

## Supplemental Information

**Table S1.** Comparative performance of the LO algorithm with swarm algorithms based on functions F1–F7

Function		LO	ABC	SSA	SCA	BA	FPA	JAYA	LEO-MPA
F1	Best	<b>0.0000E+00</b>	2.3350E-16	3.6020E-10	<b>0.0000E+00</b>	5.8240E-06	1.2930E-68	<b>0.0000E+00</b>	<b>0.0000E+00</b>
	Worst	<b>0.0000E+00</b>	4.5280E-16	1.2280E-09	<b>0.0000E+00</b>	1.1330E-03	3.3460E-60	<b>0.0000E+00</b>	<b>0.0000E+00</b>
	Mean	<b>0.0000E+00</b>	3.1550E-16	7.0400E-10	<b>0.0000E+00</b>	9.0630E-04	1.2330E-61	<b>0.0000E+00</b>	<b>0.0000E+00</b>
	Stddev.	0.0000E+00	4.9330E-17	1.7100E-10	0.0000E+00	1.9590E-04	6.0970E-61	0.0000E+00	<b>0.0000E+00</b>
F2	Best	<b>0.0000E+00</b>	7.3930E-16	1.0180E-06	<b>0.0000E+00</b>	6.0440E-02	5.0470E-49	<b>0.0000E+00</b>	<b>0.0000E+00</b>
	Worst	<b>0.0000E+00</b>	1.0920E-15	2.4600E-06	<b>0.0000E+00</b>	1.4210E-01	2.0950E-46	<b>0.0000E+00</b>	<b>0.0000E+00</b>
	Mean	<b>0.0000E+00</b>	9.5130E-16	1.4180E-06	<b>0.0000E+00</b>	1.0390E-01	3.2560E-47	<b>0.0000E+00</b>	<b>0.0000E+00</b>
	Stddev.	0.0000E+00	6.8720E-17	3.0300E-07	0.0000E+00	2.4850E-02	4.6490E-47	0.0000E+00	<b>0.0000E+00</b>
F3	Best	4.0840E-11	4.2500E-01	1.6380E-11	<b>3.7210E-79</b>	1.5440E-03	6.4260E-36	3.2450E-06	<b>0.0000E+00</b>
	Worst	6.9630E-05	4.7320E+00	5.4410E-11	5.8480E-28	2.7900E-03	<b>1.8350E-29</b>	1.8360E+02	<b>0.0000E+00</b>
	Mean	1.3700E-05	1.3010E+00	3.1910E-11	1.9590E-29	1.9530E-03	<b>7.0320E-31</b>	6.1680E+00	<b>0.0000E+00</b>
	Stddev.	1.8880E-05	8.5310E-01	1.1180E-11	1.0670E-28	3.2530E-04	3.3400E-30	3.3510E+01	<b>0.0000E+00</b>
F4	Best	3.5950E-17	5.9340E-04	2.0850E-06	9.1150E-81	2.6070E-03	2.2290E+00	<b>4.6800E-83</b>	4.4540E-60
	Worst	1.4870E-12	3.0870E-02	4.2900E-06	4.1310E-45	4.2460E-02	1.0700E+01	<b>1.6300E-73</b>	1.6845E-56
	Mean	5.1440E-14	1.4670E-02	2.9060E-06	1.3770E-46	1.3340E-02	6.1330E+00	<b>8.5570E-75</b>	8.5256E-49
	Stddev.	2.7120E-13	9.0920E-03	5.9360E-07	7.5410E-46	6.1970E-03	1.8150E+00	3.0630E-74	3.1643E-45
F5	Best	1.3940E+01	1.7760E-04	2.9000E-05	2.5740E+01	1.3310E-03	<b>0.0000E+00</b>	<b>0.0000E+00</b>	<b>0.0000E+00</b>
