

## Supplementary Material

### A. Comparison with top-rank Algorithms

The proposed PSO-HV and DE-HL are compared with winners of CEC-2013 and CEC-2017 on 50 dimensions. From Tables VIII and IX, three winners (EBOwithCMAR, JSO, NBIPOP-ACMA-ES) show better performance than the proposed PSO-HV and DE-HL. The reason is that they integrate many evolutionary algorithms and strategies to adapt to more optimization problems than a single one. Although the proposed algorithms are inferior to the three winners in optimization results, they still have their advantages of a simple structure, easy application and competitive performance. Here we use EBOwithCMAR (the top-1 algorithm in CEC-2017) as an example to explain why we claim our proposed method's advantages. It has ten critical parameters that need to be fine-tuned and consists of six algorithms and strategies including Effective Butterfly Optimizer (EBO), Covariance Matrix Adapted Retreat (CMAR), sequential quadratic programming, linear population size reduction, data sharing strategy and multi-swarm strategy. Our proposed PSO-HV has only four parameters and uses only hierarchical learning, variable population and PSO. The proposed algorithms have significantly outperformed some top-rank algorithms.

TABLE S-I

ABLATION EXPERIMENT OF HIERARCHICAL LEARNING AND VARIABLE POPULATION MECHANISM ON 28 FUNCTIONS WITH 50-D

Func	PSO-HV		PSO-H		PSO-V	
	Mean error	Std.	Mean error (Sig.)	Std.	Mean error (Sig.)	Std.
$f_1$	6.33E-13	1.53E-13	0.00E+00 (−)	3.08E-13	2.29E-12 (+)	1.34E-11
$f_2$	4.83E+06	1.92E+06	8.02E+06 (+)	4.61E+06	3.38E+06 (−)	9.86E+05
$f_3$	1.19E+07	2.61E+07	4.95E+07 (+)	5.91E+07	9.58E+08 (+)	9.45E+08
$f_4$	4.02E+04	8.72E+03	1.01E+05 (+)	9.63E+03	1.05E+03 (−)	7.21E+02
$f_5$	3.21E-11	5.93E-11	1.38E-08 (+)	8.47E-08	5.31E-13 (−)	1.64E-12
$f_6$	4.72E+01	7.32E+00	5.15E+01 (+)	1.55E+01	5.75E+01 (≈)	2.86E+01
$f_7$	9.50E-01	5.11E-01	3.77E+00 (+)	9.59E+00	1.14E+02 (+)	1.93E+01
$f_8$	2.11E+01	4.61E-02	2.11E+01 (−)	4.20E-02	2.11E+01 (−)	3.37E-02
$f_9$	1.40E+01	2.88E+00	1.99E+01 (+)	4.80E+00	4.50E+01 (+)	5.36E+00
$f_{10}$	2.75E-01	2.27E-01	3.72E-01 (+)	3.24E-01	1.17E-01 (−)	7.87E-02
$f_{11}$	7.67E+00	4.25E+00	1.97E+01 (+)	5.44E+00	1.32E+02 (+)	2.82E+01
$f_{12}$	1.70E+01	4.89E+00	3.19E+01 (+)	9.95E+00	2.24E+02 (+)	6.08E+01
$f_{13}$	4.09E+01	2.13E+01	9.30E+01 (+)	2.83E+01	3.72E+02 (+)	7.17E+01
$f_{14}$	3.14E+02	1.61E+02	4.11E+02 (+)	1.95E+02	3.61E+03 (+)	6.89E+02
$f_{15}$	2.19E+03	7.21E+02	3.36E+03 (+)	7.86E+02	7.56E+03 (+)	9.28E+02
$f_{16}$	4.52E-01	1.67E-01	6.76E-01 (+)	1.84E-01	2.82E+00 (+)	5.37E-01
$f_{17}$	5.88E+01	1.87E+00	7.00E+01 (+)	6.13E+00	2.07E+02 (+)	4.34E+01
$f_{18}$	8.97E+01	1.01E+01	1.05E+02 (+)	1.22E+01	2.59E+02 (+)	7.31E+01
$f_{19}$	5.15E+00	6.47E-01	5.50E+00 (≈)	6.60E-01	1.22E+01 (+)	4.35E+00
$f_{20}$	2.28E+01	8.04E-01	2.44E+01 (+)	3.32E-01	2.13E+01 (−)	1.07E+00
$f_{21}$	8.72E+02	3.02E+02	8.08E+02 (−)	3.68E+02	8.63E+02 (≈)	3.53E+02
$f_{22}$	2.11E+02	8.99E+01	5.85E+02 (+)	2.74E+02	4.12E+03 (+)	9.61E+02
$f_{23}$	2.18E+03	7.06E+02	3.37E+03 (+)	9.28E+02	9.16E+03 (+)	1.53E+03
$f_{24}$	2.06E+02	9.91E+00	2.22E+02 (+)	1.80E+01	3.24E+02 (+)	1.32E+01
$f_{25}$	2.96E+02	9.03E+00	3.09E+02 (+)	1.32E+01	3.56E+02 (+)	1.47E+01
$f_{26}$	2.78E+02	4.82E+01	3.20E+02 (+)	5.04E+01	4.02E+02 (+)	5.25E+01
$f_{27}$	4.61E+02	1.83E+02	7.36E+02 (+)	1.67E+02	1.48E+03 (+)	1.25E+02
$f_{28}$	4.00E+02	3.86E-09	5.75E+02 (+)	7.05E+02	1.05E+03 (+)	1.32E+03
+ / ≈ / −	PSO-HV VS		24/1/3		20/2/6	
+ / ≈ / −			PSO-H VS		21/2/5	

TABLE S-II  
WILCOXON TEST RESULTS BETWEEN PSO-HV AND RELATED ALGORITHMS ON CEC-2017 FUNCTIONS

Func	D=100				D=50				D=30			
	MAPSO [45]	APABC [46]	HGFOA [57]	HPSO [56]	MAPSO [45]	APABC [46]	HGFOA [57]	HPSO [56]	MAPSO [45]	APABC [46]	HGFOA [57]	HPSO [56]
$g_1$	≈	+	+	+	≈	+	+	+	≈	—	≈	≈
$g_3$	—	+	—	—	—	+	—	—	—	+	—	—
$g_4$	≈	—	≈	+	—	—	≈	+	—	—	≈	—
$g_5$	+	+	+	+	+	+	+	+	+	+	+	+
$g_6$	+	—	+	+	+	—	+	+	+	—	+	+
$g_7$	+	+	+	+	+	+	+	+	+	+	+	+
$g_8$	+	+	+	+	+	+	+	+	+	+	+	+
$g_9$	+	+	+	+	+	+	+	+	+	+	+	+
$g_{10}$	+	+	+	+	+	+	+	+	+	+	+	+
$g_{11}$	—	+	—	—	—	+	≈	≈	+	+	≈	≈
$g_{12}$	—	+	+	+	—	+	+	≈	—	+	≈	≈
$g_{13}$	≈	+	+	≈	+	+	+	+	+	+	—	—
$g_{14}$	—	+	—	+	—	+	—	≈	—	+	—	—
$g_{15}$	≈	+	+	≈	≈	+	—	≈	+	+	≈	≈
$g_{16}$	+	+	+	+	+	+	+	+	+	+	+	≈
$g_{17}$	+	+	+	+	+	+	+	+	+	+	+	+
$g_{18}$	—	+	—	≈	—	+	—	—	—	+	—	≈
$g_{19}$	≈	+	+	≈	≈	≈	—	—	≈	+	—	—
$g_{20}$	+	+	+	+	+	+	+	+	≈	+	+	—
$g_{21}$	+	+	+	+	+	+	+	+	+	+	+	+
$g_{22}$	+	+	+	+	+	+	+	+	+	+	+	+
$g_{23}$	+	+	+	+	+	+	+	+	+	+	+	+
$g_{24}$	+	+	+	+	+	+	+	+	+	+	+	+
$g_{25}$	—	—	≈	+	—	—	≈	+	≈	—	≈	+
$g_{26}$	+	+	+	+	+	+	≈	+	+	+	≈	≈
$g_{27}$	—	≈	≈	+	≈	+	—	+	—	≈	—	≈
$g_{28}$	—	—	—	+	≈	≈	+	+	—	—	≈	+
$g_{29}$	+	+	+	+	+	+	+	+	+	+	+	+
$g_{30}$	≈	+	+	+	—	—	+	+	≈	+	+	+
+ / ≈ / —	15/6/8	24/1/4	21/3/5	23/4/2	16/5/8	23/2/4	19/4/6	22/4/3	17/5/7	23/1/5	15/8/6	15/8/6

TABLE S-III  
WILCOXON TEST RESULTS BETWEEN PSO-HV AND RELATED ALGORITHMS ON CEC-2013 FUNCTIONS

Func	D=100				D=50				D=30			
	MAPSO [45]	APABC [46]	HGFOA [57]	HPSO [56]	MAPSO [45]	APABC [46]	HGFOA [57]	HPSO [56]	MAPSO [45]	APABC [46]	HGFOA [57]	HPSO [56]
$f_1$	—	—	+	+	—	—	+	+	—	—	+	≈
$f_2$	≈	+	—	+	—	+	—	+	—	+	—	+
$f_3$	≈	+	+	+	+	+	+	+	+	+	+	+
$f_4$	—	+	—	—	—	+	—	—	—	+	—	—
$f_5$	—	—	+	+	+	—	+	≈	+	—	+	+
$f_6$	≈	—	≈	+	—	—	≈	≈	—	—	≈	≈
$f_7$	+	+	+	+	+	+	+	+	+	+	+	+
$f_8$	≈	≈	—	≈	+	+	≈	≈	≈	≈	—	—
$f_9$	+	+	+	+	+	+	+	+	+	+	+	+
$f_{10}$	≈	+	+	+	—	+	+	+	—	+	+	+
$f_{11}$	+	—	+	≈	+	—	—	—	+	—	+	—
$f_{12}$	+	+	+	+	+	+	+	+	+	+	+	+
$f_{13}$	+	+	+	+	+	+	+	+	+	+	+	+
$f_{14}$	—	—	+	—	≈	—	+	—	≈	—	+	—
$f_{15}$	+	+	+	+	+	+	+	+	+	+	+	+
$f_{16}$	+	+	+	+	+	+	+	+	+	+	+	+
$f_{17}$	+	—	+	+	+	—	+	≈	+	—	+	—
$f_{18}$	+	+	+	+	+	+	+	+	+	+	+	+
$f_{19}$	+	—	+	+	≈	—	+	≈	≈	—	+	≈
$f_{20}$	≈	≈	≈	≈	—	+	+	—	—	—	—	—
$f_{21}$	≈	—	+	≈	+	—	≈	—	≈	—	≈	≈
$f_{22}$	—	—	+	≈	+	—	+	+	+	—	+	≈
$f_{23}$	+	+	+	+	+	+	+	+	+	+	+	+
$f_{24}$	+	+	+	+	+	+	+	+	+	+	+	+
$f_{25}$	+	+	+	+	+	+	+	+	+	+	+	+
$f_{26}$	+	—	+	≈	+	—	≈	—	—	—	—	—
$f_{27}$	+	+	+	+	+	+	+	+	+	+	+	+
$f_{28}$	≈	≈	+	≈	—	≈	+	+	—	—	+	+
+ / ≈ / —	15/8/5	15/3/10	23/2/3	19/2/7	19/2/7	17/1/10	21/4/3	17/5/6	16/4/8	15/1/12	21/2/5	16/5/7

TABLE S-IV  
WILCOXON TEST RESULTS BETWEEN PSO-HV AND OTHER COMPARISON ALGORITHMS ON CEC-2017 FUNCTIONS

Func	D=100						D=50						D=30					
	TAPSO [50]	DEPSO [51]	AWPSO [52]	HCLPSO [53]	CJADE [54]	LOTFWA [55]	TAPSO [50]	DEPSO [51]	AWPSO [52]	HCLPSO [53]	CJADE [54]	LOTFWA [55]	TAPSO [50]	DEPSO [51]	AWPSO [52]	HCLPSO [53]	CJADE [54]	LOTFWA [55]
<i>g1</i>	≈	≈	+	≈	—	—	≈	≈	+	—	—	—	≈	≈	+	—	—	—
<i>g3</i>	—	+	+	—	—	—	—	+	+	—	—	—	—	—	+	—	—	—
<i>g4</i>	—	≈	+	≈	—	—	—	≈	+	—	—	—	—	+	+	—	—	—
<i>g5</i>	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
<i>g6</i>	+	+	+	≈	—	+	+	≈	+	—	+	+	+	—	+	—	—	+
<i>g7</i>	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
<i>g8</i>	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
<i>g9</i>	+	≈	+	+	+	+	+	—	+	+	+	+	+	+	+	+	+	≈
<i>g10</i>	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
<i>g11</i>	—	—	+	—	—	—	—	≈	+	—	—	—	+	+	+	+	+	+
<i>g12</i>	—	≈	+	—	—	+	—	—	+	—	—	+	—	—	+	—	—	+
<i>g13</i>	≈	≈	+	≈	≈	+	+	≈	+	≈	≈	+	≈	≈	+	—	—	+
<i>g14</i>	—	≈	+	≈	—	—	—	—	+	—	—	—	—	≈	+	—	—	—
<i>g15</i>	≈	≈	+	≈	≈	+	+	≈	+	—	—	+	+	≈	+	—	—	+
<i>g16</i>	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
<i>g17</i>	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
<i>g18</i>	—	—	+	—	—	—	—	≈	+	—	—	—	—	—	+	—	—	—
<i>g19</i>	≈	≈	+	≈	≈	+	≈	≈	+	—	—	+	+	+	+	—	—	+
<i>g20</i>	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	≈	≈	+
<i>g21</i>	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
<i>g22</i>	+	≈	+	+	+	+	+	+	+	+	+	+	≈	+	+	+	+	+
<i>g23</i>	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
<i>g24</i>	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
<i>g25</i>	≈	≈	+	≈	≈	—	≈	+	+	—	—	—	≈	+	+	—	—	—
<i>g26</i>	+	≈	+	+	+	+	+	—	+	+	+	+	+	—	+	—	+	≈
<i>g27</i>	+	≈	+	+	+	+	+	+	+	+	+	+	+	+	+	≈	—	+
<i>g28</i>	—	—	+	—	—	—	≈	+	+	≈	+	—	—	—	+	—	—	—
<i>g29</i>	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
<i>g30</i>	≈	—	+	—	—	+	—	≈	+	—	—	+	≈	+	+	≈	—	+
+ / ≈ / —	16/6/7	13/12/4	29/0/0	15/8/6	15/4/10	21/0/8	18/4/7	16/9/4	29/0/0	15/2/12	17/1/11	21/0/8	18/5/6	19/4/6	29/0/0	13/3/13	14/1/14	20/2/7

