5.23E+08	1.26E+08
	Std	3.87E+07	1.13E+08	7.69E+07	5.55E+08	3.14E+08	8.42E+07
	CPU	0.116	0.056	0.073	0.088	0.397	0.064
F19	Mean	1.63E+09	5.93E+09	3.64E+09	1.44E+10	7.39E+09	<u>4.19E+08</u>
	Std	1.05E+09	2.14E+09	1.51E+09	4.87E+09	3.13E+09	2.81E+08
	CPU	1.095	0.380	0.313	0.322	0.659	0.309
F20	Mean	<u>3.83E+03</u>	4.12E+03	4.89E+03	4.80E+03	4.72E+03	4.27E+03
	Std	2.94E+02	2.62E+02	2.28E+02	3.10E+02	1.96E+02	3.18E+02
	CPU	0.433	0.133	0.111	0.155	0.442	0.123
F21	Mean	<u>2.91E+03</u>	3.22E+03	3.32E+03	3.49E+03	3.46E+03	3.28E+03
	Std	7.62E+01	1.39E+02	6.05E+01	1.04E+02	1.12E+02	1.93E+02
	CPU	0.494	0.163	0.155	0.181	0.466	0.158
F22	Mean	<u>1.33E+04</u>	1.68E+04	1.75E+04	1.82E+04	1.81E+04	1.68E+04
	Std	1.80E+03	7.72E+02	4.87E+02	3.80E+02	3.39E+02	5.93E+02
	CPU	0.530	0.186	0.169	0.184	0.503	0.203
F23	Mean	4.60E+03	5.20E+03	<u>3.98E+03</u>	5.27E+03	5.32E+03	4.07E+03
	Std	3.28E+02	3.76E+02	1.54E+02	3.47E+02	3.32E+02	1.88E+02
	CPU	0.656	0.217	0.194	0.230	0.539	0.208
F24	Mean	5.06E+03	5.78E+03	<u>3.97E+03</u>	5.68E+03	5.81E+03	4.22E+03
	Std	2.65E+02	3.22E+02	1.74E+02	3.17E+02	3.91E+02	1.69E+02
	CPU	0.672	0.213	0.158	0.220	0.508	0.202
F25	Mean	1.07E+04	1.80E+04	5.48E+04	5.56E+04	1.86E+04	<u>1.01E+04</u>
	Std	8.42E+02	4.22E+03	1.28E+04	8.18E+03	2.42E+03	1.54E+03
	CPU	0.756	0.219	0.194	0.230	0.486	0.200
F26	Mean	<u>1.48E+04</u>	1.91E+04	1.75E+04	3.21E+04	1.93E+04	1.64E+04
	Std	7.32E+02	1.11E+03	2.05E+03	3.24E+03	1.08E+03	8.85E+02
	CPU	0.808	0.267	0.228	0.267	0.588	0.253
F27	Mean	7.02E+03	8.50E+03	<u>4.35E+03</u>	8.79E+03	8.43E+03	5.84E+03
	Std	6.53E+02	8.64E+02	2.30E+02	6.13E+02	7.26E+02	7.46E+02
	CPU	0.948	0.314	0.275	0.306	0.605	0.286
F28	Mean	1.01E+04	1.33E+04	1.30E+04	2.40E+04	1.55E+04	<u>9.32E+03</u>
	Std	9.71E+02	1.32E+03	1.66E+03	1.71E+03	8.96E+02	1.08E+03
	CPU	0.839	0.330	0.250	0.272	0.572	0.253
F29	Mean	1.82E+04	2.60E+05	<u>1.46E+04</u>	4.16E+06	1.60E+06	1.83E+04
	Std	8.80E+03	3.43E+05	6.98E+03	4.01E+06	2.40E+06	8.08E+03
	CPU	0.583	0.250	0.220	0.220	0.525	0.189

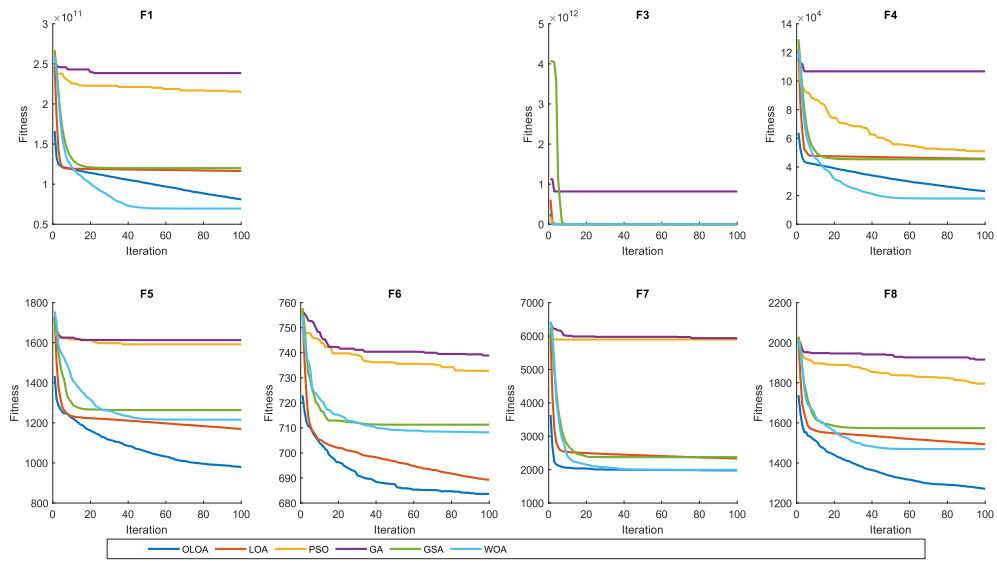
Comparison of optimization results for the CEC benchmark functions 2017 (50 Dim)