	Worst	7.7980E+01	2.4220E-02	1.3390E+02	2.8840E+01	5.4630E-01	3.9870E+00	<b>4.6120E-27</b>	1.5527E-20
	Mean	3.4140E+01	8.2800E-03	9.1380E+00	2.6760E+01	3.0930E-01	1.0630E+00	<b>7.1060E-28</b>	6.6720E-22
	Stddev.	2.3900E+01	7.3270E-03	2.9860E+01	7.9300E-01	1.4210E-01	1.7930E+00	<b>1.0410E-27</b>	2.9005E-21
F6	Best	3.8520E-31	2.7110E-16	1.7720E-11	2.3330E+00	7.3260E-04	<b>0.0000E+00</b>	1.2660E+00	1.6548E+00
	Worst	2.3270E-26	4.5990E-16	4.6740E-11	3.6950E+00	1.2020E-03	<b>9.2450E-33</b>	2.3660E+00	2.3487E+00
	Mean	9.7010E-28	3.3340E-16	2.8460E-11	2.7520E+00	9.6080E-04	<b>1.0270E-33</b>	1.7170E+00	1.3482E+00
	Stddev.	4.2680E-27	5.6640E-17	7.9380E-12	2.7170E-01	1.1020E-04	2.1910E-33	2.4360E-01	2.8267E-01
F7	Best	<b>2.2940E-07</b>	1.4460E-02	1.6440E-05	1.2680E-05	2.0120E-05	1.9270E-03	3.1600E-04	4.1553E-04
	Worst	<b>1.1960E-06</b>	3.6490E-02	1.3620E-04	1.0450E-03	9.7650E-04	1.6700E-02	1.8850E-03	9.3533E-03
	Mean	<b>5.8730E-06</b>	2.7370E-02	6.0940E-05	1.9790E-04	2.8460E-04	7.0020E-03	8.0060E-04	2.8813E-04
	Stddev.	<b>2.1270E-06</b>	4.9410E-03	2.4370E-05	1.9360E-04	2.1320E-04	3.8620E-03	3.7980E-04	2.1866E-04

**Table S2.** Comparative performance of the LO algorithm with swarm algorithms based on functions F8–F23

Function		LO	ABC	SSA	SCA	BA	FPA	JAYA	LEO-MPA
F8	Best	<b>-1.2550E+04</b>	-1.2570E+04	-3.7360E+03	-5.2220E+03	-1.2570E+04	-1.2570E+04	-1.2570E+04	-1.2569E+04
	Worst	<b>-1.0350E+04</b>	-1.2570E+04	-2.7840E+03	-4.3560E+03	-1.2570E+04	-1.2040E+04	-9.6520E+03	-1.1977E+04
	Mean	-1.1930E+04	-1.2570E+04	-3.3000E+03	-4.8300E+03	-1.2570E+04	-1.2530E+04	-1.2410E+04	<b>-1.2289E+04</b>
	Stdev.	7.6340E+02	0.0000E+00	2.9630E+02	2.2400E+02	0.0000E+00	1.2420E+02	5.3670E+02	1.4416E+02
F9	Best	9.0710E+00	<b>0.0000E+00</b>	3.9800E+00	<b>0.0000E+00</b>	1.3970E-03	3.9800E+00	2.0890E+01	<b>0.0000E+00</b>
	Worst	5.6280E+01	<b>0.0000E+00</b>	1.8900E+01	<b>0.0000E+00</b>	2.1810E-01	3.4820E+01	6.9960E+01	<b>0.0000E+00</b>
	Mean	3.0340E+01	<b>0.0000E+00</b>	1.1410E+01	<b>0.0000E+00</b>	3.4020E-02	1.7350E+01	4.1040E+01	<b>0.0000E+00</b>
	Stdev.	1.3310E+01	0.0000E+00	4.2910E+00	0.0000E+00	4.1970E-02	6.4940E+00	1.2780E+01	<b>0.0000E+00</b>