TABLE S-V  
WILCOXON TEST RESULTS BETWEEN PSO-HV AND OTHER COMPARISON ALGORITHMS ON CEC-2013 FUNCTIONS

Func	D=100						D=50						D=30					
	TAPSO [50]	DEPSO [51]	AWPSO [52]	HCLPSO [53]	CJADE [54]	LOTFWA [55]	TAPSO [50]	DEPSO [51]	AWPSO [52]	HCLPSO [53]	CJADE [54]	LOTFWA [55]	TAPSO [50]	DEPSO [51]	AWPSO [52]	HCLPSO [53]	CJADE [54]	LOTFWA [55]
<i>f1</i>	≈	—	+	≈	—	—	—	—	+	≈	—	—	—	—	+	≈	—	—
<i>f2</i>	—	—	+	≈	—	—	—	—	+	—	—	—	—	—	+	—	—	—
<i>f3</i>	+	≈	+	+	+	+	+	+	+	+	+	+	+	+	+	+	—	+
<i>f4</i>	—	+	+	—	—	—	—	+	+	—	—	—	—	+	+	—	—	—
<i>f5</i>	—	—	+	—	—	+	—	—	+	—	—	+	—	—	+	—	—	+
<i>f6</i>	—	—	+	≈	—	—	—	—	+	—	—	—	—	≈	+	—	—	—
<i>f7</i>	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
<i>f8</i>	≈	—	—	+	≈	≈	≈	≈	—	+	≈	—	—	+	—	+	+	—
<i>f9</i>	+	+	—	+	+	+	+	+	—	+	+	+	+	+	—	+	+	+
<i>f10</i>	—	—	+	≈	—	—	—	—	+	≈	—	—	—	≈	+	—	—	—
<i>f11</i>	—	+	+	—	—	+	—	+	+	—	—	+	—	+	+	—	—	+
<i>f12</i>	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
<i>f13</i>	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
<i>f14</i>	—	+	+	—	—	+	—	+	+	—	—	+	—	+	+	—	—	+
<i>f15</i>	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
<i>f16</i>	+	≈	+	+	+	—	+	—	+	+	+	—	+	—	+	+	+	—
<i>f17</i>	—	+	+	—	—	+	—	+	+	—	—	+	—	+	+	—	—	+
<i>f18</i>	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
<i>f19</i>	—	≈	+	≈	+	+	—	+	+	—	—	+	—	+	+	—	—	≈
<i>f20</i>	≈	≈	+	≈	≈	≈	—	—	+	—	—	+	—	+	+	—	—	≈
<i>f21</i>	—	≈	+	≈	—	—	≈	≈	+	—	≈	—	≈	+	+	—	≈	—
<i>f22</i>	—	+	+	—	—	+	—	+	+	—	—	+	—	+	+	—	—	+
<i>f23</i>	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
<i>f24</i>	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
<i>f25</i>	+	+	+	+	+	+	+	+	+	+	+	+	+	≈	+	+	+	+
<i>f26</i>	+	≈	+	≈	+	+	+	+	+	—	+	—	+	+	+	—	≈	—
<i>f27</i>	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
<i>f28</i>	≈	—	+	≈	≈	≈	+	—	+	—	+	—	+	—	+	≈	—	≈
+ / ≈ / —	13/4/11	15/6/7	26/0/2	13/9/6	14/3/11	18/3/7	14/2/12	18/2/8	26/0/2	13/2/13	14/2/12	18/0/10	14/1/13	20/3/5	26/0/2	13/2/13	12/2/14	16/3/9

TABLE S-VI  
COMPARISON RESULTS ON CEC 2017 ON 100-D

Func	D=100	TAPSO	DEPSO	AWPSO	HCLPSO	CJADE	LOTFWA	MAPSO	APABC	HGFOA	HPSO-DTA	PSO-HV
g1	Mean Err.	3.18E+03 (≈)	5.26E+03 (≈)	3.34E+11 (+)	5.05E+03 (≈)	3.80E-02 (-)	1.61E+02 (-)	6.84E+03 (≈)	3.82E+04 (+)	4.13E+04 (+)	2.07E+04 (+)	6.64E+03
	Median	1.49E+03	3.20E+03	3.32E+11	5.01E+03	1.59E-03	4.08E+01	6.87E+03	2.78E+04	3.46E+04	2.84E+04	1.77E+03
	Std.	4.13E+03	4.75E+03	2.81E+10	3.11E+03	9.71E-02	3.69E+02	5.94E+03	2.34E+04	1.72E+04	1.49E+04	9.14E+03
g3	Mean Err.	4.02E+04 (-)	4.02E+05 (+)	4.60E+05 (+)	4.45E+04 (-)	7.05E+04 (-)	1.19E+04 (-)	4.50E+03 (-)	6.46E+05 (+)	2.99E+04 (-)	1.38E+05 (-)	1.77E+05
	Median	3.58E+04	3.90E+05	4.59E+05	4.14E+04	1.09E-07	1.28E+04	4.95E+03	6.50E+05	2.94E+04	1.35E+05	1.74E+05
	Std.	1.38E+04	8.36E+04	3.65E+04	1.16E+04	1.22E+05	3.56E+03	1.94E+03	3.70E+04	3.62E+03	2.39E+04	3.55E+04
g4	Mean Err.	1.85E+02 (-)	2.76E+02 (≈)	9.11E+04 (+)	2.45E+02 (≈)	9.64E+01 (-)	2.40E+02 (-)	2.62E+02 (≈)	2.10E+02 (-)	2.89E+02 (≈)	4.04E+02 (+)	2.83E+02
	Median	1.93E+02	2.80E+02	9.46E+04	2.46E+02	8.05E+01	2.45E+02	2.57E+02	2.08E+02	2.92E+02	4.02E+02	2.91E+02
	Std.	5.11E+01	3.73E+01	1.27E+04	3.27E+01	5.65E+01	2.18E+01	3.67E+01	2.14E+01	4.46E+01	4.38E+01	3.54E+01
g5	Mean Err.	4.02E+02 (+)	1.46E+02 (+)	1.74E+03 (+)	2.99E+02 (+)	2.04E+02 (+)	3.99E+02 (+)	1.65E+02 (+)	3.57E+02 (+)	5.56E+02 (+)	2.73E+02 (+)	5.07E+01
	Median	4.13E+02	1.41E+02	1.76E+03	2.87E+02	2.05E+02	3.85E+02	1.68E+02	3.58E+02	5.57E+02	2.79E+02	4.97E+01
	Std.	4.56E+01	1.76E+01	6.22E+01	4.20E+01	4.07E+01	3.85E+01	1.88E+01	2.79E+01	6.87E+01	2.92E+01	1.38E+01
g6	Mean Err.	9.73E-02 (+)	2.20E-03 (+)	1.14E+02 (+)	3.80E-03 (≈)	4.03E-13 (-)	2.09E+01 (+)	1.76E+00 (+)	1.86E-13 (-)	5.01E+01 (+)	8.51E-01 (+)	3.00E-04
	Median	9.92E-02	1.95E-03	1.13E+02	1.45E-04	4.55E-13	2.28E+01	1.83E+00	2.27E-13	5.02E+01	8.28E-01	1.74E-04
	Std.	3.12E-02	1.66E-03	3.43E+00	1.10E-02	5.94E-14	2.76E+00	3.26E-01	7.66E-14	5.54E+00	1.12E-01	3.38E-04
g7	Mean Err.	6.01E+02 (+)	2.63E+02 (+)	6.70E+03 (+)	5.61E+02 (+)	4.15E+02 (+)	2.58E+02 (+)	4.58E+02 (+)	4.50E+02 (+)	1.25E+03 (+)	5.09E+02 (+)	1.42E+02
	Median	5.79E+02	2.63E+02	6.81E+03	5.51E+02	3.99E+02	2.55E+02	4.67E+02	4.54E+02	1.32E+03	4.99E+02	1.39E+02
	Std.	1.02E+02	1.63E+01	4.15E+02	1.04E+02	4.87E+01	2.07E+01	5.09E+01	1.95E+01	1.75E+02	9.00E+01	6.85E+00
g8	Mean Err.	4.18E+02 (+)	1.56E+02 (+)	1.86E+03 (+)	3.05E+02 (+)	2.11E+02 (+)	4.43E+02 (+)	1.55E+02 (+)	3.63E+02 (+)	5.82E+02 (+)	3.05E+02 (+)	5.29E+01
	Median	4.09E+02	1.59E+02	1.86E+03	2.98E+02	2.12E+02	4.37E+02	1.48E+02	3.80E+02	6.03E+02	3.16E+02	5.27E+01
	Std.	6.03E+01	2.08E+01	4.74E+01	6.39E+01	2.58E+01	2.65E+01	2.39E+01	4.73E+01	5.69E+01	4.63E+01	6.70E+00
g9	Mean Err.	9.35E+03 (+)	4.66E+00 (≈)	1.06E+05 (+)	1.98E+03 (+)	1.50E+03 (+)	1.18E+04 (+)	6.82E+02 (+)	7.60E+03 (+)	3.04E+04 (+)	8.38E+02 (+)	2.73E+01
	Median	8.26E+03	2.90E+00	1.02E+05	1.47E+03	1.05E+03	1.17E+04	6.75E+02	8.13E+03	3.11E+04	7.22E+02	8.26E+00
	Std.	4.29E+03	2.95E+00	1.20E+04	1.39E+03	9.70E+02	1.73E+03	1.79E+02	2.06E+03	4.75E+03	3.55E+02	5.21E+01
g10	Mean Err.	1.14E+04 (+)	6.94E+03 (+)	3.00E+04 (+)	1.19E+04 (+)	9.72E+03 (+)	9.89E+03 (+)	1.25E+04 (+)	9.96E+03 (+)	1.42E+04 (+)	1.13E+04 (+)	3.54E+03
	Median	1.14E+04	6.96E+03	2.99E+04	1.22E+04	9.84E+03	9.91E+03	1.26E+04	1.01E+04	1.39E+04	1.13E+04	3.87E+03
	Std.	1.16E+03	1.21E+03	3.22E+02	9.75E+02	3.27E+02	7.16E+02	1.08E+03	5.83E+02	1.08E+03	1.12E+03	1.21E+03
g11	Mean Err.	3.60E+02 (-)	1.13E+03 (-)	1.61E+05 (+)	8.21E+02 (-)	1.21E+03 (-)	1.18E+03 (-)	7.48E+02 (-)	6.95E+04 (+)	1.48E+03 (-)	1.98E+03 (-)	5.44E+03
	Median	3.46E+02	6.05E+02	1.67E+05	8.03E+02	1.18E+03	1.21E+03	7.88E+02	7.34E+04	1.45E+03	1.77E+03	4.53E+03
	Std.	7.46E+01	1.11E+03	2.90E+04	1.88E+02	3.84E+02	1.70E+02	1.27E+02	1.93E+04	3.44E+02	6.56E+02	2.45E+03
g12	Mean Err.	4.27E+05 (-)	4.14E+06 (≈)	1.54E+11 (+)	1.27E+06 (-)	6.10E+04 (-)	1.43E+07 (+)	1.48E+06 (-)	2.77E+07 (+)	4.59E+07 (+)	3.60E+07 (+)	3.66E+06
	Median	3.85E+05	5.90E+05	1.52E+11	1.36E+06	4.47E+04	1.22E+07	1.23E+06	2.56E+07	5.28E+07	3.90E+07	2.94E+06
	Std.	2.11E+05	4.91E+06	1.54E+10	3.28E+05	2.88E+04	1.01E+07	8.26E+05	9.03E+06	1.99E+07	2.38E+07	1.78E+06
g13	Mean Err.	3.42E+03 (≈)	1.66E+03 (≈)	2.98E+10 (+)	3.80E+03 (≈)	5.34E+03 (≈)	2.57E+04 (+)	5.49E+03 (≈)	1.58E+04 (+)	6.00E+04 (+)	3.29E+03 (≈)	2.66E+03
	Median	1.67E+03	4.38E+02	2.99E+10	2.56E+03	2.72E+03	2.58E+04	3.08E+03	1.42E+04	5.74E+04	2.65E+03	1.91E+03
	Std.	5.40E+03	2.33E+03	4.64E+09	3.33E+03	6.66E+03	4.23E+03	5.59E+03	9.24E+03	2.39E+04	1.93E+03	2.76E+03
g14	Mean Err.	3.67E+04 (-)	6.56E+05 (≈)	4.93E+07 (+)	2.56E+05 (≈)	6.73E+02 (-)	1.10E+05 (-)	1.01E+05 (-)	8.61E+06 (+)	1.08E+03 (-)	1.06E+06 (+)	4.33E+05
	Median	2.80E+04	1.17E+05	5.25E+07	2.13E+05	5.25E+02	9.05E+04	9.24E+04	8.32E+06	9.71E+02	7.63E+05	3.37E+05
	Std.	2.77E+04	7.78E+05	1.49E+07	1.38E+05	3.39E+02	5.46E+04	4.49E+04	2.28E+06	2.69E+02	9.28E+05	2.29E+05
g15	Mean Err.	7.66E+02 (≈)	2.19E+03 (≈)	1.26E+10 (+)	7.51E+02 (≈)	8.98E+02 (≈)	1.86E+04 (+)	1.67E+03 (≈)	1.41E+04 (+)	1.40E+04 (+)	1.08E+03 (≈)	1.98E+03
	Median	5.45E+02	1.25E+03	1.22E+10	6.30E+02	7.57E+02	1.91E+04	8.35E+02	1.08E+04	1.34E+04	1.02E+03	1.07E+03
	Std.	6.99E+02	2.28E+03	3.56E+09	4.77E+02	7.86E+02	3.75E+03	1.81E+03	9.84E+03	6.23E+03	3.86E+02	2.08E+03
g16	Mean Err.	3.41E+03 (+)	2.32E+03 (+)	1.55E+04 (+)	3.02E+03 (+)	2.45E+03 (+)	2.58E+03 (+)	2.76E+03 (+)	3.31E+03 (+)	3.96E+03 (+)	2.73E+03 (+)	5.82E+02
	Median	3.42E+03	2.26E+03	1.57E+04	2.92E+03	2.42E+03	2.49E+03	2.75E+03	3.24E+03	3.85E+03	2.73E+03	5.57E+02
	Std.	6.69E+02	6.38E+02	2.39E+03	6.34E+02	3.70E+02	3.89E+02	4.91E+02	4.04E+02	6.33E+02	2.54E+02	3.10E+02
g17	Mean Err.	2.90E+03 (+)	1.62E+03 (+)	1.56E+06 (+)	2.48E+03 (+)	2.00E+03 (+)	1.82E+03 (+)	2.46E+03 (+)	2.42E+03 (+)	2.93E+03 (+)	2.13E+03 (+)	3.06E+02
	Median	2.89E+03	1.79E+03	8.61E+05	2.53E+03	1.91E+03	1.86E+03	2.32E+03	2.39E+03	2.95E+03	2.12E+03	2.66E+02
	Std.	5.41E+02	4.67E+02	1.49E+06	5.16E+02	3.47E+02	2.16E+02	3.84E+02	2.97E+02	4.51E+02	1.87E+02	2.16E+02
g18	Mean Err.	1.36E+05 (-)	1.44E+05 (-)	7.59E+07 (+)	2.40E+05 (-)	2.46E+03 (-)	3.38E+05 (-)	2.67E+05 (-)	4.64E+06 (+)	7.72E+04 (-)	1.60E+06 (≈)	1.00E+06
	Median	9.88E+04	1.44E+05	7.68E+07	2.33E+05	2.41E+03	3.18E+05	2.42E+05	4.66E+06	7.45E+04	1.38E+06	8.31E+05
	Std.	1.06E+05	2.60E+04	2.16E+07	8.71E+04	1.33E+03	7.61E+04	1.53E+05	1.88E+06	3.45E+04	6.09E+05	5.41E+05
g19	Mean Err.	3.43E+03 (≈)	1.32E+03 (≈)	1.05E+10 (+)	9.47E+02 (≈)	4.55E+03 (≈)	3.54E+05 (+)	4.34E+03 (≈)	8.07E+03 (+)	2.00E+04 (+)	9.94E+02 (≈)	2.04E+03
	Median	1.05E+03	4.60E+02	1.01E+10	3.65E+02	9.81E+02	3.79E+05	2.48E+03	5.93E+03	1.38E+04	8.21E+02	6.03E+02
	Std.	4.33E+03	1.36E+03	2.41E+09	1.23E+03	6.97E+03	1.38E+05	4.92E+03	4.91E+03	1.87E+04	6.92E+02	3.66E+03
g20	Mean Err.	2.42E+03 (+)	1.43E+03 (+)	5.19E+03 (+)	2.30E+03 (+)	1.85E+03 (+)	2.11E+03 (+)	1.97E+03 (+)	2.18E+03 (+)	2.34E+03 (+)	1.72E+03 (+)	4.35E+02
	Median	2.34E+03	1.50E+03	5.25E+03	2.32E+03	1.89E+03	2.10E+03	1.80E+03	2.17E+03	2.36E+03	1.75E+03	3.93E+02
	Std.	5.65E+02	4.56E+02	3.06E+02	3.10E+02	2.11E+02	2.53E+02	4.50E+02	1.87E+02	3.72E+02	2.65E+02	1.70E+02
g21	Mean Err.	6.32E+02 (+)	3.81E+02 (+)	2.47E+03 (+)	5.71E+02 (+)	4.15E+02 (+)	7.43E+02 (+)	3.80E+02 (+)	6.08E+02 (+)	9.26E+02 (+)	5.17E+02 (+)	2.76E+02
	Median	6.28E+02	3.86E+02	2.47E+03	5.76E+02	4.12E+02	7.52E+02	3.82E+02	6.10E+02	9.35E+02	5.29E+02	2.75E+02
	Std.	5.47E+01	1.60E+01	1.45E+02	6.36E+01	2.39E+01	3.76E+01	2.14E+01	1.77E+01	1.23E+02	5.41E+01	9.87E+00
g22	Mean Err.	1.22E+04 (+)	3.71E+03 (≈)	3.19E+04 (+)	1.30E+04 (+)	1.14E+04 (+)	1.21E+04 (+)	1.32E+04 (+)	1.15E+04 (+)	1.62E+04 (+)	1.21E+04 (+)	1.00E+02
	Median	1.36E+04	1.00E+02	3.15E+04	1.29E+04	1.14E+04	1.21E+04	1.32E+04	1.14E+04	1.66E+04	1.23E+04	1.00E+02
	Std.	4.39E+03	4.19E+03	5.73E+02	1.23E+03	6.95E+02	5.25E+02	1.82E+03	5.29E+02	2.02E+03	9.36E+02	1.13E+00
g23	Mean Err.	8.56E+02 (+)	6.72E+02 (+)	4.59E+03 (+)	8.10E+02 (+)	6.66E+02 (+)	1.35E+03 (+)	6.66E+02 (+)	7.30E+02 (+)	1.60E+03 (+)	7.66E+02 (+)	5.85E+02
	Median	8.35E+02	6.73E+02	4.63E+03	8.07E+02	6.60E+02	1.36E+03	6.68E+02	7.29E+02	1.58E+03	7.60E+02	5.85E+02
	Std.	6.88E+01	3.97E+01	5.17E+02	2.68E+01	1.85E+0						