Function		OLOA	LOA	PSO	GA	GSA	WOA
F30	Mean	3.18E+09	9.56E+09	5.03E+09	1.91E+10	1.47E+10	<u>1.02E+09</u>
	Std	2.25E+09	3.00E+09	1.71E+09	4.47E+09	6.57E+09	3.60E+08
	CPU	1.314	0.467	0.403	0.409	0.722	0.406

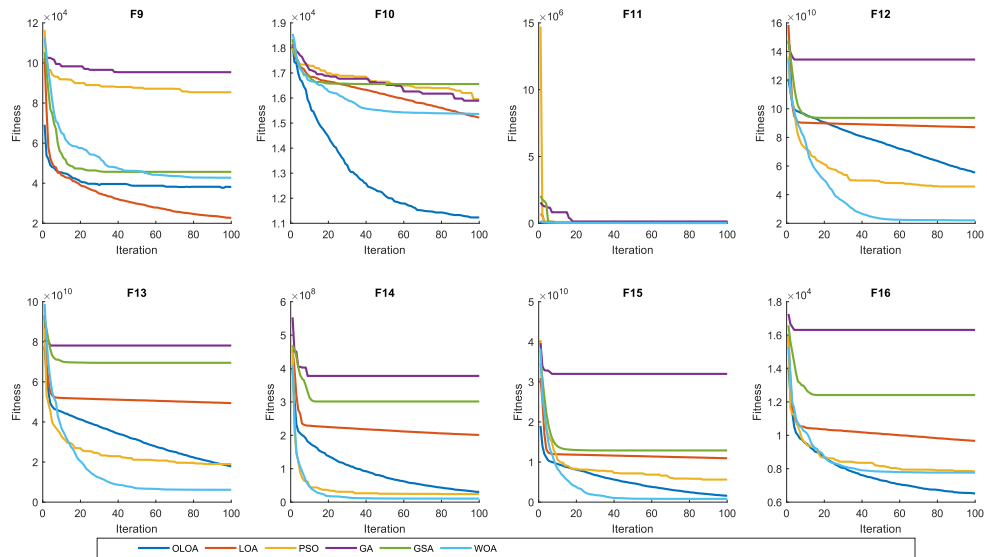
P-value of the T-test analysis for the CEC benchmark functions 2017 (50 Dim)

Function	OLOA versus LOA	OLOA versus PSO	OLOA versus GA	OLOA versus GSA	OLOA versus WOA
F1	2.43E-04	1.62E-12	8.46E-17	9.64E-08	2.26E-03
F2			Deleted		
F3	2.73E-02	2.57E-09	2.37E-01	3.17E-01	1.56E-06
F4	1.10E-07	8.19E-04	7.25E-13	6.30E-08	1.85E-03
F5	1.03E-08	8.13E-17	5.96E-16	7.18E-13	5.13E-10
F6	1.31E-01	1.26E-09	4.26E-13	1.14E-08	4.66E-06
F7	1.95E-04	2.02E-17	3.78E-17	3.41E-07	6.64E-01
F8	7.59E-11	2.95E-12	1.41E-17	6.33E-12	7.50E-08
F9	3.57E-06	3.42E-10	1.57E-11	1.33E-02	2.53E-01
F10	1.32E-11	1.30E-11	4.66E-12	7.93E-15	1.92E-11
F11	5.05E-04	6.36E-07	7.87E-03	8.40E-05	8.65E-01
F12	5.15E-04	5.80E-02	5.79E-07	6.88E-06	3.34E-06
F13	3.64E-08	6.36E-01	9.80E-09	2.14E-08	1.13E-08
F14	7.87E-05	3.94E-01	2.95E-05	3.85E-11	3.81E-03
F15	4.48E-07	9.98E-03	2.06E-11	1.13E-07	9.59E-02
F16	6.15E-05	3.05E-03	2.11E-09	3.92E-07	4.15E-02
F17	1.54E-04	1.34E-01	3.84E-03	2.18E-04	2.20E-03
F18	6.52E-04	1.67E-02	1.64E-05	2.45E-04	5.83E-02
F19	2.12E-05	2.77E-03	2.12E-07	3.04E-05	2.43E-03
F20	2.87E-02	4.22E-08	1.01E-06	2.47E-07	4.20E-03
F21	8.07E-06	9.59E-11	3.67E-11	1.99E-10	2.43E-05
F22	1.98E-05	1.12E-06	1.11E-07	1.38E-07	1.79E-05
F23	1.20E-03	4.14E-05	3.10E-04	1.12E-04	3.47E-04
F24	3.32E-05	2.43E-09	1.70E-04	8.62E-05	1.14E-07
F25	3.76E-05	2.47E-09	1.21E-12	1.30E-08	3.20E-01
F26	7.88E-09	1.28E-03	2.65E-12	2.46E-09	5.41E-04
F27	4.22E-04	4.03E-10	6.99E-06	2.42E-04	1.46E-03
F28	1.15E-05	2.02E-04	1.41E-14	1.90E-10	9.10E-02
F29	3.92E-02	3.31E-01	4.32E-03	5.21E-02	9.83E-01
F30	4.10E-05	5.29E-02	8.47E-09	5.60E-05	7.50E-03