F10	Best	<b>4.4410E-15</b>	2.2200E-14	1.1460E-06	4.4410E-15	1.2920E-02	4.4410E-15	4.4410E-15	4.4409E-14
	Worst	<b>7.9940E-15</b>	3.2860E-14	2.7050E-06	2.0090E+01	2.6320E-02	2.9570E+00	1.5100E-14	4.4409E-14
	Mean	<b>6.8090E-15</b>	2.8480E-14	2.1420E-06	4.7440E+00	2.2490E-02	2.0940E+00	1.0480E-14	4.4409E-16
	Stdev.	1.7030E-15	3.1890E-15	3.3870E-07	8.5930E+00	3.4880E-03	5.7070E-01	3.6320E-15	3.3435E-15
F11	Best	<b>0.0000E+00</b>	<b>0.0000E+00</b>	<b>4.4280E-02</b>	<b>0.0000E+00</b>	3.7140E-05	<b>0.0000E+00</b>	<b>0.0000E+00</b>	<b>0.0000E+00</b>
	Worst	<b>0.0000E+00</b>	<b>0.0000E+00</b>	5.7590E-01	<b>0.0000E+00</b>	2.2170E-02	9.9980E-02	3.9200E-02	<b>0.0000E+00</b>
	Mean	<b>0.0000E+00</b>	<b>0.0000E+00</b>	2.4430E-01	<b>0.0000E+00</b>	3.8230E-03	2.2510E-02	9.6030E-03	<b>0.0000E+00</b>
	Stdev.	<b>0.0000E+00</b>	0.0000E+00	1.1440E-01	0.0000E+00	6.4560E-03	2.0960E-02	9.8800E-03	<b>0.0000E+00</b>
F12	Best	2.7810E-32	2.0090E-16	6.7110E-14	1.7040E-01	6.1360E-06	<b>1.5710E-32</b>	1.0740E-01	2.7810E-29
	Worst	<b>8.3430E-29</b>	3.3300E-16	3.7090E-13	7.2100E-01	9.9550E-06	4.1470E-01	1.9790E+00	1.5705E-28
	Mean	<b>6.3590E-30</b>	3.0070E-16	2.0440E-13	2.3450E-01	8.0380E-06	3.1100E-02	8.0000E-01	1.5705E-29
	Stdev.	1.7130E-29	3.1380E-17	8.0970E-14	9.7070E-02	8.1740E-07	9.4890E-02	6.2290E-01	5.5674E-28
F13	Best	2.9960E-31	2.2470E-16	4.4770E-13	1.4200E+00	7.7970E-05	1.3500E-32	1.3500E-32	<b>1.3498E-32</b>
	Worst	<b>3.5820E-23</b>	3.2830E-16	2.2000E-12	1.9370E+00	1.1150E-02	2.1020E-02	1.0990E-02	<b>1.3498E-32</b>
	Mean	<b>2.8610E-24</b>	2.9820E-16	1.1170E-12	1.7140E+00	1.2240E-03	1.2660E-03	1.0990E-03	<b>1.3498E-32</b>
	Stdev.	<b>1.5670E-23</b>	2.1200E-17	4.4170E-13	1.3180E-01	3.3620E-03	5.2000E-03	3.3530E-03	5.5674E-18
F14	Best	<b>9.9800E-01</b>	<b>9.9800E-01</b>	<b>9.9800E-01</b>	<b>9.9800E-01</b>	<b>9.9800E-01</b>	<b>9.9800E-01</b>	<b>9.9800E-01</b>	9.9800E-01
	Worst	<b>9.9800E-01</b>	<b>9.9800E-01</b>	<b>9.9800E-01</b>	<b>9.9800E-01</b>	<b>9.9800E-01</b>	<b>9.9800E-01</b>	<b>9.9800E-01</b>	9.9800E-01
	Mean	<b>9.9800E-01</b>	<b>9.9800E-01</b>	<b>9.9800E-01</b>	<b>9.9800E-01</b>	<b>9.9800E-01</b>	<b>9.9800E-01</b>	<b>9.9800E-01</b>	9.9800E-01