TABLE S-VII  
COMPARISON RESULTS ON CEC 2017 ON 50-D

Func	D=50	TAPSO	DEPSO	AWPSO	HCLPSO	CJADE	LOTFWA	MAPSO	APABC	HGFOA	HPSO-DTA	PSO-HV
g1	Mean Err.	3.47E+03 (≈)	2.30E+03 (≈)	1.08E+11 (+)	9.81E+02 (−)	4.27E-10 (−)	2.10E+02 (−)	2.17E+03 (≈)	3.02E+04 (+)	1.09E+04 (+)	1.37E+04 (+)	2.67E+03
	Median	1.87E+03	8.09E+02	1.09E+11	7.12E+02	1.59E-12	7.27E+01	1.09E+03	3.24E+04	6.32E+03	1.42E+04	9.69E+02
	Std.	3.64E+03	3.37E+03	1.70E+10	8.31E+02	9.41E-10	3.46E+02	2.53E+03	1.19E+04	7.36E+03	7.21E+03	3.66E+03
g3	Mean Err.	6.03E+02 (−)	9.47E+04 (+)	1.82E+05 (+)	4.42E+00 (−)	7.46E+03 (−)	3.10E-01 (−)	1.12E+02 (−)	2.72E+05 (+)	9.89E+02 (−)	2.20E+04 (−)	6.24E+04
	Median	6.21E+01	8.88E+04	1.79E+05	2.01E+00	6.82E-13	1.99E-01	9.10E+01	2.66E+05	7.50E+02	1.81E+04	6.14E+04
	Std.	1.76E+03	2.70E+04	2.64E+04	6.55E+00	2.09E+04	3.47E-01	9.01E+01	3.04E+04	8.84E+02	1.01E+04	1.36E+04
g4	Mean Err.	4.37E+01 (−)	1.85E+02 (≈)	2.69E+04 (+)	9.14E+01 (−)	3.44E+01 (−)	1.02E+02 (−)	1.31E+02 (−)	4.85E+01 (−)	1.67E+02 (≈)	2.03E+02 (+)	1.72E+02
	Median	2.85E+01	2.05E+02	2.62E+04	1.01E+02	2.85E+01	1.03E+02	1.19E+02	4.42E+01	1.59E+02	1.89E+02	1.69E+02
	Std.	4.50E+01	4.30E+01	5.58E+03	4.90E+01	3.97E+01	3.83E+01	2.86E+01	2.13E+01	3.84E+01	3.36E+01	4.11E+01
g5	Mean Err.	1.32E+02 (+)	5.99E+01 (+)	7.21E+02 (+)	1.04E+02 (+)	6.66E+01 (+)	1.45E+02 (+)	6.60E+01 (+)	1.14E+02 (+)	1.98E+02 (+)	1.08E+02 (+)	1.83E+01
	Median	1.25E+02	5.97E+01	7.25E+02	1.05E+02	6.60E+01	1.46E+02	6.47E+01	1.15E+02	2.06E+02	1.14E+02	1.79E+01
	Std.	3.01E+01	1.28E+01	4.82E+01	2.14E+01	9.76E+00	1.68E+01	1.18E+01	1.30E+01	3.94E+01	1.85E+01	4.78E+00
g6	Mean Err.	2.57E-02 (+)	7.78E-05 (≈)	9.65E+01 (+)	5.75E-13 (−)	3.73E-04 (+)	4.58E+00 (+)	1.22E+00 (+)	9.36E-14 (−)	3.05E+01 (+)	2.24E-01 (+)	7.17E-05
	Median	2.06E-02	8.41E-06	9.74E+01	5.68E-13	1.14E-13	3.65E+00	1.21E+00	1.14E-13	2.97E+01	1.90E-01	2.16E-05
	Std.	1.79E-02	2.61E-04	6.15E+00	1.93E-13	2.26E-03	4.07E+00	5.56E-01	4.93E-14	7.10E+00	1.28E-01	1.41E-04
g7	Mean Err.	1.82E+02 (+)	1.01E+02 (+)	2.39E+03 (+)	1.82E+02 (+)	1.18E+02 (+)	1.14E+02 (+)	2.04E+02 (+)	1.56E+02 (+)	4.51E+02 (+)	1.75E+02 (+)	6.48E+01
	Median	1.80E+02	9.95E+01	2.37E+03	1.88E+02	1.15E+02	1.14E+02	2.02E+02	1.55E+02	4.64E+02	1.70E+02	6.40E+01
	Std.	2.53E+01	9.07E+00	2.01E+02	2.02E+01	1.01E+01	1.26E+01	3.80E+01	1.28E+01	6.14E+01	2.18E+01	3.31E+00
g8	Mean Err.	1.32E+02 (+)	5.96E+01 (+)	7.42E+02 (+)	9.77E+01 (+)	6.20E+01 (+)	1.32E+02 (+)	6.99E+01 (+)	1.15E+02 (+)	2.05E+02 (+)	1.10E+02 (+)	1.77E+01
	Median	1.30E+02	5.67E+01	7.43E+02	9.85E+01	6.18E+01	1.45E+02	6.67E+01	1.15E+02	2.03E+02	1.15E+02	1.61E+01
	Std.	2.39E+01	1.29E+01	4.63E+01	2.09E+01	9.54E+00	1.58E+01	1.71E+01	1.30E+01	4.17E+01	1.33E+01	4.97E+00
g9	Mean Err.	1.13E+03 (+)	1.50E+00 (−)	3.86E+04 (+)	1.83E+02 (+)	1.24E+01 (+)	3.29E+03 (+)	2.30E+02 (+)	5.28E+02 (+)	6.20E+03 (+)	5.62E+01 (+)	1.50E+00
	Median	9.09E+02	9.98E-01	3.85E+04	1.16E+02	7.15E+00	3.29E+03	2.19E+02	4.81E+02	6.54E+03	5.10E+01	4.54E-01
	Std.	7.30E+02	1.62E+00	5.34E+03	1.83E+02	1.23E+01	1.13E+03	1.24E+02	2.74E+02	1.82E+03	3.10E+01	5.78E+00
g10	Mean Err.	4.47E+03 (+)	2.98E+03 (+)	1.32E+04 (+)	4.06E+03 (+)	3.57E+03 (+)	4.45E+03 (+)	4.72E+03 (+)	3.75E+03 (+)	7.35E+03 (+)	4.43E+03 (+)	9.68E+02
	Median	4.49E+03	3.03E+03	1.33E+04	4.04E+03	3.61E+03	4.54E+03	4.82E+03	3.82E+03	7.34E+03	4.28E+03	9.32E+02
	Std.	7.64E+02	7.00E+02	4.06E+02	4.69E+02	4.07E+02	4.34E+02	8.08E+02	3.75E+02	1.15E+03	4.61E+02	4.26E+02
g11	Mean Err.	1.44E+02 (−)	1.99E+02 (≈)	1.62E+04 (+)	1.45E+02 (−)	1.45E+02 (−)	1.88E+02 (−)	1.66E+02 (−)	3.52E+03 (+)	2.51E+02 (≈)	1.83E+02 (≈)	2.36E+02
	Median	1.30E+02	1.93E+02	1.55E+04	1.42E+02	1.40E+02	1.87E+02	1.62E+02	3.57E+03	2.69E+02	1.89E+02	1.86E+02
	Std.	4.25E+01	6.67E+01	4.08E+03	4.32E+01	5.36E+01	3.70E+01	4.83E+01	1.81E+03	6.98E+01	3.28E+01	1.39E+02
g12	Mean Err.	7.67E+04 (−)	2.28E+05 (−)	4.19E+10 (+)	3.24E+05 (−)	7.25E+03 (−)	2.96E+06 (+)	5.11E+05 (−)	4.62E+06 (+)	6.30E+06 (+)	3.02E+06 (≈)	1.38E+06
	Median	6.37E+04	2.14E+05	4.08E+10	2.81E+05	5.22E+03	2.72E+06	3.98E+05	4.86E+06	7.42E+06	2.50E+06	1.23E+06
	Std.	4.40E+04	1.30E+05	8.50E+09	2.00E+05	6.05E+03	1.62E+06	4.19E+05	2.04E+06	3.08E+06	2.32E+06	6.97E+05
g13	Mean Err.	4.21E+03 (+)	1.90E+03 (≈)	1.85E+10 (+)	1.00E+03 (≈)	1.59E+03 (≈)	2.92E+04 (+)	5.80E+03 (+)	3.25E+04 (+)	2.69E+04 (+)	4.55E+03 (+)	1.43E+03
	Median	2.26E+03	8.78E+02	1.67E+10	8.05E+02	9.05E+02	2.99E+04	2.84E+03	2.91E+04	2.75E+04	4.92E+03	8.50E+02
	Std.	6.45E+03	2.71E+03	8.26E+09	8.34E+02	3.31E+03	8.69E+03	6.84E+03	1.96E+04	1.20E+04	2.95E+03	1.61E+03
g14	Mean Err.	9.51E+03 (−)	2.22E+04 (−)	1.01E+07 (+)	2.31E+04 (−)	8.83E+03 (−)	6.34E+03 (−)	3.66E+04 (−)	1.72E+06 (+)	3.17E+02 (−)	3.73E+04 (≈)	4.75E+04
	Median	4.85E+03	2.09E+04	8.55E+06	1.64E+04	2.88E+02	4.46E+03	2.70E+04	1.29E+06	3.10E+02	3.07E+04	4.12E+04
	Std.	1.59E+04	1.58E+04	6.70E+06	1.86E+04	2.99E+04	4.92E+03	3.25E+04	1.34E+06	4.06E+01	2.99E+04	2.81E+04
g15	Mean Err.	6.91E+03 (+)	4.47E+03 (≈)	2.25E+09 (+)	5.01E+02 (−)	4.56E+02 (−)	1.08E+04 (+)	2.75E+03 (≈)	1.42E+04 (+)	1.38E+03 (−)	2.55E+03 (≈)	3.45E+03
	Median	6.25E+03	3.21E+03	2.02E+09	3.63E+02	3.61E+02	1.08E+04	1.83E+03	1.30E+04	1.26E+03	2.36E+03	3.03E+03
	Std.	6.15E+03	4.04E+03	1.09E+09	4.71E+02	5.06E+02	2.91E+03	3.11E+03	5.94E+03	2.50E+02	1.34E+03	3.00E+03
g16	Mean Err.	1.32E+03 (+)	8.54E+02 (+)	5.45E+03 (+)	1.09E+03 (+)	8.80E+02 (+)	9.28E+02 (+)	9.63E+02 (+)	1.19E+03 (+)	1.16E+03 (+)	8.10E+02 (+)	2.87E+02
	Median	1.38E+03	7.60E+02	5.41E+03	1.07E+03	9.14E+02	9.42E+02	8.47E+02	1.19E+03	1.23E+03	8.04E+02	2.50E+02
	Std.	4.03E+02	2.72E+02	5.99E+02	2.60E+02	2.26E+02	1.74E+02	3.46E+02	2.09E+02	3.24E+02	1.53E+02	1.51E+02
g17	Mean Err.	1.01E+03 (+)	7.68E+02 (+)	3.93E+03 (+)	7.82E+02 (+)	6.37E+02 (+)	8.05E+02 (+)	9.66E+02 (+)	8.65E+02 (+)	8.26E+02 (+)	5.92E+02 (+)	2.23E+02
	Median	1.01E+03	7.48E+02	3.86E+03	7.65E+02	6.42E+02	8.12E+02	9.73E+02	8.72E+02	8.16E+02	6.09E+02	1.77E+02
	Std.	2.73E+02	2.29E+02	5.70E+02	2.14E+02	1.42E+02	1.41E+02	2.37E+02	1.69E+02	2.25E+02	1.57E+02	1.36E+02
g18	Mean Err.	4.19E+04 (−)	1.34E+06 (≈)	4.29E+07 (+)	7.85E+04 (−)	5.89E+04 (−)	1.25E+05 (−)	1.48E+05 (−)	2.10E+06 (+)	5.01E+03 (−)	4.76E+05 (−)	7.71E+05
	Median	2.93E+04	2.99E+05	3.90E+07	6.80E+04	3.30E+02	1.19E+05	1.20E+05	2.10E+06	3.67E+03	4.47E+05	7.73E+05
	Std.	3.46E+04	2.12E+06	1.93E+07	4.28E+04	2.22E+05	4.61E+04	1.29E+05	9.32E+05	4.43E+03	2.11E+05	4.15E+05
g19	Mean Err.	1.30E+04 (≈)	1.30E+04 (≈)	9.08E+08 (+)	1.21E+03 (−)	3.35E+02 (−)	8.92E+04 (+)	1.25E+04 (≈)	1.55E+04 (≈)	3.33E+02 (−)	1.15E+02 (−)	1.41E+04
	Median	1.17E+04	1.22E+04	7.77E+08	2.69E+02	1.85E+02	7.39E+04	1.06E+04	1.43E+04	3.51E+02	1.08E+02	1.41E+04
	Std.	8.67E+03	6.17E+03	4.69E+08	2.08E+03	7.67E+02	6.43E+04	6.75E+03	5.53E+03	8.80E+01	3.94E+01	4.68E+03
g20	Mean Err.	7.44E+02 (+)	4.22E+02 (+)	1.91E+03 (+)	5.61E+02 (+)	3.84E+02 (+)	5.84E+02 (+)	5.20E+02 (+)	6.58E+02 (+)	6.73E+02 (+)	3.08E+02 (+)	4.60E+01
	Median	7.32E+02	3.71E+02	1.92E+03	5.77E+02	4.01E+02	5.89E+02	5.23E+02	6.43E+02	6.80E+02	3.27E+02	3.39E+01
	Std.	2.79E+02	2.60E+02	1.37E+02	2.07E+02	1.23E+02	1.21E+02	2.16E+02	1.58E+02	2.20E+02	1.35E+02	5.82E+01
g21	Mean Err.	3.32E+02 (+)	2.63E+02 (+)	9.86E+02 (+)	3.01E+02 (+)	2.60E+02 (+)	3.49E+02 (+)	2.69E+02 (+)	3.20E+02 (+)	4.01E+02 (+)	2.98E+02 (+)	2.20E+02
	Median	3.27E+02	2.61E+02	9.83E+02	3.00E+02	2.58E+02	3.52E+02	2.67E+02	3.27E+02	4.09E+02	3.00E+02	2.21E+02
	Std.	2.78E+01	1.26E+01	5.32E+01	1.96E+01	1.02E+01	1.84E+01	1.45E+01	2.61E+01	3.03E+01	1.59E+01	4.63E+00
g22	Mean Err.	4.96E+03 (+)	4.36E+02 (+)	1.38E+04 (+)	3.67E+03 (+)	3.71E+03 (+)	3.33E+03 (+)	4.72E+03 (+)	4.20E+03 (+)	8.26E+03 (+)	2.90E+03 (+)	1.00E+02
	Median	5.35E+03	1.00E+02	1.38E+04	4.78E+03	4.29E+03	4.58E+03	5.27E+03	4.45E+03	7.74E+03	4.00E+03	1.00E+02
	Std.	1.60E+03	1.18E+03	4.97E+02	2.14E+03	1.60E+03	2.32E+03	2.02E+03	1.10E+03	1.60E+03	2.28E+03	6.87E-09
g23	Mean Err.	6.04E+02 (+)	4.92E+02 (+)	2.01E+03 (+)	5.52E+02 (+)	6.21E+02 (+)	6.61E+02 (+)	4.91E+02 (+)	5.65E+02 (+)	7.05E+02 (+)	5.42E+02 (+)	4.28E+02
	Median	6.05E+02	4.93E+02	1.99E+03	5.51E+02	6.21E+02	6.59E+02	4.91E+02	5.66E+02	7.17E+02	5.40E+02	4.29E+02
	Std.	3.38E+01	1.82E+01	1.78E+0								