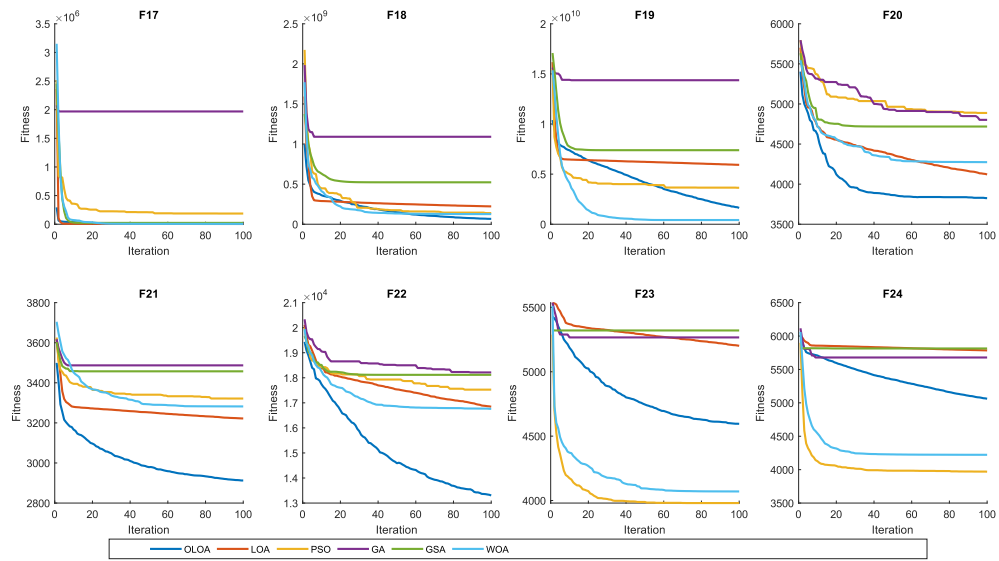
CEC Benchmark
2017



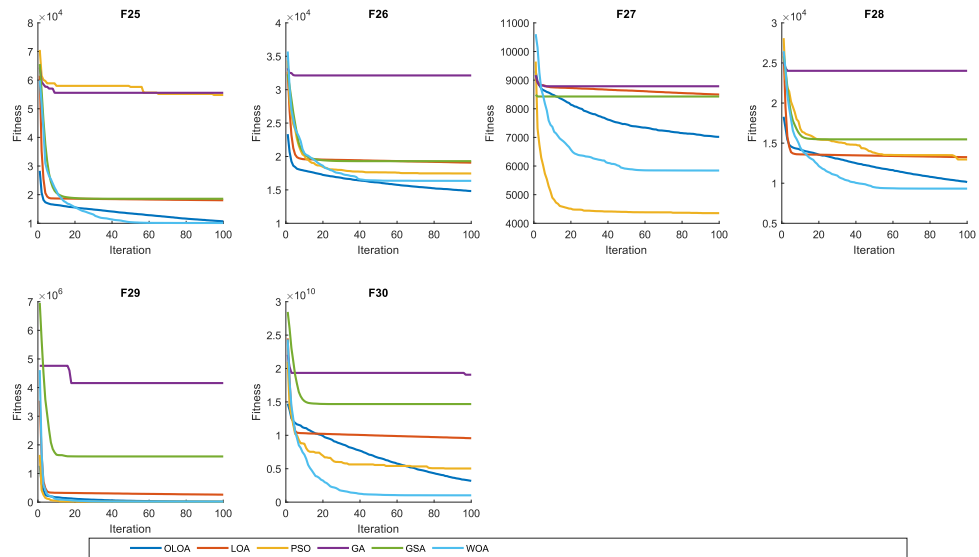
CEC Benchmark
2017



CEC Benchmark
2017



CEC Benchmark
2017



CEC 2017 Benchmark Function 100 Dimensions

Comparison of optimization results for the CEC benchmark functions 2017 (100 Dim)

Function		OLOA	LOA	PSO	GA	GSA	WOA
F1	Mean	2.14E+11	2.96E+11	5.81E+11	5.90E+11	3.28E+11	<u>2.12E+11</u>
	Std	7.44E+09	2.73E+10	3.64E+10	3.02E+10	2.21E+10	1.23E+10
	CPU	0.522	0.172	0.192	0.213	0.795	0.164
F2	Mean	The Function F2 was Delete in CEC 2017					
	Std						
	CPU						
F3	Mean	<u>4.60E+05</u>	4.93E+05	1.55E+06	3.43E+13	4.36E+08	9.20E+05
	Std	8.43E+04	7.16E+04	2.70E+05	9.52E+13	7.62E+08	8.71E+04
	CPU	0.472	0.172	0.138	0.173	0.805	0.158
F4	Mean	6.82E+04	1.20E+05	2.39E+05	3.09E+05	1.43E+05	<u>6.14E+04</u>
	Std	9.36E+03	3.51E+04	2.69E+04	5.18E+04	3.22E+04	1.21E+04
	CPU	0.534	0.194	0.175	0.191	0.795	0.192
F5	Mean	<u>1.74E+03</u>	2.14E+03	3.02E+03	3.00E+03	2.35E+03	2.13E+03
	Std	5.64E+01	1.10E+02	1.29E+02	6.00E+01	8.67E+01	9.33E+01
	CPU	0.792	0.228	0.175	0.192	0.806	0.191
F6	Mean	<u>6.97E+02</u>	7.03E+02	7.61E+02	7.50E+02	7.26E+02	7.17E+02
	Std	3.90E+00	5.28E+00	6.95E+00	7.23E+00	2.89E+00	3.93E+00
	CPU	0.983	0.411	0.248	0.300	0.939	0.283
F7	Mean	<u>3.91E+03</u>	4.89E+03	1.31E+04	1.27E+04	5.98E+03	3.92E+03
	Std	1.28E+02	5.11E+02	8.36E+02	3.72E+02	2.31E+02	1.05E+02
	CPU	0.794	0.238	0.236	0.234	0.806	0.177
F8	Mean	<u>2.23E+03</u>	2.57E+03	3.36E+03	3.40E+03	2.87E+03	2.59E+03
	Std	4.76E+01	9.02E+01	1.53E+02	1.35E+02	8.76E+01	1.07E+02
	CPU	0.642	0.214	0.172	0.230	0.794	0.205
F9	Mean	8.51E+04	<u>6.20E+04</u>	2.12E+05	2.08E+05	1.16E+05	9.92E+04
	Std	5.11E+03	6.52E+03	2.87E+04	1.43E+04	1.20E+04	2.83E+04
	CPU	0.584	0.233	0.200	0.194	0.811	0.183
F10	Mean	<u>2.52E+04</u>	3.16E+04	3.43E+04	3.41E+04	3.48E+04	3.15E+04
	Std	1.52E+03	1.36E+03	5.72E+02	5.80E+02	5.55E+02	1.28E+03
	CPU	0.622	0.205	0.194	0.216	0.852	0.227
F11	Mean	<u>2.26E+05</u>	2.80E+05	7.81E+05	3.16E+10	2.32E+06	4.55E+05
	Std	5.48E+04	4.39E+04	1.66E+05	8.25E+10	6.07E+06	1.09E+05
	CPU	0.555	0.180	0.170	0.223	0.773	0.175
F12	Mean	1.51E+11	2.04E+11	1.95E+11	3.58E+11	2.30E+11	<u>1.15E+11</u>
	Std	1.22E+10	3.22E+10	1.71E+10	4.78E+10	1.95E+10	1.55E+10
	CPU	0.650	0.227	0.191	0.225	0.834	0.175
F13	Mean	2.91E+10	4.99E+10	4.26E+10	9.65E+10	5.93E+10	<u>2.20E+10</u>
	Std	9.19E+09	1.01E+10	8.05E+09	8.49E+09	1.08E+10	5.14E+09
	CPU	0.538	0.186	0.173	0.214	0.747	0.175
F14	Mean	<u>2.49E+07</u>	2.32E+08	1.77E+08	1.03E+09	3.51E+08	5.80E+07
	Std	1.06E+07	1.14E+08	1.02E+08	2.89E+08	1.89E+08	3.44E+07
	CPU	0.639	0.214	0.197	0.245	0.884	0.227
F15	Mean	1.36E+10	2.58E+10	1.83E+10	4.81E+10	3.15E+10	<u>7.14E+09</u>