	Stdev.	5.8290E-11	0.0000E+00	7.1420E-17	6.0530E-10	0.0000E+00	0.0000E+00	8.0770E-10	0.0000E+00
F15	Best	<b>3.0750E-04</b>	3.1350E-04	3.0750E-04	3.0800E-04	3.0750E-04	3.0750E-04	3.0750E-04	3.0789E-04
	Worst	7.1880E-04	3.8880E-04	1.2230E-03	3.1260E-04	3.0760E-04	<b>3.0750E-04</b>	1.2240E-03	3.0789E-04
	Mean	3.6590E-04	3.4470E-04	5.5170E-04	3.0990E-04	3.0750E-04	<b>3.0750E-04</b>	3.3800E-04	3.0789E-04
	Stdev.	1.2280E-04	2.1330E-05	4.1190E-04	1.3600E-06	1.8020E-08	<b>1.0800E-19</b>	1.6730E-04	9.2262E-18
F16	Best	<b>-1.0320E+00</b>	-1.0320E+00	-1.0320E+00	-1.0320E+00	-1.0320E+00	-1.0320E+00	-1.0320E+00	-1.0316E+00
	Worst	<b>-1.0320E+00</b>	-1.0320E+00	-1.0320E+00	-1.0320E+00	-1.0320E+00	-1.0320E+00	-1.0320E+00	-1.0316E+00
	Mean	<b>-1.0320E+00</b>	-1.0320E+00	-1.0320E+00	-1.0320E+00	-1.0320E+00	-1.0320E+00	-1.0320E+00	-1.0316E+00
	Stdev.	6.7750E-16	6.7750E-16	0.0000E+00	1.4940E-07	3.5650E-09	6.7750E-16	0.0000E+00	6.7752E-16
F17	Best	<b>3.9790E-01</b>	3.9790E-01	3.9790E-01	3.9790E-01	3.9790E-01	3.9790E-01	3.9790E-01	3.9889E-01
	Worst	<b>3.9790E-01</b>	3.9790E-01	3.9790E-01	3.9790E-01	3.9790E-01	3.9790E-01	3.9800E-01	3.9889E-01
	Mean	<b>3.9790E-01</b>	3.9790E-01	3.9790E-01	3.9790E-01	3.9790E-01	3.9790E-01	3.9890E-01	3.9789E-01
	Stdev.	<b>0.0000E+00</b>	<b>0.0000E+00</b>	<b>0.0000E+00</b>	5.7810E-06	1.6200E-09	<b>0.0000E+00</b>	1.5460E-05	<b>0.0000E+00</b>
F18	Best	<b>3.0000E+00</b>	<b>3.0000E+00</b>	<b>3.0000E+00</b>	<b>3.0000E+00</b>	<b>3.0000E+00</b>	<b>3.0000E+00</b>	<b>3.0000E+00</b>	<b>3.0000E+00</b>
	Worst	<b>3.0000E+00</b>	<b>3.0000E+00</b>	<b>3.0000E+00</b>	<b>3.0000E+00</b>	<b>3.0000E+00</b>	<b>3.0000E+00</b>	<b>3.0000E+00</b>	<b>3.0000E+00</b>
	Mean	<b>3.0000E+00</b>	<b>3.0000E+00</b>	<b>3.0000E+00</b>	<b>3.0000E+00</b>	<b>3.0000E+00</b>	<b>3.0000E+00</b>	<b>3.0000E+00</b>	<b>3.0000E+00</b>
	Stdev.	1.8140E-15	1.8200E-13	0.0000E+00	9.0570E-10	1.2650E-07	4.8090E-16	<b>0.0000E+00</b>	1.1397E-15
F19	Best	<b>-3.8630E+00</b>	<b>-3.8630E+00</b>	<b>-3.8630E+00</b>	<b>-3.8630E+00</b>	<b>-3.8630E+00</b>	<b>-3.8630E+00</b>	<b>-3.8630E+00</b>	<b>-3.8628E+00</b>