TABLE S-VIII  
COMPARISON RESULTS ON CEC 2017 ON 30-D

Func	D=30	TAPSO	DEPSO	AWPSO	HCLPSO	CJADE	LOTFWA	MAPSO	APABC	HGFOA	HPSO-DTA	PSO-HV
g <sub>1</sub>	Mean Err.	3.63E+03 (≈)	2.05E+03 (≈)	4.07E+10 (+)	9.78E+01 (−)	3.37E-14 (−)	2.56E+02 (−)	3.31E+03 (≈)	1.32E+03 (−)	4.34E+03 (≈)	3.65E+03 (≈)	2.81E+03
	Median	2.62E+03	1.39E+03	3.98E+10	1.71E+01	2.84E-14	6.34E+01	1.87E+03	1.33E+03	1.93E+03	2.10E+03	1.76E+03
	Std.	3.59E+03	2.17E+03	8.36E+09	3.01E+02	2.27E-14	3.75E+02	4.15E+03	8.87E+02	5.90E+03	3.83E+03	2.88E+03
g <sub>3</sub>	Mean Err.	3.99E-13 (−)	1.98E+04 (−)	7.96E+04 (+)	1.03E-10 (−)	3.18E+03 (−)	8.92E-04 (−)	2.59E+00 (−)	1.28E+05 (+)	1.83E+01 (−)	1.35E+03 (−)	2.51E+04
	Median	2.84E-13	2.05E+04	8.16E+04	1.67E-11	2.27E-13	5.41E-04	1.57E+00	1.26E+05	1.78E+01	1.16E+03	2.30E+04
	Std.	3.95E-13	1.03E+04	1.36E+04	2.47E-10	6.84E+03	1.01E-03	3.27E+00	1.97E+04	1.11E+01	8.35E+02	9.85E+03
g <sub>4</sub>	Mean Err.	3.75E+01 (−)	1.14E+02 (+)	8.97E+03 (+)	5.32E+01 (−)	3.04E+01 (−)	5.88E+01 (−)	8.94E+01 (−)	3.57E+01 (−)	7.71E+01 (≈)	8.41E+01 (−)	1.08E+02
	Median	5.86E+01	1.18E+02	8.53E+03	6.84E+01	3.99E+00	6.93E+01	8.83E+01	2.68E+01	7.49E+01	8.05E+01	1.15E+02
	Std.	2.95E+01	9.98E+00	3.43E+03	2.84E+01	2.99E+01	2.90E+01	5.42E+00	3.01E+01	2.44E+01	1.56E+01	1.66E+01
g <sub>5</sub>	Mean Err.	5.52E+01 (+)	3.12E+01 (+)	3.80E+02 (+)	3.86E+01 (+)	4.74E+01 (+)	6.74E+01 (+)	3.87E+01 (+)	4.74E+01 (+)	8.91E+01 (+)	4.72E+01 (+)	8.37E+00
	Median	5.47E+01	2.89E+01	3.81E+02	3.98E+01	4.73E+01	6.67E+01	3.79E+01	4.76E+01	9.45E+01	4.68E+01	7.96E+00
	Std.	1.41E+01	1.03E+01	3.36E+01	7.99E+00	5.09E+00	9.80E+00	1.03E+01	7.42E+00	1.61E+01	8.26E+00	3.13E+00
g <sub>6</sub>	Mean Err.	7.30E-03 (+)	4.42E-06 (−)	7.67E+01 (+)	2.45E-13 (−)	1.14E-13 (−)	3.94E-01 (+)	2.74E-01 (+)	2.90E-14 (−)	1.30E+01 (+)	2.42E-02 (+)	1.91E-05
	Median	3.98E-03	1.37E-07	7.72E+01	2.27E-13	1.14E-13	8.50E-02	2.11E-01	0.00E+00	9.78E+00	1.42E-02	4.06E-06
	Std.	1.04E-02	1.23E-05	7.62E+00	9.48E-14	0.00E+00	6.96E-01	3.43E-01	5.00E-14	6.16E+00	1.87E-02	4.45E-05
g <sub>7</sub>	Mean Err.	7.98E+01 (+)	5.22E+01 (+)	1.05E+03 (+)	7.89E+01 (+)	5.56E+01 (+)	6.24E+01 (+)	9.35E+01 (+)	7.57E+01 (+)	1.74E+02 (+)	7.22E+01 (+)	3.71E+01
	Median	7.83E+01	5.17E+01	1.06E+03	7.98E+01	5.46E+01	6.07E+01	9.39E+01	7.61E+01	1.72E+02	8.36E+01	3.65E+01
	Std.	1.36E+01	5.50E+00	1.17E+02	9.90E+00	4.93E+00	8.68E+00	1.97E+01	7.96E+00	2.28E+01	2.55E+01	2.26E+00
g <sub>8</sub>	Mean Err.	5.61E+01 (+)	2.74E+01 (+)	3.42E+02 (+)	4.00E+01 (+)	5.15E+01 (+)	6.30E+01 (+)	3.60E+01 (+)	5.72E+01 (+)	7.09E+01 (+)	5.03E+01 (+)	9.08E+00
	Median	5.27E+01	2.59E+01	3.40E+02	4.15E+01	5.20E+01	6.37E+01	3.38E+01	5.80E+01	6.77E+01	5.09E+01	8.95E+00
	Std.	1.53E+01	6.69E+00	2.65E+01	6.72E+00	4.74E+00	1.05E+01	1.06E+01	9.13E+00	1.74E+01	8.26E+00	3.19E+00
g <sub>9</sub>	Mean Err.	7.81E+01 (+)	2.49E-01 (+)	1.06E+04 (+)	7.33E+00 (+)	3.04E-01 (+)	2.45E-02 (≈)	5.01E+01 (+)	8.15E+01 (+)	4.44E+02 (+)	5.73E+00 (+)	4.81E-02
	Median	4.53E+01	8.95E-02	1.07E+04	4.36E+00	1.14E-13	3.41E-13	4.05E+01	7.34E+01	1.96E+02	6.72E+00	3.41E-13
	Std.	1.02E+02	4.20E-01	2.00E+03	1.36E+01	6.00E-01	1.63E-01	4.14E+01	4.74E+01	5.65E+02	3.48E+00	1.69E-01
g <sub>10</sub>	Mean Err.	2.52E+03 (+)	2.08E+03 (+)	7.20E+03 (+)	1.97E+03 (+)	1.84E+03 (+)	2.41E+03 (+)	2.60E+03 (+)	1.92E+03 (+)	4.26E+03 (+)	2.18E+03 (+)	5.53E+02
	Median	2.50E+03	2.06E+03	7.27E+03	1.99E+03	1.83E+03	2.46E+03	2.61E+03	1.93E+03	4.25E+03	2.18E+03	4.86E+02
	Std.	5.78E+02	5.06E+02	2.68E+02	3.33E+02	2.65E+02	3.74E+02	5.71E+02	2.92E+02	4.92E+02	5.23E+02	3.37E+02
g <sub>11</sub>	Mean Err.	9.46E+01 (+)	1.02E+02 (+)	4.14E+03 (+)	5.02E+01 (+)	4.84E+01 (+)	9.96E+01 (+)	9.40E+01 (+)	1.44E+03 (+)	1.05E+02 (≈)	4.87E+01 (≈)	3.24E+01
	Median	9.08E+01	9.10E+01	3.96E+03	5.07E+01	4.30E+01	1.00E+02	8.39E+01	1.20E+03	1.01E+02	4.42E+01	8.46E+00
	Std.	4.01E+01	3.95E+01	1.28E+03	2.03E+01	2.35E+01	2.72E+01	3.96E+01	1.09E+03	4.52E+01	2.29E+01	3.80E+01
g <sub>12</sub>	Mean Err.	2.23E+04 (−)	6.34E+04 (−)	5.76E+09 (+)	1.67E+04 (−)	4.26E+03 (−)	4.35E+05 (+)	4.20E+04 (−)	8.40E+05 (+)	4.15E+05 (≈)	3.00E+05 (≈)	2.54E+05
	Median	1.70E+04	2.46E+04	5.23E+09	1.33E+04	2.14E+03	3.44E+05	3.76E+04	8.09E+05	2.33E+05	2.78E+05	2.33E+05
	Std.	1.96E+04	1.70E+05	2.21E+09	1.11E+04	4.91E+03	4.20E+05	2.70E+04	3.99E+05	3.44E+05	2.56E+05	1.67E+05
g <sub>13</sub>	Mean Err.	1.16E+04 (≈)	1.13E+04 (≈)	2.45E+09 (+)	3.61E+02 (−)	1.70E+02 (−)	2.06E+04 (+)	1.92E+04 (+)	2.98E+04 (+)	3.34E+03 (−)	7.81E+02 (−)	1.17E+04
	Median	6.64E+03	8.90E+03	2.06E+09	2.57E+02	1.12E+02	1.80E+04	1.55E+04	2.49E+04	3.10E+03	8.25E+02	9.57E+03
	Std.	1.52E+04	9.18E+03	1.59E+09	3.17E+02	2.05E+02	8.77E+03	1.46E+04	1.71E+04	9.58E+02	4.68E+02	8.82E+03
g <sub>14</sub>	Mean Err.	4.47E+03 (−)	2.57E+04 (≈)	4.48E+05 (+)	2.27E+03 (−)	2.80E+03 (−)	8.12E+02 (−)	1.89E+03 (−)	2.64E+05 (+)	1.36E+02 (−)	5.91E+03 (−)	2.67E+04
	Median	1.14E+03	7.04E+03	3.90E+05	1.68E+03	9.47E+01	5.74E+02	1.28E+03	2.23E+05	1.24E+02	5.24E+03	1.27E+04
	Std.	1.74E+04	6.51E+04	2.65E+05	2.00E+03	9.42E+03	6.30E+02	1.75E+03	1.88E+05	3.09E+01	4.29E+03	5.37E+04
g <sub>15</sub>	Mean Err.	5.31E+03 (+)	1.70E+03 (≈)	1.04E+08 (+)	2.61E+02 (−)	4.91E+02 (−)	1.12E+04 (+)	6.38E+03 (+)	1.25E+04 (+)	4.36E+02 (≈)	9.11E+02 (≈)	1.02E+03
	Median	2.65E+03	9.20E+02	9.04E+07	1.53E+02	1.19E+02	1.00E+04	1.77E+03	9.58E+03	4.31E+02	8.04E+02	5.70E+02
	Std.	7.04E+03	2.12E+03	5.66E+07	3.65E+02	1.46E+03	5.06E+03	9.07E+03	9.26E+03	9.87E+01	5.65E+02	1.30E+03
g <sub>16</sub>	Mean Err.	8.20E+02 (+)	7.62E+02 (+)	2.86E+03 (+)	4.87E+02 (+)	4.05E+02 (+)	5.48E+02 (+)	5.29E+02 (+)	6.41E+02 (+)	6.16E+02 (+)	2.99E+02 (≈)	1.23E+02
	Median	8.46E+02	7.87E+02	2.75E+03	4.97E+02	4.00E+02	5.31E+02	5.10E+02	6.52E+02	6.27E+02	3.01E+02	1.99E+01
	Std.	2.88E+02	2.77E+02	4.73E+02	1.85E+02	1.38E+02	1.35E+02	2.69E+02	1.47E+02	2.13E+02	1.31E+02	1.55E+02
g <sub>17</sub>	Mean Err.	2.77E+02 (+)	3.44E+02 (+)	1.24E+03 (+)	9.55E+01 (+)	2.89E+02 (+)	1.29E+02 (+)	9.89E+01 (+)	2.02E+02 (+)	1.41E+02 (+)	7.15E+01 (+)	4.15E+01
	Median	2.73E+02	3.57E+02	1.15E+03	7.55E+01	2.61E+02	1.25E+02	7.26E+01	1.96E+02	1.24E+02	6.50E+01	2.77E+01
	Std.	1.74E+02	1.59E+02	2.84E+02	5.32E+01	5.27E+01	4.13E+01	4.59E+01	1.05E+02	6.33E+01	2.87E+01	5.20E+01
g <sub>18</sub>	Mean Err.	3.82E+04 (−)	6.13E+04 (−)	5.67E+06 (+)	6.15E+04 (−)	1.29E+04 (−)	5.58E+04 (−)	7.88E+04 (−)	3.81E+05 (+)	4.25E+02 (−)	1.17E+05 (≈)	1.92E+05
	Median	3.50E+04	5.50E+04	4.44E+06	5.07E+04	7.79E+01	5.24E+04	6.09E+04	3.80E+05	3.62E+02	1.04E+05	1.41E+05
	Std.	2.05E+04	3.37E+04	3.76E+06	5.15E+04	3.87E+04	2.68E+04	5.11E+04	2.05E+05	1.53E+02	7.37E+04	1.43E+05
g <sub>19</sub>	Mean Err.	5.38E+03 (+)	4.87E+03 (+)	1.89E+08 (+)	1.75E+02 (−)	1.81E+02 (−)	9.26E+04 (+)	5.45E+03 (≈)	1.04E+04 (+)	1.26E+02 (−)	6.21E+02 (−)	3.29E+03
	Median	4.05E+03	4.02E+03	1.74E+08	9.27E+01	9.43E+01	7.63E+04	3.46E+03	9.33E+03	1.13E+02	6.92E+02	2.75E+03
	Std.	5.96E+03	3.37E+03	9.22E+07	1.74E+02	4.09E+02	7.34E+04	6.38E+03	5.72E+03	3.20E+01	3.49E+02	2.94E+03
g <sub>20</sub>	Mean Err.	2.52E+02 (+)	2.83E+02 (+)	7.61E+02 (+)	1.42E+02 (≈)	1.03E+02 (≈)	2.26E+02 (+)	1.39E+02 (≈)	2.17E+02 (+)	2.52E+02 (+)	7.23E+01 (−)	1.22E+02
	Median	1.99E+02	2.13E+02	7.53E+02	1.62E+02	7.16E+01	2.31E+02	1.67E+02	1.97E+02	2.58E+02	6.25E+01	1.40E+02
	Std.	1.47E+02	1.26E+02	1.02E+02	6.98E+01	6.50E+01	6.13E+01	6.08E+01	9.32E+01	8.14E+01	3.65E+01	4.36E+01
g <sub>21</sub>	Mean Err.	2.54E+02 (+)	2.33E+02 (+)	5.67E+02 (+)	2.33E+02 (+)	2.27E+02 (+)	2.60E+02 (+)	2.35E+02 (+)	2.52E+02 (+)	2.62E+02 (+)	2.49E+02 (+)	2.10E+02
	Median	2.55E+02	2.33E+02	5.66E+02	2.44E+02	2.27E+02	2.70E+02	2.34E+02	2.53E+02	2.72E+02	2.48E+02	2.09E+02
	Std.	1.41E+01	5.60E+00	3.83E+01	4.02E+01	5.50E+00	4.14E+01	8.38E+00	2.02E+01	5.92E+01	1.08E+01	3.49E+00
g <sub>22</sub>	Mean Err.	4.88E+02 (≈)	1.00E+02 (+)	5.13E+03 (+)	1.00E+02 (+)	1.67E+02 (+)	1.00E+02 (+)	1.00E+02 (+)	2.29E+02 (+)	1.00E+02 (+)	1.00E+02 (+)	1.00E+02
	Median	1.00E+02	1.00E+02	4.96E+03	1.00E+02	1.00E+02	1.00E+02	1.00E+02	1.10E+02	1.00E+02	1.00E+02	1.00E+02
	Std.	1.08E+03	3.44E-01	1.23E+03	8.04E-01	3.35E+02	1.44E-10	9.11E-01	4.88E+02	2.49E-01	1.04E-01	1.93E-11
g <sub>23</sub>	Mean Err.	4.30E+02 (+)	3.86E+02 (+)	1.12E+03 (+)	3.95E+02 (+)	4.21E+02 (+)	4.38E+02 (+)	3.88E+02 (+)	4.00E+02 (+)	4.55E+02 (+)	3.91E+02 (+)	3.48E+02
	Median	4.28E+02	3.84E+02	1.11E+03	3.96E+02	4.2						