Comparison of optimization results for the CEC benchmark functions 2017 (100 Dim)

Function		OLOA	LOA	PSO	GA	GSA	WOA
F16	Std	3.47E+09	3.48E+09	6.14E+09	4.58E+09	5.84E+09	2.04E+09
	CPU	0.528	0.186	0.170	0.206	0.800	0.194
	Mean	<u>1.61E+04</u>	2.33E+04	1.82E+04	4.08E+04	2.87E+04	2.02E+04
	Std	2.96E+03	2.40E+03	2.07E+03	6.98E+03	3.41E+03	2.06E+03
	CPU	0.570	0.203	0.191	0.219	0.855	0.178
F17	Mean	<u>1.06E+06</u>	7.25E+06	2.10E+06	2.09E+08	3.13E+07	1.08E+06
	Std	1.28E+06	7.84E+06	1.74E+06	1.18E+08	1.87E+07	1.12E+06
	CPU	0.922	0.375	0.303	0.330	0.889	0.302
F18	Mean	<u>4.27E+07</u>	2.88E+08	2.56E+08	1.75E+09	8.10E+08	5.38E+07
	Std	2.32E+07	2.35E+08	7.71E+07	5.51E+08	2.82E+08	2.55E+07
	CPU	0.569	0.195	0.169	0.192	0.842	0.198
F19	Mean	1.39E+10	2.22E+10	1.64E+10	4.61E+10	3.49E+10	<u>6.26E+09</u>
	Std	4.53E+09	3.42E+09	3.80E+09	8.87E+09	5.12E+09	2.49E+09
	CPU	2.466	0.822	0.680	0.717	1.333	0.675
F20	Mean	<u>6.22E+03</u>	7.57E+03	8.77E+03	8.71E+03	8.84E+03	7.89E+03
	Std	6.94E+02	5.49E+02	4.15E+02	2.08E+02	5.18E+02	5.12E+02
	CPU	1.297	0.313	0.263	0.284	0.839	0.303
F21	Mean	4.82E+03	5.19E+03	4.96E+03	5.40E+03	5.41E+03	<u>4.75E+03</u>
	Std	2.66E+02	3.27E+02	1.62E+02	2.65E+02	1.74E+02	2.30E+02
	CPU	1.717	0.553	0.458	0.497	1.070	0.361
F22	Mean	<u>2.80E+04</u>	3.53E+04	3.60E+04	3.65E+04	3.80E+04	3.51E+04
	Std	8.42E+02	7.03E+02	7.24E+02	5.15E+02	5.54E+02	1.12E+03
	CPU	1.777	0.588	0.430	0.536	1.038	0.483
F23	Mean	7.18E+03	8.30E+03	<u>5.48E+03</u>	8.46E+03	8.33E+03	5.59E+03
	Std	5.15E+02	5.39E+02	2.30E+02	8.24E+02	8.24E+02	2.87E+02
	CPU	2.263	0.714	0.588	0.580	1.214	0.605
F24	Mean	1.20E+04	1.43E+04	<u>7.27E+03</u>	1.36E+04	1.47E+04	7.65E+03
	Std	6.07E+02	8.82E+02	5.02E+02	1.27E+03	1.37E+03	8.44E+02
	CPU	2.291	0.717	0.594	0.659	1.219	0.613
F25	Mean	2.07E+04	3.70E+04	1.30E+05	1.32E+05	4.14E+04	<u>2.07E+04</u>
	Std	1.34E+03	6.88E+03	1.73E+04	1.70E+04	4.91E+03	2.49E+03
	CPU	2.491	0.811	0.700	0.709	1.241	0.672
F26	Mean	4.60E+04	6.31E+04	4.72E+04	9.73E+04	6.83E+04	<u>4.40E+04</u>
	Std	3.02E+03	7.80E+03	3.83E+03	9.68E+03	5.68E+03	2.45E+03
	CPU	2.770	0.925	0.742	0.789	1.380	0.698
F27	Mean	1.24E+04	1.69E+04	<u>6.84E+03</u>	1.65E+04	1.82E+04	8.73E+03
	Std	1.19E+03	1.31E+03	9.68E+02	1.46E+03	1.32E+03	1.02E+03
	CPU	3.244	1.091	0.869	0.913	1.488	0.891
F28	Mean	2.86E+04	3.86E+04	3.66E+04	6.96E+04	4.48E+04	<u>2.45E+04</u>
	Std	2.10E+03	3.28E+03	3.25E+03	3.47E+03	5.29E+03	1.19E+03
	CPU	3.044	0.988	0.819	0.816	1.450	0.806
F29	Mean	1.24E+05	1.24E+06	1.58E+06	2.52E+07	3.20E+06	<u>6.80E+04</u>
	Std	1.08E+05	1.17E+06	1.90E+06	2.00E+07	2.38E+06	6.21E+04
	CPU	2.002	0.644	0.531	0.570	1.136	0.530