	Worst	<b>-3.8630E+00</b>	<b>-3.8630E+00</b>	<b>-3.8630E+00</b>	<b>-3.8550E+00</b>	<b>-3.8630E+00</b>	<b>-3.8630E+00</b>	<b>-3.8630E+00</b>	<b>-3.8628E+00</b>
	Mean	<b>-3.8630E+00</b>	<b>-3.8630E+00</b>	<b>-3.8630E+00</b>	<b>-3.8560E+00</b>	<b>-3.8630E+00</b>	<b>-3.8630E+00</b>	<b>-3.8630E+00</b>	<b>-3.8628E+00</b>
	Stdev.	2.7100E-15	2.7100E-15	2.0450E-15	2.6900E-03	4.0700E-07	2.7100E-15	2.7100E-15	2.7101E-15
F20	Best	<b>-3.3220E+00</b>	<b>-3.3220E+00</b>	<b>-3.3220E+00</b>	<b>-3.1320E+00</b>	<b>-3.3220E+00</b>	<b>-3.3220E+00</b>	<b>-3.3220E+00</b>	<b>-3.3220E+00</b>
	Worst	-3.2030E+00	<b>-3.3220E+00</b>	-3.2030E+00	-1.5780E+00	-3.2030E+00	<b>-3.3220E+00</b>	-3.2030E+00	-3.2031E+00
	Mean	-3.3180E+00	<b>-3.3220E+00</b>	-3.2150E+00	-2.9250E+00	-3.2820E+00	<b>-3.3220E+00</b>	-3.2670E+00	-3.3061E+00
	Stdev.	2.1710E-02	1.3550E-15	3.6280E-02	3.5930E-01	5.6980E-02	0.0000E+00	6.0300E-02	4.1107E-02
F21	Best	<b>-1.0150E+01</b>	<b>-1.0150E+01</b>	<b>-1.0150E+01</b>	-1.0120E+01	<b>-1.0150E+01</b>	<b>-1.0150E+01</b>	<b>-1.0150E+01</b>	-1.0153E+01
	Worst	-2.6830E+00	<b>-1.0150E+01</b>	<b>-1.0150E+01</b>	-4.9650E-01	<b>-1.0150E+01</b>	<b>-1.0150E+01</b>	-2.6310E+00	-1.0153E+01
	Mean	-9.9040E+00	<b>-1.0150E+01</b>	<b>-1.0150E+01</b>	-3.3210E+00	<b>-1.0150E+01</b>	<b>-1.0150E+01</b>	-8.1430E+00	-1.0153E+01
	Stdev.	1.3640E+00	2.6310E-07	3.4780E-13	3.2900E+00	2.6310E-07	0.0000E+00	2.9760E+00	7.2269E-15
F22	Best	-1.0400E+01	<b>-1.0400E+01</b>	<b>-1.0400E+01</b>	-1.0170E+01	-1.0150E+01	<b>-1.0400E+01</b>	<b>-1.0400E+01</b>	-1.0403E+01
	Worst	<b>-1.0400E+01</b>	<b>-1.0400E+01</b>	<b>-1.0400E+01</b>	-5.2400E-01	-1.0150E+01	<b>-1.0400E+01</b>	-1.8380E+01	-5.0877E+00
	Mean	<b>-1.0400E+01</b>	<b>-1.0400E+01</b>	<b>-1.0400E+01</b>	-5.3910E+01	-1.0150E+01	<b>-1.0400E+01</b>	-8.5510E+01	-1.0626E+01
	Stdev.	<b>6.2650E-07</b>	1.8510E-05	2.8260E-13	3.5420E+00	2.6310E-07	0.0000E+00	2.8230E+00	9.7043E-01
F23	Best	<b>-1.0540E+01</b>	-1.0540E+01	-1.0540E+01	-1.0410E+01	-1.0150E+01	-1.0540E+01	-1.0540E+01	-1.0536E+01
	Worst	<b>-1.0540E+01</b>	-1.0540E+01	-5.1760E+00	-9.4700E-01	-1.0150E+01	-1.0540E+01	-2.4210E+01	-1.0536E+01