TABLE S-IX  
COMPARISON RESULTS ON CEC 2013 ON 100-D

Func	D=100	TAPSO	DEPSO	AWPSO	HCLPSO	CJADE	LOTFWA	MAPSO	APABC	HGFOA	HPSO-DTA	PSO-HV
f <sub>1</sub>	Mean Err.	8.11E-10 (≈)	2.27E-13 (−)	2.18E+05 (+)	2.15E-12 (≈)	9.72E-13 (−)	3.93E-13 (−)	2.27E-13 (−)	3.51E-13 (−)	6.88E-03 (+)	9.52E-07 (+)	2.21E-12
	Median	1.18E-11	4.55E-13	2.22E+05	2.05E-12	9.09E-13	4.55E-13	2.27E-13	4.55E-13	6.65E-03	5.60E-09	2.27E-12
	Std.	2.64E-09	2.69E-13	2.11E+04	1.86E-13	2.29E-13	1.06E-13	0.00E+00	1.19E-13	2.06E-03	3.04E-06	5.39E-13
f <sub>2</sub>	Mean Err.	1.58E+06 (−)	5.45E+06 (−)	7.19E+09 (+)	9.74E+06 (≈)	3.24E+05 (−)	5.13E+06 (−)	7.61E+06 (≈)	5.83E+07 (+)	6.58E+06 (−)	1.06E+08 (+)	9.93E+06
	Median	1.31E+06	4.17E+06	7.30E+09	1.01E+07	2.77E+05	4.99E+06	8.01E+06	5.80E+07	6.33E+06	1.09E+08	1.01E+07
	Std.	7.34E+05	3.77E+06	1.29E+09	2.64E+06	8.46E+04	2.74E+06	3.24E+06	7.17E+06	1.36E+06	3.01E+07	2.05E+06
f <sub>3</sub>	Mean Err.	4.66E+09 (+)	2.35E+08 (≈)	2.96E+20 (+)	2.83E+09 (+)	8.60E+08 (+)	4.84E+08 (+)	2.73E+08 (≈)	2.17E+10 (+)	2.27E+09 (+)	1.19E+10 (+)	1.46E+08
	Median	3.99E+09	2.56E+08	1.19E+20	2.52E+09	7.25E+08	3.75E+08	2.24E+08	2.15E+10	1.57E+09	1.14E+10	7.33E+07
	Std.	2.81E+09	1.69E+08	3.76E+20	1.83E+09	6.87E+08	2.74E+08	1.82E+08	6.65E+09	1.82E+09	3.11E+09	1.81E+08
f <sub>4</sub>	Mean Err.	1.31E+04 (−)	1.96E+05 (+)	2.68E+05 (+)	8.19E+03 (−)	9.15E+03 (−)	6.81E+01 (−)	2.35E+02 (−)	3.71E+05 (+)	1.94E+03 (−)	2.23E+04 (−)	9.50E+04
	Median	1.39E+04	1.94E+05	2.63E+05	8.09E+03	4.37E-03	6.33E+01	2.15E+02	3.65E+05	1.93E+03	1.92E+04	9.30E+04
	Std.	4.23E+03	3.01E+04	2.18E+04	2.20E+03	2.04E+04	1.93E+01	8.42E+01	2.65E+04	6.13E+02	7.14E+03	1.18E+04
f <sub>5</sub>	Mean Err.	1.17E-11 (−)	1.14E-13 (−)	6.47E+04 (+)	2.84E-12 (−)	1.18E-12 (−)	3.20E-03 (+)	7.49E-09 (−)	2.27E-13 (−)	2.57E-01 (+)	6.59E-05 (+)	1.02E-07
	Median	1.36E-12	2.27E-13	6.37E+04	2.84E-12	1.14E-12	3.19E-03	5.91E-12	2.27E-13	2.40E-01	1.83E-07	4.91E-08
	Std.	2.05E-11	1.19E-13	8.84E+03	3.22E-13	2.70E-13	1.77E-04	2.17E-08	0.00E+00	6.47E-02	2.17E-04	1.73E-07
f <sub>6</sub>	Mean Err.	1.11E+02 (−)	2.08E+02 (−)	5.33E+04 (+)	2.14E+02 (≈)	1.33E+02 (−)	1.68E+02 (−)	2.67E+02 (≈)	2.04E+02 (−)	2.31E+02 (≈)	4.48E+02 (+)	2.54E+02
	Median	9.04E+01	2.05E+02	5.36E+04	2.13E+02	1.57E+02	1.73E+02	2.72E+02	2.03E+02	2.24E+02	4.49E+02	2.54E+02
	Std.	4.80E+01	3.10E+01	6.21E+03	3.92E+01	6.53E+01	4.30E+01	2.40E+01	2.10E+01	6.54E+01	3.34E+01	4.44E+01
f <sub>7</sub>	Mean Err.	1.19E+02 (+)	4.47E+00 (+)	1.51E+07 (+)	9.18E+01 (+)	1.18E+02 (+)	1.18E+02 (+)	4.71E+01 (+)	3.99E+02 (+)	1.46E+02 (+)	1.01E+02 (+)	2.59E+00
	Median	1.17E+02	4.30E+00	1.04E+07	9.24E+01	1.17E+02	1.15E+02	4.83E+01	3.78E+02	1.43E+02	1.03E+02	2.17E+00
	Std.	1.32E+01	1.63E+00	1.44E+07	1.23E+01	1.68E+01	9.53E+00	7.07E+00	1.23E+02	3.09E+01	1.17E+01	9.71E-01
f <sub>8</sub>	Mean Err.	2.13E+01 (≈)	2.12E+01 (−)	2.13E+01 (−)	2.13E+01 (+)	2.13E+01 (≈)	2.13E+01 (≈)	2.13E+01 (≈)	2.13E+01 (≈)	2.12E+01 (−)	2.13E+01 (≈)	2.13E+01
	Median	2.13E+01	2.12E+01	2.13E+01	2.13E+01	2.13E+01	2.13E+01	2.13E+01	2.13E+01	2.12E+01	2.13E+01	2.13E+01
	Std.	3.88E-02	7.78E-02	2.98E-02	2.42E-02	5.14E-02	3.76E-02	3.45E-02	3.06E-02	3.22E-02	2.72E-02	2.73E-02
f <sub>9</sub>	Mean Err.	1.11E+02 (+)	5.15E+01 (+)	1.61E+02 (−)	1.13E+02 (+)	1.35E+02 (+)	8.81E+01 (+)	8.38E+01 (+)	1.41E+02 (+)	1.16E+02 (+)	1.19E+02 (+)	4.34E+01
	Median	1.07E+02	5.00E+01	1.62E+02	1.10E+02	1.36E+02	8.81E+01	8.04E+01	1.40E+02	1.16E+02	1.19E+02	4.20E+01
	Std.	1.00E+01	4.88E+00	2.45E+00	1.29E+01	4.56E+00	6.30E+00	1.07E+01	3.26E+00	6.52E+00	6.17E+00	5.90E+00
f <sub>10</sub>	Mean Err.	4.14E-02 (−)	1.11E-01 (−)	3.21E+04 (+)	1.20E+00 (≈)	4.79E-02 (−)	5.33E-02 (−)	9.78E-01 (≈)	1.50E+01 (+)	2.57E+00 (+)	6.39E+01 (+)	1.02E+00
	Median	2.71E-02	9.85E-02	3.23E+04	1.25E+00	5.41E-02	5.42E-02	1.04E+00	1.49E+01	2.50E+00	5.81E+01	1.16E+00
	Std.	3.74E-02	8.70E-02	4.04E+03	9.36E-02	2.82E-02	3.13E-02	2.35E-01	2.42E+00	5.35E-01	3.04E+01	3.95E-01
f <sub>11</sub>	Mean Err.	3.82E-10 (−)	5.61E+01 (+)	3.61E+03 (+)	7.26E-01 (−)	2.35E+00 (−)	4.42E+02 (+)	4.80E+01 (+)	9.05E-02 (−)	1.07E+03 (+)	1.26E+01 (≈)	2.27E-01
	Median	1.82E-12	5.57E+01	3.58E+03	5.15E-03	1.14E-13	4.35E+02	4.68E+01	1.14E-13	1.11E+03	1.31E+01	1.43E+01
	Std.	7.73E-10	6.59E+00	3.15E+02	9.00E-01	3.62E+00	5.71E+01	1.22E+01	3.00E-01	1.57E+02	1.91E+00	1.53E+01
f <sub>12</sub>	Mean Err.	5.09E+02 (+)	1.58E+02 (+)	3.65E+03 (+)	3.77E+02 (+)	3.16E+02 (+)	3.84E+02 (+)	1.82E+02 (+)	1.50E+03 (+)	1.08E+03 (+)	3.19E+02 (+)	4.81E+01
	Median	4.94E+02	1.55E+02	3.63E+03	3.74E+02	3.17E+02	3.79E+02	1.87E+02	1.50E+03	1.11E+03	3.04E+02	5.07E+01
	Std.	6.45E+01	1.96E+01	2.84E+02	5.11E+01	5.05E+01	4.41E+01	3.63E+01	1.75E+02	1.23E+02	5.37E+01	9.19E+00
f <sub>13</sub>	Mean Err.	8.96E+02 (+)	3.89E+02 (+)	3.68E+03 (+)	6.29E+02 (+)	5.97E+02 (+)	8.03E+02 (+)	3.49E+02 (+)	1.74E+03 (+)	1.39E+03 (+)	5.60E+02 (+)	1.11E+02
	Median	9.21E+02	3.75E+02	3.65E+03	6.21E+02	5.89E+02	8.09E+02	3.52E+02	1.76E+03	1.29E+03	5.38E+02	1.10E+02
	Std.	1.12E+02	5.81E+01	3.16E+02	5.17E+01	6.55E+01	6.44E+01	4.11E+01	9.97E+01	2.02E+02	6.86E+01	2.34E+01
f <sub>14</sub>	Mean Err.	2.83E+00 (−)	2.70E+03 (+)	3.10E+04 (+)	9.32E+01 (−)	1.78E-01 (−)	9.81E+03 (+)	4.68E+02 (−)	1.89E+00 (−)	1.57E+04 (+)	5.63E+02 (−)	8.79E+02
	Median	2.58E+00	2.84E+03	3.11E+04	3.55E+01	1.81E-01	9.62E+03	4.72E+02	2.12E+00	1.53E+04	5.29E+02	7.84E+02
	Std.	1.38E+00	6.45E+02	5.18E+02	9.77E+01	2.02E-02	7.80E+02	2.08E+02	1.03E+00	2.30E+03	1.18E+02	3.13E+02
f <sub>15</sub>	Mean Err.	1.67E+04 (+)	8.05E+03 (+)	3.06E+04 (+)	1.52E+04 (+)	1.42E+04 (+)	1.12E+04 (+)	1.36E+04 (+)	1.59E+04 (+)	1.67E+04 (+)	1.80E+04 (+)	5.22E+03
	Median	1.58E+04	8.04E+03	3.05E+04	1.42E+04	1.43E+04	1.10E+04	1.40E+04	1.63E+04	1.57E+04	1.80E+04	5.47E+03
	Std.	4.92E+03	1.09E+03	4.81E+02	1.80E+03	6.20E+02	8.63E+02	1.63E+03	8.36E+02	3.35E+03	1.47E+03	1.22E+03
f <sub>16</sub>	Mean Err.	2.28E+00 (+)	4.35E-01 (≈)	3.99E+00 (+)	2.32E+00 (+)	2.06E+00 (+)	4.42E-02 (−)	2.73E+00 (+)	2.11E+00 (+)	3.11E+00 (+)	2.91E+00 (+)	4.55E-01
	Median	1.99E+00	4.54E-01	4.01E+00	2.27E+00	2.07E+00	4.21E-02	2.52E+00	2.16E+00	3.07E+00	2.90E+00	4.48E-01
	Std.	9.81E-01	9.52E-02	2.33E-01	2.96E-01	3.63E-01	9.00E-03	6.62E-01	2.45E-01	2.53E-01	3.11E-01	1.24E-01
f <sub>17</sub>	Mean Err.	1.04E+02 (−)	1.96E+02 (+)	6.79E+03 (+)	1.10E+02 (−)	1.02E+02 (−)	2.70E+02 (+)	1.74E+02 (+)	1.02E+02 (−)	1.32E+03 (+)	1.10E+02 (+)	1.24E+02
	Median	1.04E+02	1.94E+02	6.75E+03	1.10E+02	1.02E+02	2.74E+02	1.73E+02	1.02E+02	1.33E+03	1.50E+02	1.24E+02
	Std.	9.07E-01	1.09E+01	4.72E+02	1.47E+00	1.97E-01	2.39E+01	1.71E+01	9.11E-02	9.71E+01	8.94E+00	6.40E+00
f <sub>18</sub>	Mean Err.	6.29E+02 (+)	3.55E+02 (+)	6.87E+03 (+)	4.49E+02 (+)	4.44E+02 (+)	2.72E+02 (+)	4.36E+02 (+)	1.66E+03 (+)	1.34E+03 (+)	4.80E+02 (+)	1.66E+02
	Median	6.32E+02	3.52E+02	6.91E+03	4.16E+02	4.53E+02	2.78E+02	4.29E+02	1.63E+03	1.30E+03	4.70E+02	1.64E+02
	Std.	9.44E+01	3.65E+01	4.37E+02	5.40E+01	4.88E+01	1.70E+01	6.78E+01	1.26E+02	1.73E+02	6.88E+01	1.53E+01
f <sub>19</sub>	Mean Err.	5.79E+00 (−)	1.13E+01 (≈)	1.07E+07 (+)	9.09E+00 (≈)	1.22E+01 (+)	1.48E+01 (+)	1.19E+01 (+)	1.01E+00 (−)	7.54E+01 (+)	1.73E+01 (+)	1.00E+01
	Median	5.73E+00	1.11E+01	1.12E+07	8.91E+00	1.20E+01	1.42E+01	1.23E+01	1.05E+00	7.58E+01	1.75E+01	9.60E+00
	Std.	1.00E+00	1.46E+00	3.90E+06	1.30E+00	2.66E+00	2.65E+00	1.82E+00	2.27E-01	8.37E+00	2.11E+00	1.34E+00
f <sub>20</sub>	Mean Err.	4.99E+01 (≈)	5.00E+01 (≈)	5.00E+01 (+)	5.00E+01 (≈)	5.00E+01 (≈)	5.00E+01 (≈)	5.00E+01 (≈)	5.00E+01 (≈)	5.00E+01 (≈)	5.00E+01 (≈)	5.00E+01
	Median	5.00E+01	5.00E+01	5.00E+01	5.00E+01	5.00E+01	5.00E+01	5.00E+01	5.00E+01	5.00E+01	5.00E+01	5.00E+01
	Std.	2.00E-01	0.00E+00	2.13E-13	0.00E+00	5.42E-11	0.00E+00	0.00E+00	6.46E-07	0.00E+00	1.48E-01	0.00E+00
f <sub>21</sub>	Mean Err.	3.91E+02 (−)	4.00E+02 (≈)	1.42E+04 (+)	3.55E+02 (≈)	3.82E+02 (−)	3.82E+02 (−)	3.91E+02 (≈)	3.13E+02 (−)	4.27E+02 (+)	4.08E+02 (≈)	3.91E+02
	Median	4.00E+02	4.00E+02	1.43E+04	4.00E+02	4.00E+02	4.00E+02	4.00E+02	3.00E+02	4.27E+02	4.27E+02	4.00E+02
	Std.	3.02E+01	4.82E-13	9.65E+02	5.22E+01	4.05E+01	6.03E+01	3.02E+01	3.12E+01	7.83E-03	3.86E+01	3.02E+01
f <sub>22</sub>	Mean Err.	4.96E+01 (−)	3.03E+03 (+)	3.38E+04 (+)	1.55E+02 (−)	3.59E+01 (−)	1.43E+04 (+)	4.35E+02 (−)	1.84E+01 (−)	1.91E+04 (+)	1.25E+03 (≈)	1.18E+03
	Median	2.30E+01	2.99E+03	3.38E+04	1.37E+02	1.76E+01	1.42E+04	4.31E+0				