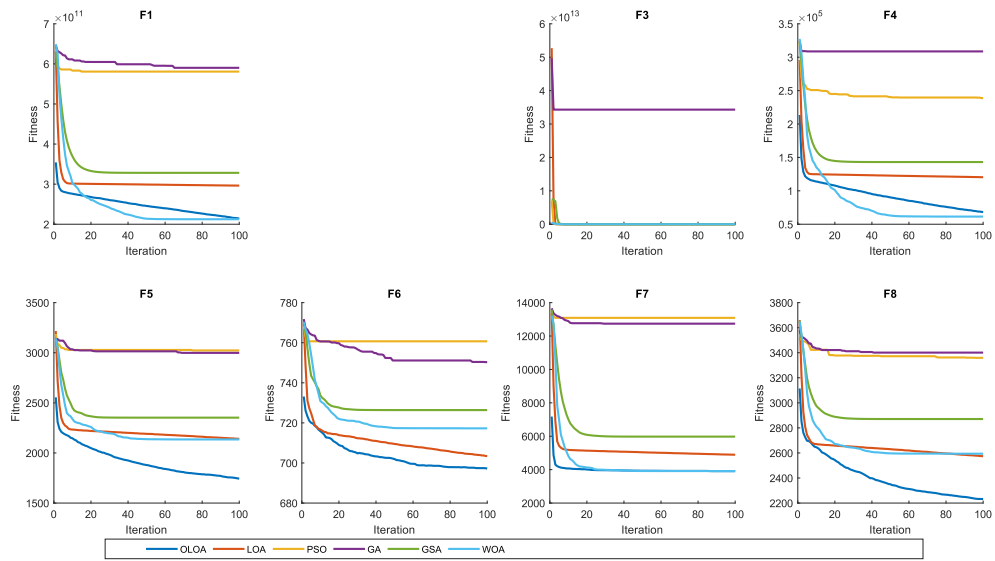
Comparison of optimization results for the CEC benchmark functions 2017 (100 Dim)

Function		OLOA	LOA	PSO	GA	GSA	WOA
F30	Mean	2.73E+10	4.03E+10	2.44E+10	7.80E+10	5.19E+10	<u>1.42E+10</u>
	Std	7.07E+09	5.56E+09	2.86E+09	1.44E+10	5.43E+09	4.49E+09
	CPU	3.430	1.133	0.914	0.959	1.542	0.947

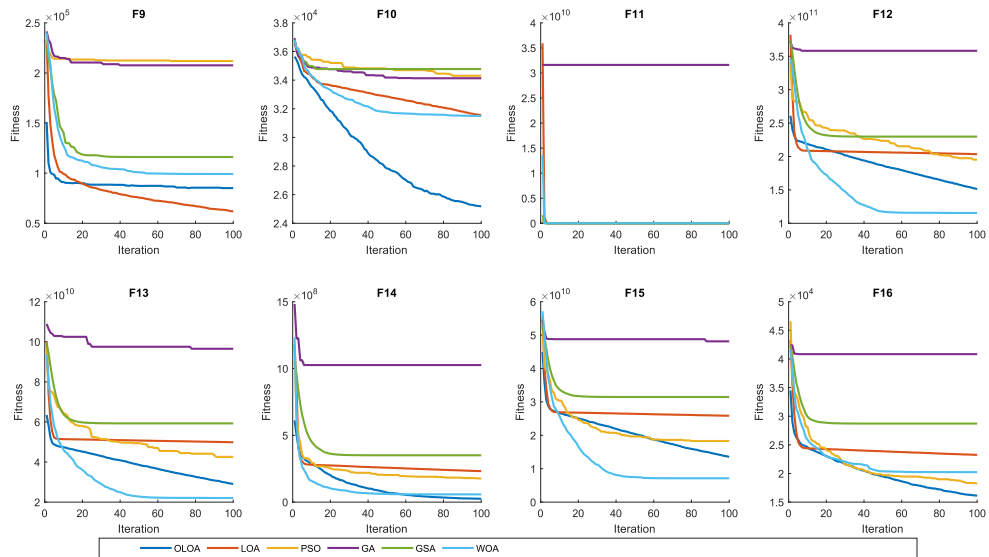
P-value of the T-test analysis for the CEC benchmark functions 2017 (100 Dim)