	Mean	<b>-1.0540E+01</b>	-1.0540E+00	-1.0000E+01	-6.2120E+01	-1.0150E+01	-1.0540E+01	-9.9950E+01	-1.0636E+01
	Stdev.	<b>1.0210E-11</b>	2.2020E-05	1.6360E+00	2.7930E+00	2.6310E-07	0.0000E+00	2.0590E+00	9.3299E-10

**Table S3.** p\_values of the Wilcoxon statistical test between the proposed LO algorithm and ABC, SCA, BA, FPA, JAYA, and LEO-MPA

Function	ABC		SSA		SCA		BAT		FPA		JAYA		LEO-MPA	
	P Value	Results	P Value	Results	P Value	Results	P Value	Results	P Value	Results	P Value	Results	P Value	Results
F1	1.0E-05	+	1.0E-05	+	N/A	-	1.0E-05	+	1.0E-05	+	N/A	-	N/A	-
F2	1.0E-05	+	1.0E-05	+	N/A	-	1.0E-05	+	1.0E-05	+	1.0E-05	+	1.0E-05	+
F3	1.0E-05	+	1.0E-05	+	1.0E-05	+	1.0E-05	+	1.0E-05	+	1.0E-05	+	1.0E-05	+
F4	1.0E-05	+	1.0E-05	+	1.0E-05	+	1.0E-05	+	1.0E-05	+	0.5	-	0.5	-
F5	1.0E-05	+	1.0E-05	+	1.0E-05	+	1.0E-05	+	1.0E-05	+	N/A	-	N/A	-
F6	1.0E-05	+	1.0E-05	+	1.0E-05	+	1.0E-05	+	0.5	-	1.0E-05	+	1.0E-05	+
F7	1.0E-05	+	0.41	-	N/A	-	1.0E-05	+	1.0E-05	+	1.0E-05	+	1.0E-05	+
F8	1.0E-05	+	1.0E-05	+	1.0E-05	+	N/A	-	1.0E-05	+	1.0E-05	+	1.0E-05	+
F9	0.12843	-	1.0E-05	+	0.5	-	1.0E-05	+	1.0E-05	+	1.0E-05	+	1.0E-05	+
F10	1.0E-05	+	1.0E-05	+	1.0E-05	+	1.0E-05	+	1.0E-05	+	1.0E-05	+	1.0E-05	+
F11	1.0E-05	+	1.0E-05	+	0.0128	-	1.0E-05	+	1.0E-05	+	1.0E-05	+	0.5	-
F12	1.0E-05	+	1.0E-05	+	1.0E-05	+	1.0E-05	+	1.0E-05	+	1.0E-05	+	1.0E-05	+
F13	1.0E-05	+	1.0E-05	+	1.0E-05	+	1.0E-05	+	1.0E-05	+	1.0E-05	+	1.0E-05	+
F14	1.0E-05	+	1.0E-05	+	1.0E-05	+	1.0E-05	+	1.0E-05	+	1.0E-05	+	0.5	-
F15	1.0E-05	+	1.0E-05	+	1.0E-05	+	1.0E-05	+	1.0E-05	+	1.0E-05	+	1.0E-05	+
F16	1.0E-05	+	1.0E-05	+	1.0E-05	+	1.0E-05	+	1.0E-05	+	1.0E-05	+	0.5	-
F17	1.0E-05	+	1.0E-05	+	1.0E-05	+	1.0E-05	+	1.0E-05	+	1.0E-05	+	1.0E-05	+
F18	1.0E-05	+	1.0E-05	+	1.0E-05	+	1.0E-05	+	1.0E-05	+	1.0E-05	+	1.0E-05	+
F19	1.0E-05	+	1.0E-05	+	1.0E-05	+	1.0E-05	+	1.0E-05	+	1.0E-05	+	1.0E-05	+
F20	1.0E-05	+	1.0E-05	+	1.0E-05	+	1.0E-05	+	1.0E-05	+	1.0E-05	+	1.0E-05	+
F21	1.0E-05	+	1.0E-05	+	1.0E-05	+	1.0E-05	+	1.0E-05	+	1.0E-05	+	1.0E-05	+
F22	1.0E-05	+	1.0E-05	+	1.0E-05	+	1.0E-05	+	1.0E-05	+	1.0E-05	+	1.0E-05	+
F23	1.0E-05	+	1.0E-05	+	1.0E-05	+	1.0E-05	+	1.0E-05	+	1.0E-05	+	1.0E-05	+