TABLE S-X  
COMPARISON RESULTS ON CEC 2013 ON 50-D

Func	D=50	TAPSO	DEPSO	AWPSO	HCLPSO	CJADE	LOTFWA	MAPSO	APABC	HGFOA	HPSO-DTA	PSO-HV
f <sub>1</sub>	Mean Err.	2.81E-13 (-)	2.27E-13(-)	7.61E+04 (+)	6.33E-13 (≈)	2.36E-13 (-)	2.18E-13 (-)	0.00E+00(-)	2.23E-13 (-)	1.65E-03 (+)	3.60E-12 (+)	6.33E-13
	Median	2.27E-13	2.27E-13	7.66E+04	6.82E-13	2.27E-13	2.27E-13	0.00E+00	2.27E-13	1.45E-03	1.59E-12	6.82E-13
	Std.	9.74E-14	3.22E-14	1.09E+04	1.46E-13	4.46E-14	4.46E-14	0.00E+00	3.18E-14	4.70E-04	4.31E-12	1.53E-13
f <sub>2</sub>	Mean Err.	3.46E+05 (-)	2.83E+06(-)	1.23E+09 (+)	1.41E+06 (-)	2.49E+04 (-)	1.93E+06 (-)	2.35E+06(-)	2.22E+07(+)	1.69E+06 (-)	1.98E+07 (+)	4.83E+06
	Median	2.86E+05	7.32E+05	1.21E+09	1.34E+06	2.02E+04	1.90E+06	2.11E+06	2.30E+07	1.75E+06	1.53E+07	4.65E+06
	Std.	1.77E+05	3.55E+06	3.94E+08	4.26E+05	1.85E+04	5.21E+05	9.34E+05	5.06E+06	5.24E+05	1.18E+07	1.92E+06
f <sub>3</sub>	Mean Err.	2.70E+08(+)	7.11E+07 (+)	5.25E+13 (+)	1.74E+08(+)	2.07E+07(+)	1.30E+08(+)	4.15E+07 (+)	5.12E+09(+)	3.77E+08 (+)	6.06E+08 (+)	1.19E+07
	Median	1.76E+08	3.72E+07	7.55E+12	1.33E+08	8.06E+06	1.05E+08	2.78E+07	4.95E+09	2.93E+08	4.24E+08	3.79E+06
	Std.	2.86E+08	9.56E+07	1.46E+14	1.64E+08	2.91E+07	9.69E+07	3.85E+07	2.48E+09	2.65E+08	5.40E+08	2.61E+07
f <sub>4</sub>	Mean Err.	5.69E+03 (-)	1.05E+05 (+)	1.11E+05 (+)	1.87E+03 (-)	8.33E+03 (-)	7.01E+02 (-)	2.81E+02(-)	1.68E+05(+)	1.54E+03 (-)	1.28E+04 (-)	4.02E+04
	Median	5.12E+03	1.06E+05	1.11E+05	1.85E+03	1.06E+03	6.75E+02	2.57E+02	1.70E+05	1.36E+03	1.11E+04	4.07E+04
	Std.	3.00E+03	1.47E+04	1.37E+04	7.28E+02	1.63E+04	2.56E+02	1.06E+02	1.49E+04	5.22E+02	4.19E+03	8.72E+03
f <sub>5</sub>	Mean Err.	3.23E-13 (-)	1.14E-13(-)	1.56E+04 (+)	8.16E-13 (-)	3.03E-13 (-)	3.46E-03(+)	1.39E-08 (+)	1.14E-13 (-)	5.48E-02 (+)	1.78E-11 (≈)	3.21E-11
	Median	3.41E-13	1.14E-13	1.55E+04	7.96E-13	3.41E-13	3.49E-03	1.14E-13	1.14E-13	5.74E-02	7.62E-12	1.28E-11
	Std.	7.67E-14	0.00E+00	4.25E+03	1.24E-13	6.30E-14	3.49E-04	7.81E-08	0.00E+00	1.00E-02	2.25E-11	5.93E-11
f <sub>6</sub>	Mean Err.	4.10E+01 (-)	4.41E+01(-)	8.01E+03 (+)	4.44E+01 (-)	4.39E+01 (-)	4.35E+01 (-)	4.42E+01(-)	4.45E+01 (-)	6.38E+01 (≈)	4.64E+01 (≈)	4.72E+01
	Median	4.34E+01	4.37E+01	8.03E+03	4.42E+01	4.34E+01	4.35E+01	4.35E+01	4.46E+01	4.91E+01	4.65E+01	4.62E+01
	Std.	1.23E+01	1.57E+00	1.66E+03	8.66E-01	1.54E+00	1.43E-03	1.25E+00	1.92E+00	2.48E+01	6.87E-01	7.32E+00
f <sub>7</sub>	Mean Err.	7.93E+01(+)	7.69E+00 (+)	3.24E+03 (+)	3.90E+01(+)	5.51E+01(+)	8.02E+01(+)	3.44E+01 (+)	1.47E+02(+)	8.71E+01 (+)	5.25E+01 (+)	9.50E-01
	Median	7.75E+01	7.00E+00	2.30E+03	3.93E+01	5.69E+01	8.05E+01	3.39E+01	1.46E+02	9.11E+01	5.51E+01	7.71E-01
	Std.	1.44E+01	4.17E+00	3.07E+03	1.04E+01	1.39E+01	1.00E+01	7.26E+00	1.68E+01	2.19E+01	8.49E+00	5.11E-01
f <sub>8</sub>	Mean Err.	2.11E+01 (≈)	2.11E+01(≈)	2.11E+01(-)	2.11E+01(+)	2.11E+01 (≈)	2.11E+01 (-)	2.11E+01 (+)	2.11E+01(+)	2.11E+01 (≈)	2.11E+01 (≈)	2.11E+01
	Median	2.11E+01	2.11E+01	2.11E+01	2.11E+01	2.11E+01	2.11E+01	2.11E+01	2.11E+01	2.11E+01	2.11E+01	2.11E+01
	Std.	6.49E-02	4.01E-02	3.08E-02	3.31E-02	7.33E-02	5.57E-02	3.21E-02	3.66E-02	2.64E-02	2.22E-02	4.61E-02
f <sub>9</sub>	Mean Err.	4.08E+01(+)	2.16E+01 (+)	7.26E+01(-)	4.04E+01(+)	5.68E+01(+)	2.98E+01(+)	3.53E+01 (+)	5.82E+01(+)	4.63E+01 (+)	4.56E+01 (+)	1.40E+01
	Median	4.13E+01	2.17E+01	7.30E+01	3.89E+01	5.70E+01	2.96E+01	3.44E+01	5.87E+01	4.41E+01	4.58E+01	1.35E+01
	Std.	5.11E+00	3.23E+00	1.49E+00	7.35E+00	2.44E+00	4.52E+00	7.25E+00	3.22E+00	4.67E+00	5.32E+00	2.88E+00
f <sub>10</sub>	Mean Err.	7.15E-02 (-)	1.77E-01(-)	1.00E+04 (+)	2.33E-01 (≈)	4.02E-02 (-)	4.53E-02 (-)	6.93E-02(-)	6.01E+00(+)	1.16E+00 (+)	6.77E+00 (+)	2.75E-01
	Median	5.42E-02	1.40E-01	9.99E+03	2.07E-01	3.20E-02	3.70E-02	6.58E-02	5.88E+00	1.13E+00	4.21E+00	2.17E-01
	Std.	5.33E-02	1.15E-01	1.96E+03	1.36E-01	2.98E-02	2.94E-02	3.73E-02	1.35E+00	5.30E-02	5.04E+00	2.27E-01
f <sub>11</sub>	Mean Err.	2.57E-13 (-)	2.25E+01 (+)	1.27E+03 (+)	2.73E-13 (-)	1.95E-02 (-)	1.27E+02(+)	2.48E+01 (+)	5.46E-14 (-)	3.00E+02 (+)	2.37E+00 (-)	7.67E+00
	Median	1.14E-13	2.23E+01	1.31E+03	2.84E-13	0.00E+00	1.29E+02	2.39E+01	5.68E-14	2.99E+02	2.03E+00	6.98E+00
	Std.	3.93E-13	4.31E+00	1.53E+02	8.43E-14	1.39E-01	1.98E+01	6.58E+00	1.11E-14	3.51E+01	1.43E+00	4.25E+00
f <sub>12</sub>	Mean Err.	1.74E+02(+)	5.27E+01 (+)	1.23E+03 (+)	1.27E+02(+)	8.11E+01(+)	1.45E+02(+)	7.40E+01 (+)	4.49E+02(+)	3.05E+02 (+)	1.09E+02 (+)	1.70E+01
	Median	1.72E+02	5.27E+01	1.21E+03	1.28E+02	8.02E+01	1.43E+02	7.26E+01	4.55E+02	2.99E+02	1.07E+02	1.69E+01
	Std.	3.55E+01	1.04E+01	1.28E+02	2.49E+01	1.52E+01	2.35E+01	1.82E+01	6.78E+01	5.56E+01	2.38E+01	4.89E+00
f <sub>13</sub>	Mean Err.	3.29E+02(+)	1.39E+02 (+)	1.29E+03 (+)	2.43E+02(+)	1.89E+02(+)	2.82E+02(+)	1.54E+02 (+)	5.70E+02(+)	4.32E+02 (+)	2.36E+02 (+)	4.09E+01
	Median	3.29E+02	1.34E+02	1.28E+03	2.37E+02	1.88E+02	2.76E+02	1.46E+02	5.75E+02	4.28E+02	2.45E+02	3.63E+01
	Std.	5.71E+01	2.76E+01	1.31E+02	4.67E+01	3.17E+01	3.66E+01	4.22E+01	7.40E+01	3.83E+01	2.37E+01	2.13E+01
f <sub>14</sub>	Mean Err.	7.97E-01 (-)	1.09E+03 (+)	1.38E+04 (+)	2.66E+01 (-)	1.49E-01 (-)	4.33E+03(+)	2.46E+02(≈)	1.07E+00 (-)	9.16E+03 (+)	1.69E+02 (-)	3.14E+02
	Median	8.45E-01	1.03E+03	1.39E+04	3.26E+00	1.37E-01	4.40E+03	1.94E+02	8.08E-01	9.89E+03	1.48E+02	2.85E+02
	Std.	6.87E-01	3.37E+02	3.59E+02	5.82E+01	1.04E-01	4.15E+02	1.86E+02	9.37E-01	1.76E+03	7.21E+01	1.61E+02
f <sub>15</sub>	Mean Err.	7.63E+03(+)	4.61E+03 (+)	1.43E+04 (+)	7.07E+03(+)	6.66E+03(+)	5.48E+03(+)	7.07E+03 (+)	7.89E+03(+)	9.98E+03 (+)	8.08E+03 (+)	2.19E+03
	Median	7.71E+03	4.51E+03	1.44E+04	6.93E+03	6.75E+03	5.50E+03	7.00E+03	7.91E+03	1.03E+04	8.14E+03	2.01E+03
	Std.	1.34E+03	7.72E+02	4.03E+02	8.07E+02	4.42E+02	5.13E+02	8.47E+02	5.73E+02	1.40E+03	7.63E+02	7.21E+02
f <sub>16</sub>	Mean Err.	1.76E+00(+)	3.61E-01(-)	3.40E+00 (+)	1.66E+00(+)	1.56E+00(+)	5.55E-02 (-)	2.02E+00 (+)	1.67E+00(+)	2.61E+00 (+)	2.58E+00 (+)	4.52E-01
	Median	1.51E+00	3.44E-01	3.43E+00	1.64E+00	1.40E+00	5.58E-02	1.94E+00	1.63E+00	2.57E+00	2.54E+00	4.12E-01
	Std.	9.88E-01	1.26E-01	3.07E-01	3.07E-01	5.66E-01	1.65E-02	5.65E-01	2.80E-01	3.02E-01	2.82E-01	1.67E-01
f <sub>17</sub>	Mean Err.	5.15E+01 (-)	8.67E+01 (+)	2.49E+03 (+)	5.12E+01 (-)	5.08E+01 (-)	1.13E+02(+)	8.72E+01 (+)	5.08E+01 (-)	4.92E+02 (+)	5.64E+01 (≈)	5.88E+01
	Median	5.14E+01	8.53E+01	2.41E+03	5.12E+01	5.08E+01	1.11E+02	8.43E+01	5.08E+01	4.83E+02	6.47E+01	5.86E+01
	Std.	2.85E-01	6.88E+00	3.01E+02	2.31E-01	3.60E-14	1.38E+01	1.27E+01	4.15E-02	7.24E+01	2.03E+01	1.87E+00
f <sub>18</sub>	Mean Err.	1.99E+02(+)	1.27E+02 (+)	2.44E+03 (+)	1.67E+02(+)	1.36E+02(+)	1.16E+02(+)	1.52E+02 (+)	5.10E+02(+)	4.74E+02 (+)	1.59E+02 (+)	8.97E+01
	Median	1.81E+02	1.26E+02	2.45E+03	1.69E+02	1.37E+02	1.17E+02	1.38E+02	5.12E+02	4.66E+02	1.55E+02	8.82E+01
	Std.	7.29E+01	1.59E+01	2.48E+02	2.71E+01	1.09E+01	1.19E+01	4.36E+01	4.82E+01	3.02E+01	3.85E+01	1.01E+01
f <sub>19</sub>	Mean Err.	2.41E+00 (-)	6.09E+00 (+)	1.26E+06 (+)	1.72E+00 (-)	2.93E+00 (-)	6.03E+00(+)	5.48E+00(≈)	4.15E-01 (-)	2.76E+01 (+)	6.09E+00 (≈)	5.15E+00
	Median	2.32E+00	5.96E+00	1.13E+06	1.66E+00	2.90E+00	6.21E+00	5.44E+00	4.02E-01	2.64E+01	5.97E+00	5.05E+00
	Std.	5.20E-01	7.83E-01	7.61E+05	4.12E-01	4.71E-01	1.09E+00	1.19E+00	1.16E-01	3.15E+00	7.02E-01	6.47E-01
f <sub>20</sub>	Mean Err.	2.13E+01 (-)	2.11E+01(-)	2.49E+01 (+)	1.99E+01 (-)	1.99E+01 (-)	2.33E+01(+)	1.90E+01(-)	2.37E+01(+)	2.15E+01 (-)	2.06E+01 (-)	2.28E+01
	Median	2.10E+01	2.12E+01	2.49E+01	2.00E+01	1.99E+01	2.34E+01	1.90E+01	2.40E+01	2.14E+01	2.04E+01	2.29E+01
	Std.	1.59E+00	1.09E+00	1.16E-01	9.67E-01	7.93E-01	9.71E-01	8.85E-01	8.24E-01	6.51E-01	6.42E-01	8.04E-01
f <sub>21</sub>	Mean Err.	8.96E+02 (≈)	9.70E+02(≈)	6.17E+03 (+)	2.64E+02 (-)	7.88E+02 (≈)	2.00E+02 (-)	9.90E+02 (+)	2.51E+02 (-)	7.99E+02 (≈)	2.01E+02 (-)	8.72E+02
	Median	8.36E+02	1.12E+03	6.18E+03	2.11E+02	1.12E+03	2.00E+02	1.12E+03	2.02E+02	8.36E+02	2.00E+02	8.36E+02
	Std.	2.90E+02	1.80E+02	3.73E+02	1.49E+02	4.14E+02	1.45E-13	2.37E+02	1.44E+02	3.22E+02	2.16E+00	3.02E+02
f <sub>22</sub>	Mean Err.	4.02E+01 (-)	1.10E+03 (+)	1.53E+04 (+)	3.94E+01 (-)	1.19E+01 (-)	6.04E+03(+)	3.10E+02 (+)	8.15E+00 (-)	1.01E+04 (+)	3.73E+02 (+)	2.11E+02
	Median	1.17E+01	1.04E+03	1.53E+04	2.33E+01	1.19E+01	6.05E+03	3.00E+02	8.44E+00	1.04E+04	3.40E+02	1.91E+02
	Std.	6.90.										