Function	OLOA versus LOA	OLOA versus PSO	OLOA versus GA	OLOA versus GSA	OLOA versus WOA
F1	3.07E-08	3.88E-17	1.05E-18	7.67E-12	7.44E-01
F2			Deleted		
F3	3.56E-01	3.88E-10	2.70E-01	8.75E-02	5.06E-10
F4	2.47E-04	2.49E-13	2.43E-11	1.38E-06	1.81E-01
F5	6.67E-09	1.68E-16	1.74E-20	3.29E-13	1.22E-09
F6	7.56E-03	1.74E-15	6.66E-14	2.33E-13	1.05E-09
F7	1.39E-05	7.42E-18	1.73E-23	2.37E-15	9.26E-01
F8	3.66E-09	1.48E-14	1.10E-15	7.77E-14	1.31E-08
F9	5.61E-08	5.44E-11	1.45E-15	6.06E-07	1.38E-01
F10	1.09E-08	7.60E-13	1.09E-12	3.02E-13	8.26E-09
F11	2.47E-02	8.03E-09	2.41E-01	2.90E-01	1.24E-05
F12	1.38E-04	3.10E-06	9.91E-11	2.62E-09	2.00E-05
F13	1.37E-04	2.63E-03	1.51E-12	2.69E-06	4.84E-02
F14	1.94E-05	1.84E-04	2.18E-09	3.70E-05	9.49E-03
F15	2.84E-07	4.77E-02	2.28E-13	1.34E-07	8.54E-05
F16	1.34E-05	8.18E-02	5.53E-09	5.96E-08	2.02E-03
F17	2.39E-02	1.43E-01	2.56E-05	7.39E-05	9.60E-01
F18	4.15E-03	1.26E-07	1.20E-08	8.85E-08	3.19E-01
F19	2.00E-04	1.90E-01	6.21E-09	1.37E-08	1.91E-04
F20	1.38E-04	9.43E-09	2.45E-09	1.73E-08	9.05E-06
F21	1.23E-02	1.64E-01	1.18E-04	1.30E-05	5.44E-01
F22	3.76E-14	1.11E-14	4.82E-16	3.66E-17	4.09E-12
F23	1.63E-04	1.93E-08	5.96E-04	1.49E-03	9.46E-08
F24	3.15E-06	2.07E-13	1.87E-03	1.97E-05	9.15E-11
F25	7.92E-07	9.79E-14	6.20E-14	1.62E-10	9.57E-01
F26	4.52E-06	4.68E-01	4.38E-12	2.18E-09	1.22E-01
F27	2.01E-07	1.14E-09	1.87E-06	4.49E-09	8.13E-07
F28	1.88E-07	3.97E-06	2.55E-17	4.44E-08	3.73E-05
F29	7.47E-03	2.57E-02	8.89E-04	6.92E-04	1.73E-01
F30	2.37E-04	2.49E-01	8.73E-09	7.20E-08	1.02E-04

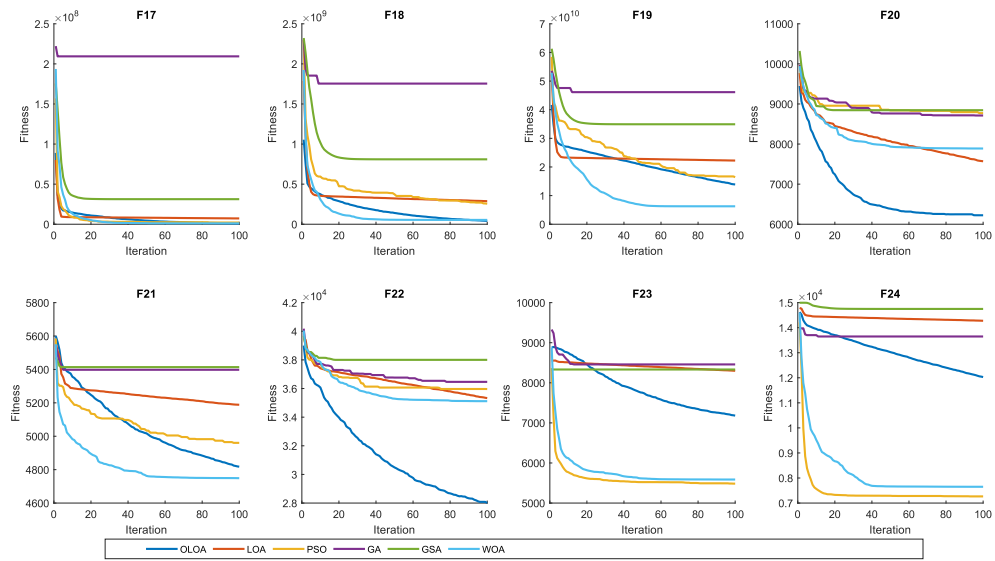
CEC Benchmark
2017



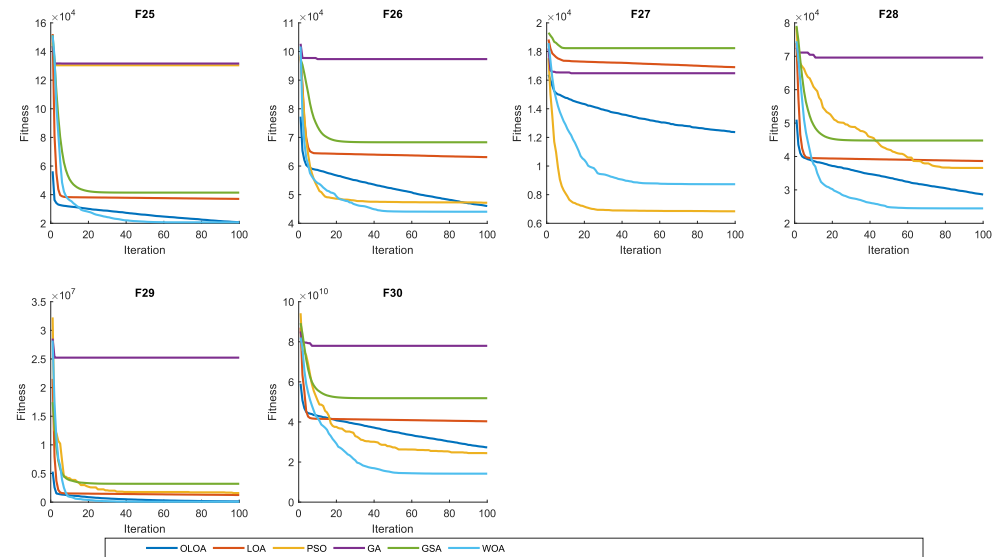
CEC Benchmark
2017



CEC Benchmark
2017



CEC Benchmark
2017



CEC 2022 Benchmark Function 10 Dimensions

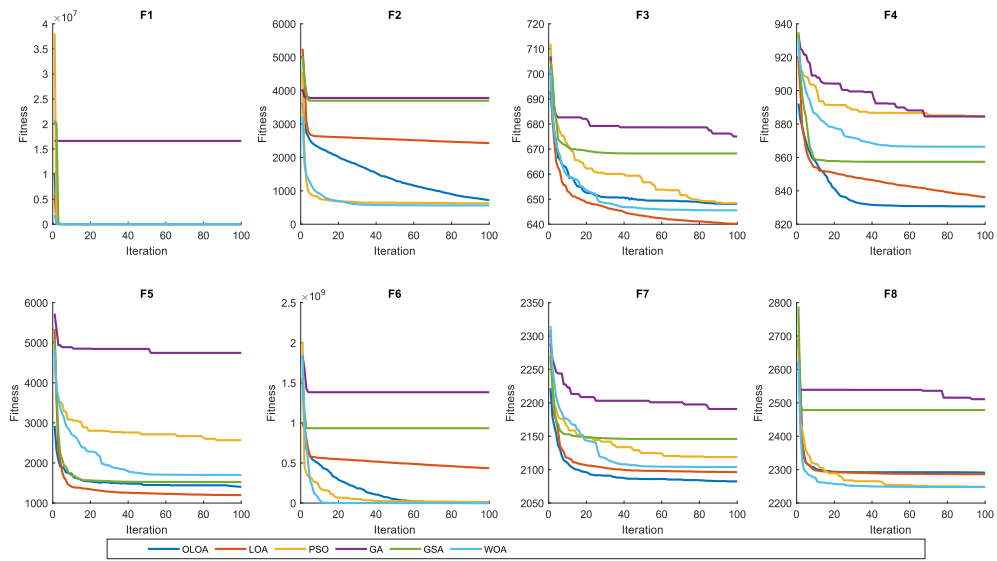
Comparison of optimization results for the CEC benchmark functions 2022 (10 Dim)

Function		OLOA	LOA	PSO	GA	GSA	WOA
F1	Mean	<u>8.67E+03</u>	1.34E+04	3.09E+04	1.66E+07	3.27E+04	3.22E+04
	Std	3.49E+03	6.02E+03	1.24E+04	4.53E+07	2.18E+04	7.25E+03
	CPU	0.063	0.061	0.094	0.109	0.384	0.103
F2	Mean	7.24E+02	2.43E+03	6.26E+02	3.78E+03	3.70E+03	<u>5.62E+02</u>
	Std	3.09E+02	1.40E+03	1.51E+02	1.27E+03	1.24E+03	1.24E+02
	CPU	0.066	0.020	0.067	0.075	0.314	0.061
F3	Mean	6.48E+02	<u>6.40E+02</u>	6.48E+02	6.75E+02	6.68E+02	6.46E+02
	Std	1.13E+01	9.58E+00	7.69E+00	9.18E+00	8.27E+00	1.83E+01
	CPU	0.195	0.048	0.069	0.111	0.286	0.056
F4	Mean	<u>8.31E+02</u>	8.36E+02	8.84E+02	8.85E+02	8.57E+02	8.66E+02
	Std	1.04E+01	8.72E+00	1.35E+01	1.75E+01	6.92E+00	2.03E+01
	CPU	0.034	0.014	0.033	0.072	0.111	0.034
F5	Mean	1.40E+03	<u>1.20E+03</u>	2.57E+03	4.75E+03	1.53E+03	1.70E+03
	Std	2.53E+02	1.74E+02	3.88E+02	1.19E+03	2.57E+02	4.71E+02
	CPU	0.028	0.023	0.031	0.047	0.120	0.036
F6	Mean	<u>1.80E+04</u>	4.35E+08	1.40E+07	1.38E+09	9.33E+08	2.58E+05
	Std	1.64E+04	5.08E+08	7.46E+06	8.72E+08	4.70E+08	3.69E+05
	CPU	0.016	0.011	0.038	0.080	0.130	0.031
F7	Mean	<u>2.08E+03</u>	2.10E+03	2.12E+03	2.19E+03	2.15E+03	2.10E+03
	Std	2.18E+01	3.26E+01	2.19E+01	4.68E+01	3.52E+01	3.71E+01
	CPU	0.117	0.044	0.052	0.127	0.217	0.047
F8	Mean	2.29E+03	2.29E+03	2.25E+03	2.51E+03	2.48E+03	<u>2.25E+03</u>
	Std	6.43E+01	6.62E+01	9.32E+00	1.52E+02	1.44E+02	2.27E+01
	CPU	0.141	0.128	0.130	0.144	0.238	0.086
F9	Mean	2.69E+03	2.84E+03	2.70E+03	3.01E+03	2.86E+03	<u>2.66E+03</u>
	Std	4.04E+01	1.44E+02	6.95E+01	1.42E+02	1.20E+02	4.88E+01
	CPU	0.116	0.036	0.081	0.119	0.286	0.080
F10	Mean	2.70E+03	2.78E+03	<u>2.56E+03</u>	2.78E+03	3.33E+03	2.77E+03
	Std	2.07E+02	1.64E+02	8.69E+01	3.58E+02	6.20E+02	4.50E+02
	CPU	0.200	0.050	0.069	0.138	0.323	0.095
F11	Mean	3.34E+03	3.78E+03	3.20E+03	4.12E+03	4.46E+03	<u>3.09E+03</u>
	Std	2.74E+02	2.57E+02	4.81E+02	5.19E+02	5.28E+02	2.85E+02
	CPU	0.225	0.088	0.117	0.145	0.388	0.122
F12	Mean	3.01E+03	3.15E+03	<u>2.88E+03</u>	3.21E+03	3.38E+03	2.93E+03
	Std	5.21E+01	1.03E+02	1.78E+01	1.29E+02	1.94E+02	4.69E+01
	CPU	0.328	0.081	0.105	0.188	0.395	0.128