TABLE S-XI  
COMPARISON RESULTS ON CEC 2013 ON 30-D

Func	D=30	TAPSO	DEPSO	AWPSO	HCLPSO	CJADE	LOTFWA	MAPSO	APABC	HGFOA	HPSO-DTA	PSO-HV
$f_1$	Mean Err.	1.11E-13 (−)	0.00E+00 (−)	3.95E+04 (+)	2.76E-13 (≈)	1.78E-14 (−)	6.24E-14 (−)	0.00E+00 (−)	0.00E+00 (−)	3.68E-04 (+)	3.31E-13 (≈)	3.03E-13
	Median	0.00E+00	0.00E+00	3.91E+04	2.27E-13	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.76E-04	2.27E-13	2.27E-13
	Std.	1.15E-13	1.07E-13	7.26E+03	9.44E-14	6.17E-14	1.02E-13	0.00E+00	0.00E+00	1.53E-04	1.56E-13	1.08E-13
$f_2$	Mean Err.	1.59E+05 (−)	1.36E+06 (−)	4.25E+08 (+)	3.19E+05 (−)	5.69E+03 (−)	1.23E+06 (−)	1.54E+06 (−)	1.50E+07 (+)	4.27E+05 (−)	1.10E+07 (+)	3.50E+06
	Median	1.19E+05	6.17E+05	3.62E+08	2.95E+05	4.26E+03	1.19E+06	1.29E+06	1.50E+07	3.70E+05	8.88E+06	3.55E+06
	Std.	1.33E+05	1.51E+06	1.64E+08	1.40E+05	4.33E+03	4.87E+05	1.11E+06	3.18E+06	2.08E+05	7.13E+06	1.16E+06
$f_3$	Mean Err.	2.06E+08 (+)	3.01E+07 (+)	1.18E+15 (+)	3.09E+07 (+)	1.02E+06 (−)	2.31E+07 (+)	1.34E+07 (+)	9.39E+08 (+)	7.47E+07 (+)	7.45E+07 (+)	3.09E+06
	Median	4.49E+07	3.82E+06	1.28E+14	1.07E+07	2.62E+04	1.34E+07	8.73E+06	8.77E+08	4.85E+07	6.92E+07	1.70E+06
	Std.	4.45E+08	8.65E+07	2.79E+15	6.64E+07	1.95E+06	2.50E+07	1.78E+07	5.61E+08	6.73E+07	5.09E+07	3.95E+06
$f_4$	Mean Err.	6.28E+03 (−)	6.57E+04 (+)	6.33E+04 (+)	5.77E+02 (−)	2.74E+03 (−)	1.95E+03 (−)	2.57E+02 (−)	1.03E+05 (+)	9.41E+02 (−)	6.29E+03 (−)	2.95E+04
	Median	5.41E+03	6.51E+04	6.24E+04	5.23E+02	4.59E-04	1.80E+03	2.05E+02	1.05E+05	8.50E+02	5.78E+03	2.94E+04
	Std.	4.00E+03	1.29E+04	1.07E+04	3.29E+02	8.61E+03	7.83E+02	1.63E+02	1.22E+04	5.12E+02	2.13E+03	7.48E+03
$f_5$	Mean Err.	1.45E-13 (−)	1.14E-13 (−)	9.41E+03 (+)	3.37E-13 (−)	1.23E-13 (−)	3.41E-03 (+)	1.18E-09 (+)	1.05E-13 (−)	1.69E-02 (+)	1.05E-12 (+)	6.58E-13
	Median	1.14E-13	1.14E-13	9.17E+03	3.41E-13	1.14E-13	3.32E-03	0.00E+00	1.14E-13	1.64E-02	1.02E-12	5.68E-13
	Std.	5.61E-14	4.82E-14	3.51E+03	7.18E-14	3.83E-14	5.20E-04	8.42E-09	3.09E-14	4.12E-03	4.91E-13	2.77E-13
$f_6$	Mean Err.	0.08E+00 (−)	4.60E+01 (≈)	5.82E+03 (+)	1.42E+01 (−)	4.95E+00 (−)	1.31E+01 (−)	1.95E+01 (−)	1.75E+01 (−)	4.22E+01 (≈)	3.31E+01 (≈)	4.28E+01
	Median	3.92E+00	4.49E+01	5.99E+03	1.39E+01	3.30E-12	1.48E+01	1.79E+01	1.79E+01	2.65E+01	2.67E+01	3.92E+01
	Std.	1.24E+01	2.72E+01	1.80E+03	1.42E+00	1.53E+01	4.68E+00	3.58E+00	3.71E+00	2.89E+01	1.78E+01	2.73E+01
$f_7$	Mean Err.	7.66E+01 (+)	4.60E+00 (+)	2.83E+04 (+)	1.62E+01 (+)	2.28E+01 (+)	5.03E+01 (+)	2.21E+01 (+)	1.14E+02 (+)	5.54E+01 (+)	2.44E+01 (+)	4.40E-01
	Median	6.90E+01	2.66E+00	6.71E+03	1.55E+01	1.83E+01	4.93E+01	2.20E+01	1.14E+02	4.95E+01	2.36E+01	4.30E-01
	Std.	3.14E+01	5.14E+00	6.40E+04	7.45E+00	1.33E+01	1.28E+01	5.51E+00	2.04E+01	2.05E+01	5.80E+00	2.29E-01
$f_8$	Mean Err.	2.09E+01 (−)	2.10E+01 (+)	2.10E+01 (−)	2.09E+01 (≈)	2.09E+01 (≈)	2.08E+01 (−)	2.10E+01 (≈)	2.09E+01 (≈)	2.09E+01 (−)	2.09E+01 (−)	2.09E+01
	Median	2.09E+01	2.10E+01	2.10E+01	2.09E+01	2.09E+01	2.08E+01	2.10E+01	2.10E+01	2.09E+01	2.09E+01	2.10E+01
	Std.	7.87E-02	4.65E-02	4.13E-02	4.87E-02	7.10E-02	7.34E-02	5.02E-02	5.26E-02	3.26E-02	6.91E-02	6.52E-02
$f_9$	Mean Err.	2.09E+01 (+)	1.21E+01 (+)	3.96E+01 (−)	1.79E+01 (+)	2.78E+01 (+)	1.44E+01 (+)	1.71E+01 (+)	3.03E+01 (+)	2.48E+01 (+)	2.26E+01 (+)	8.09E+00
	Median	2.08E+01	1.21E+01	3.97E+01	1.76E+01	2.79E+01	1.44E+01	1.67E+01	3.06E+01	2.51E+01	2.41E+01	7.91E+00
	Std.	3.71E+00	2.34E+00	1.36E+00	4.01E+00	2.01E+00	2.14E+00	4.01E+00	2.34E+00	5.57E+00	2.97E+00	1.84E+00
$f_{10}$	Mean Err.	8.99E-02 (−)	2.05E-01 (≈)	5.15E+03 (+)	1.82E-01 (−)	5.37E-02 (−)	4.95E-02 (−)	6.75E-02 (−)	2.82E+00 (+)	9.11E-01 (+)	1.25E+00 (+)	2.44E-01
	Median	7.39E-02	1.77E-01	4.92E+03	1.70E-01	4.67E-02	4.44E-02	5.67E-02	2.79E+00	9.08E-01	1.28E+00	2.14E-01
	Std.	6.04E-02	1.17E-01	1.28E+03	7.66E-02	3.49E-02	2.84E-02	4.32E-02	8.26E-01	1.17E-01	3.90E-01	1.43E-01
$f_{11}$	Mean Err.	1.00E-13 (−)	1.23E+01 (+)	6.89E+02 (+)	1.00E-13 (−)	0.00E+00 (−)	6.15E+01 (+)	1.49E+01 (+)	0.00E+00 (−)	1.20E+02 (+)	2.82E-01 (−)	3.22E+00
	Median	5.68E-14	1.20E+01	7.02E+02	1.14E-13	0.00E+00	6.37E+01	1.49E+01	0.00E+00	1.25E+02	1.70E-03	2.29E+00
	Std.	1.93E-13	3.36E+00	9.52E+01	2.69E-14	0.00E+00	1.33E+01	5.64E+00	0.00E+00	2.63E+01	4.59E-01	2.74E+00
$f_{12}$	Mean Err.	7.34E+01 (+)	2.74E+01 (+)	6.85E+02 (+)	4.90E+01 (+)	2.67E+01 (+)	7.22E+01 (+)	4.05E+01 (+)	1.57E+02 (+)	1.08E+02 (+)	5.03E+01 (+)	7.61E+00
	Median	7.06E+01	2.79E+01	6.90E+02	4.68E+01	2.50E+01	7.26E+01	3.69E+01	1.56E+02	1.08E+02	5.33E+01	7.00E+00
	Std.	2.03E+01	7.49E+00	8.30E+01	1.54E+01	7.28E+00	1.19E+01	1.21E+01	2.80E+01	3.01E+01	9.65E+00	3.11E+00
$f_{13}$	Mean Err.	1.50E+02 (+)	5.90E+01 (+)	6.91E+02 (+)	1.20E+02 (+)	6.29E+01 (+)	1.35E+02 (+)	8.69E+01 (+)	2.28E+02 (+)	1.76E+02 (+)	1.08E+02 (+)	1.36E+01
	Median	1.51E+02	5.82E+01	6.72E+02	1.19E+02	6.38E+01	1.40E+02	7.98E+01	2.28E+02	1.68E+02	1.06E+02	1.17E+01
	Std.	2.70E+01	2.07E+01	1.02E+02	2.82E+01	1.57E+01	2.51E+01	3.15E+01	2.31E+01	5.14E+01	2.54E+01	9.51E+00
$f_{14}$	Mean Err.	4.05E-01 (−)	7.82E+02 (+)	7.38E+03 (+)	8.65E+00 (−)	9.27E-02 (−)	2.41E+03 (+)	2.35E+02 (≈)	3.87E-01 (−)	5.15E+03 (+)	5.77E+01 (−)	2.85E+02
	Median	2.29E-01	8.14E+02	7.44E+03	1.18E+00	8.33E-02	2.42E+03	1.98E+02	1.04E-01	5.22E+03	5.53E+01	2.70E+02
	Std.	4.22E-01	2.64E+02	3.59E+02	2.88E+01	3.49E-02	3.29E+02	1.46E+02	7.06E-01	5.33E+02	2.33E+01	1.47E+02
$f_{15}$	Mean Err.	3.68E+03 (+)	2.09E+03 (+)	7.36E+03 (+)	3.32E+03 (+)	3.09E+03 (+)	2.63E+03 (+)	3.37E+03 (+)	3.85E+03 (+)	4.97E+03 (+)	3.85E+03 (+)	1.02E+03
	Median	3.75E+03	2.21E+03	7.41E+03	3.35E+03	3.10E+03	2.66E+03	3.29E+03	3.86E+03	5.14E+03	3.83E+03	9.87E+02
	Std.	6.24E+02	4.98E+02	3.10E+02	4.79E+02	3.16E+02	2.54E+02	6.48E+02	4.94E+02	7.04E+02	6.93E+02	3.09E+02
$f_{16}$	Mean Err.	1.39E+00 (+)	2.97E-01 (−)	2.56E+00 (+)	1.05E+00 (+)	1.41E+00 (+)	5.85E-02 (−)	1.36E+00 (+)	1.27E+00 (+)	1.41E+00 (+)	1.30E+00 (+)	4.45E-01
	Median	1.23E+00	2.59E-01	2.57E+00	1.07E+00	1.17E+00	5.55E-02	1.36E+00	1.28E+00	1.47E+00	1.86E+00	4.24E-01
	Std.	7.70E-01	1.26E-01	2.38E-01	2.61E-01	7.08E-01	1.74E-02	3.66E-01	2.37E-01	5.12E-01	4.68E-01	1.95E-01
$f_{17}$	Mean Err.	3.10E+01 (−)	4.80E+01 (+)	1.08E+03 (+)	3.05E+01 (−)	3.04E+01 (−)	6.36E+01 (+)	5.34E+01 (+)	3.05E+01 (−)	2.03E+02 (+)	1.19E+01 (−)	3.44E+01
	Median	3.09E+01	4.73E+01	1.10E+03	3.05E+01	3.04E+01	6.37E+01	5.15E+01	3.04E+01	1.87E+02	8.56E+00	3.45E+01
	Std.	3.36E-01	4.84E+00	1.44E+02	9.68E-02	3.24E-14	8.73E+00	7.73E+00	7.85E-02	3.63E+01	9.15E+00	1.19E+00
$f_{18}$	Mean Err.	1.03E+02 (+)	6.12E+01 (+)	1.10E+03 (+)	8.50E+01 (+)	6.39E+01 (+)	6.18E+01 (+)	7.73E+01 (+)	2.07E+02 (+)	2.27E+02 (+)	7.69E+01 (+)	5.80E+01
	Median	8.44E+01	6.03E+01	1.11E+03	8.03E+01	6.43E+01	6.24E+01	7.24E+01	2.07E+02	2.22E+02	7.70E+01	5.69E+01
	Std.	4.52E+01	8.21E+00	1.21E+02	2.13E+01	7.52E+00	8.88E+00	1.93E+01	2.41E+01	2.83E+01	2.27E+01	8.79E+00
$f_{19}$	Mean Err.	1.34E+00 (−)	3.91E+00 (+)	3.33E+05 (+)	1.19E+00 (−)	1.22E+00 (−)	3.32E+00 (≈)	3.07E+00 (≈)	1.99E-01 (−)	1.19E+01 (+)	2.97E+00 (≈)	3.10E+00
	Median	1.31E+00	3.95E+00	2.80E+05	1.18E+00	1.19E+00	3.39E+00	3.10E+00	1.97E-01	1.15E+01	2.91E+00	3.14E+00
	Std.	3.27E-01	6.36E-01	2.52E+05	1.49E-01	1.81E-01	7.79E-01	8.01E-01	5.33E-02	2.68E+00	6.61E-01	4.07E-01
$f_{20}$	Mean Err.	1.20E+01 (−)	1.46E+01 (+)	1.50E+01 (+)	1.06E+01 (−)	1.07E+01 (−)	1.36E+01 (≈)	1.07E+01 (−)	1.27E+01 (−)	1.23E+01 (−)	1.13E+01 (−)	1.35E+01
	Median	1.18E+01	1.50E+01	1.50E+01	1.05E+01	1.07E+01	1.37E+01	1.08E+01	1.28E+01	1.23E+01	1.11E+01	1.34E+01
	Std.	1.11E+00	1.09E+00	4.68E-02	6.89E-01	7.17E-01	8.01E-01	6.79E-01	6.15E-01	5.73E-01	4.70E-01	9.48E-01
$f_{21}$	Mean Err.	3.48E+02 (≈)	3.36E+02 (+)	2.89E+03 (+)	2.14E+02 (−)	3.17E+02 (≈)	2.00E+02 (−)	3.12E+02 (≈)	2.27E+02 (−)	3.30E+02 (≈)	2.51E+02 (≈)	3.17E+02
	Median	3.00E+02	3.00E+02	2.85E+03	2.02E+02	3.00E+02	2.00E+02	3.00E+02	2.08E+02	3.00E+02	2.40E+02	3.00E+02
	Std.	8.07E+01	7.37E+01	2.36E+02	3.00E+01	6.48E+01	6.67E-02	5.95E+01	3.56E+01	7.86E+01	4.90E+01	7.50E+01
$f_{22}$	Mean Err.	1.09E+02 (−)	5.36E+02 (+)	8.06E+03 (+)	8.93E+01 (−)	8.21E+01 (−)	2.98E+03 (+)	2.99E+02 (+)	1.97E+01 (−)	5.07E+03 (+)	2.28E+02 (≈)	2.11E+02
	Median	1.08E+02	4.50E+02	8.09E+03	1.11E+02	1.06E+02	3.02E+03	2.84E+02	9.95E+00	5.32E+03	1.98E+02	1.84E+02
	Std.	3.61E+01	2.73E+02	3.35E+02	4.10E+01	4.10E+01	3.92E+02	1.42E+02	2.61E+01	6.85E+02	6.02E+01	7.34E+01
$f_{23}$	Mean Err.	4.22E+03 (+)	3.55E+03 (+)	8.25E+03 (+)	3.63E+03 (+)	3.26E+03 (+)	3.09E+03 (+)	3.60E+03 (+)	4.91E+03 (+)	4.87E+03 (+)	3.76E+03 (+)	1.29E+03
	Median	3.96E+03	3.54E+03	8.27E+03	3.71E+03	3.31E+03	3.07E+03	3.68E+03	4.91E+03	4.84E+03	3.71E+03	1.15E+03
	Std.	9.60E+02	8.60E+02	3.33E+02	6.44E+02	5.06E+02	3.53E+02	6.09E+02	6.02E+02	8.78E+02	1.15E+03	7.05E+02
$f_{24}$	Mean Err.	2.63E+02 (+)	2.11E+02 (+)	3.91E+02 (+)	2.26E+02 (+)	2.40E+02 (+)	2.39E+02 (+)	2.32E+02 (+)	2.85E+02 (+)	2.56E+02 (+)	2.56E+02 (+)	2.01E+02