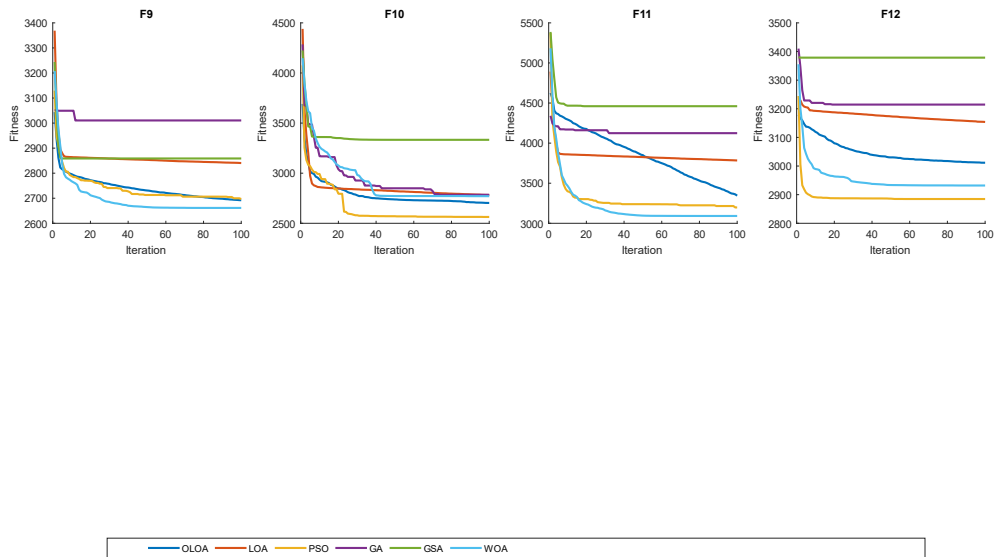
P-value of the T-test analysis for the CEC benchmark functions 2022 (10 Dim)

Function	OLOA versus LOA	OLOA versus PSO	OLOA versus GA	OLOA versus GSA	OLOA versus WOA
F1	4.51E-02	3.51E-05	2.61E-01	2.91E-03	2.99E-08
F2	1.42E-03	3.80E-01	7.06E-07	7.93E-07	1.43E-01
F3	1.03E-01	9.43E-01	1.57E-05	2.57E-04	7.07E-01
F4	2.18E-01	9.70E-09	1.33E-07	2.51E-06	1.03E-04
F5	5.04E-02	2.64E-07	7.78E-08	2.92E-01	9.51E-02
F6	1.44E-02	1.32E-05	9.02E-05	6.30E-06	5.48E-02
F7	2.78E-01	1.52E-03	3.13E-06	1.26E-04	1.31E-01
F8	8.70E-01	5.24E-02	5.35E-04	1.45E-03	6.10E-02
F9	5.77E-03	8.56E-01	2.24E-06	6.02E-04	1.42E-01
F10	3.59E-01	6.46E-02	5.41E-01	6.95E-03	6.71E-01
F11	1.66E-03	4.13E-01	5.38E-04	1.30E-05	5.77E-02
F12	1.07E-03	9.05E-07	2.12E-04	1.79E-05	2.10E-03

CEC Benchmark
2022



CEC Benchmark
2022



توضیحات الگوریتم و روش کارکرد.

در این الگوریتم از مقاله پایه Opposition Based Learning استفاده شده است که به همراه الگوریتم اصلی LOA ترکیب شده است.

در این الگوریتم از یک تابع متقابل سازی استفاده شده است که در آن از روش ترکیبی Random OBL استفاده کرده ایم.

در هر بار فراخوانی تابع متقابل سازی، یک جمعیت متقابل بر اساس مفهوم عدد متقابل ساخته می شود که از فرمول زیر به دست می آید.

$$OppositePopulation = LB + UB - Population.*rand(0,1)$$

در این فرمول موقعیت هر عضو در یک عدد تصادفی ضرب می گردد تا انحراف جواب های تولید شده را افزایش دهد و شانس تولید جوابهای متناسب تر بهبود یابد.

در ادامه به ازای دو جمعیت اصلی و متقابل تابع هزینه محاسبه شده و در یک حلقه تکرار به طول جمعیت اصلی بررسی می گردد که آیا مقدار برآزش عضو متقابل بهتر از عضو اصلی است یا خیر. در صورتی که عضو متقابل بهتر از عضو اصلی باشد عضو متقابل با عضو اصلی جایگزین شده و در غیر این صورت عضو اصلی بدون تغییر باقی می ماند.

در انتها جمعیت نهایی بر اساس مقدار تابع هزینه مرتب شده و به عنوان خروجی برگردانده می شود.

در الگوریتم اصلی تغییراتی اعمال نشده است فقط در ابتدای هر تکرار الگوریتم تابع متقابل سازی فراخوانی شده و جمعیت برگردانده شده به عنوان جمعیت اصلی در نظر گرفته می شود.

پارامترهای اجرایی الگوریتم
در این مسئله بهینه سازی با توجه به مقاله اصلی تلاش شده است تعداد از الگوریتم های مرجع مقاله مورد بررسی قرار گیرند ولی با توجه به عدم وجود اطلاعات درست از الگوریتم، کد خروجی برای تابع ارزیابی ۲۰۱۷ کارایی بیان شده را نداشته است. ولیکن با وجود این مورد، مقادیر استفاده شده در مسئله بهینه سازی تماما مشابه مقاله اصلی است به جز پارامترهای زیر.

$$crossover_rate = 0.8 \text{ Crossover rate}$$

$$mutation_rate = 0.3 \text{ Mutation rate}$$

$$sigma = 0.9 \text{ Mutation standard deviation}$$

پارامترهای اصلی مقایسه نیز مانند الگوریتم اصلی در نظر گرفته شده است و تعداد اجرا ۱۰، بیشترین تعداد تکرار ۱۰۰ و تعداد متغیرهای تصمیم برای ایجاد یک تفاوت معنا دار در نتایج ۳۰ گرفته شده است.