TABLE S-XII  
COMPARISON RESULTS FOR PSO-HV, DE-HL AND TOP-RANK ALGORITHMS ON CEC 2017 ON 50-D.

Func		EBOwithCMAR	JSO	RB-IPOP-CMA-ES	LSHADE	PPSO	TLBO-FL	DYYPO	MOS-SOCO	PSO-HV	DE-HL
$g_1$	Mean Err.	0.00E+00 ( $\approx$ )	0.00E+00( $\approx$ )	1.13E-07 (+)	0.00E+00( $\approx$ )	3.89E+02(+)	6.06E+05(+)	6.57E+03(+)	1.49E+04(+)	2.67E+03(+)	0.00E+00
	Std.	0.00E+00	0.00E+00	4.26E-08	0.00E+00	2.95E+02	2.21E+06	7.09E+03	1.23E+04	3.66E+03	0.00E+00
$g_3$	Mean Err.	0.00E+00 ( $\approx$ )	0.00E+00( $\approx$ )	0.00E+00 ( $\approx$ )	0.00E+00( $\approx$ )	8.65E+02(+)	2.57E+04(+)	4.67E+01(+)	3.36E+04(+)	6.24E+04(+)	0.00E+00
	Std.	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.86E+02	4.88E+03	2.30E+02	1.71E+04	1.36E+04	0.00E+00
$g_4$	Mean Err.	4.29E+01 (-)	5.62E+01( $\approx$ )	2.96E+01 (-)	8.18E+01(+)	9.13E+01(+)	1.90E+02(+)	1.37E+02(+)	2.81E+01(-)	1.72E+02(+)	5.58E+01
	Std.	3.32E+01	4.88E+01	4.07E+01	4.84E+01	3.61E+01	4.58E+01	4.97E+01	2.63E+01	4.11E+01	4.96E+01
$g_5$	Mean Err.	7.58E+00 (-)	1.64E+01(-)	2.79E+00 (-)	1.22E+01(-)	2.01E+02(+)	9.67E+01(+)	1.95E+02(+)	1.34E+02(+)	1.83E+01(+)	2.44E+01
	Std.	2.42E+00	3.46E+00	1.44E+00	2.05E+00	1.37E+01	1.73E+01	3.95E+01	2.07E+01	4.78E+00	3.35E+00
$g_6$	Mean Err.	8.54E-08 (-)	1.09E-06(-)	1.63E-07 (-)	5.69E-05( $\approx$ )	3.18E+01(+)	4.51E+00(+)	3.84E+00(+)	0.00E+00(-)	7.17E-05(+)	2.67E-05
	Std.	1.14E-07	2.63E-06	1.38E-07	3.71E-04	3.91E+00	1.70E+00	2.03E+00	0.00E+00	1.41E-04	2.44E-05
$g_7$	Mean Err.	5.79E+01 (-)	6.65E+01(-)	5.66E+01 (-)	6.32E+01(-)	2.78E+02(+)	1.74E+02(+)	2.61E+02(+)	1.81E+02(+)	6.48E+01( $\approx$ )	7.47E+01
	Std.	1.53E+00	3.47E+00	1.39E+00	1.71E+00	3.42E+01	4.38E+01	4.27E+01	2.26E+01	3.31E+00	3.72E+00
$g_8$	Mean Err.	7.91E+00 (-)	1.70E+01(-)	2.58E+00 (-)	1.20E+01(-)	1.99E+02(+)	9.33E+01(+)	1.90E+02(+)	1.38E+02(+)	1.77E+01(-)	3.04E+01
	Std.	2.47E+00	3.14E+00	1.79E+00	2.28E+00	1.52E+01	1.58E+01	4.70E+01	2.46E+01	4.97E+00	6.55E+00
$g_9$	Mean Err.	0.00E+00 ( $\approx$ )	0.00E+00( $\approx$ )	0.00E+00 ( $\approx$ )	0.00E+00( $\approx$ )	6.06E+03(+)	1.30E+03(+)	3.51E+03(+)	1.21E+03(+)	1.50E+00(+)	0.00E+00
	Std.	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.28E+02	1.05E+03	1.86E+03	5.08E+02	5.78E+00	0.00E+00
$g_{10}$	Mean Err.	3.11E+03 (-)	3.14E+03(-)	1.73E+03 (-)	3.18E+03(-)	5.20E+03(+)	1.27E+04(+)	4.80E+03(+)	4.73E+03(+)	9.68E+02(-)	3.37E+03
	Std.	4.01E+02	3.67E+02	9.53E+02	2.55E+02	5.51E+02	3.97E+02	6.41E+02	7.01E+02	4.26E+02	3.94E+02
$g_{11}$	Mean Err.	2.64E+01 ( $\approx$ )	2.79E+01(+)	1.83E+02 (+)	4.86E+01(+)	1.27E+02(+)	1.69E+02(+)	1.90E+02(+)	1.95E+02(+)	2.36E+02(+)	2.24E+01
	Std.	3.36E+00	3.33E+00	5.20E+01	7.92E+00	1.45E+01	4.79E+01	5.19E+01	6.05E+01	1.39E+02	1.58E+00
$g_{12}$	Mean Err.	1.94E+03 (+)	1.68E+03(+)	2.44E+06 (+)	2.17E+03(+)	5.52E+05(+)	9.16E+05(+)	7.75E+06(+)	1.45E+05(+)	1.38E+06(+)	6.66E+02
	Std.	8.34E+02	5.23E+02	1.74E+07	4.52E+02	2.03E+05	8.94E+05	5.08E+06	8.95E+04	6.97E+05	2.12E+02
$g_{13}$	Mean Err.	4.14E+01 ( $\approx$ )	3.06E+01( $\approx$ )	1.65E+03 (+)	6.27E+01(+)	8.47E+02(+)	8.01E+03(+)	7.55E+03(+)	1.09E+04(+)	1.43E+03(+)	2.94E+01
	Std.	2.48E+01	2.12E+01	1.15E+03	2.83E+01	5.63E+02	5.14E+03	7.38E+03	1.26E+04	1.61E+03	2.42E+01
$g_{14}$	Mean Err.	3.12E+01 ( $\approx$ )	2.50E+01( $\approx$ )	2.42E+02 (+)	2.91E+01( $\approx$ )	1.95E+04(+)	8.63E+04(+)	2.89E+04(+)	3.78E+04(+)	4.75E+04(+)	2.57E+01
	Std.	3.52E+00	1.87E+00	7.07E+01	2.92E+00	1.00E+04	4.96E+04	2.75E+04	3.23E+04	2.81E+04	9.04E-01
$g_{15}$	Mean Err.	2.94E+01 (+)	2.39E+01( $\approx$ )	5.29E+02 (+)	4.08E+01(+)	1.19E+03(+)	6.88E+03(+)	8.24E+03(+)	1.22E+04(+)	3.45E+03(+)	1.99E+01
	Std.	5.20E+00	2.49E+00	1.15E+02	9.92E+00	7.80E+02	5.91E+03	7.00E+03	7.87E+03	3.00E+03	1.09E+00
$g_{16}$	Mean Err.	3.46E+02 (-)	4.51E+02(+)	8.90E+02 (+)	3.77E+02(-)	1.24E+03(+)	8.47E+02(+)	1.31E+03(+)	1.40E+03(+)	2.87E+02(-)	4.31E+02
	Std.	1.46E+02	1.38E+02	3.66E+02	1.18E+02	2.28E+02	3.05E+02	4.08E+02	2.55E+02	1.51E+02	8.76E+01
$g_{17}$	Mean Err.	2.75E+02 (-)	2.83E+02(-)	3.98E+02 (+)	2.55E+02(-)	1.03E+03(+)	8.53E+02(+)	8.88E+02(+)	9.49E+02(+)	2.23E+02(+)	3.22E+02
	Std.	8.63E+01	8.61E+01	1.58E+02	7.46E+01	1.54E+02	4.12E+02	2.65E+02	2.18E+02	1.36E+02	1.02E+02
$g_{18}$	Mean Err.	3.20E+01 (+)	2.43E+01( $\approx$ )	3.57E+02 (+)	3.93E+01(+)	2.09E+05(+)	1.15E+06(+)	1.81E+05(+)	1.88E+05(+)	7.71E+05(+)	2.24E+01
	Std.	5.99E+00	2.02E+00	1.56E+02	1.11E+01	8.67E+04	5.13E+05	8.14E+04	9.98E+04	4.15E+05	8.44E-01
$g_{19}$	Mean Err.	2.45E+01 (+)	1.41E+01( $\approx$ )	1.39E+02 (+)	2.46E+01(+)	8.67E+03(+)	1.45E+04(+)	9.64E+03(+)	2.42E+04(+)	1.41E+04(+)	1.38E+01
	Std.	3.94E+00	2.26E+00	4.77E+01	8.82E+00	3.91E+03	9.40E+03	8.85E+03	1.32E+04	4.68E+03	1.70E+00
$g_{20}$	Mean Err.	1.47E+02 (-)	1.40E+02(-)	5.47E+02 (+)	1.74E+02(+)	7.70E+02(+)	1.04E+03(+)	6.54E+02(+)	7.98E+02(+)	4.60E+01(-)	1.58E+02
	Std.	7.44E+01	7.74E+01	2.33E+02	7.93E+01	1.92E+02	3.87E+02	2.79E+02	2.31E+02	5.82E+01	5.20E+01
$g_{21}$	Mean Err.	2.11E+02 (-)	2.19E+02( $\approx$ )	2.06E+02 (-)	2.13E+02( $\approx$ )	4.33E+02(+)	2.81E+02(+)	4.02E+02(+)	3.46E+02(+)	2.20E+02( $\approx$ )	2.28E+02
	Std.	4.06E+00	3.77E+00	3.23E+00	1.95E+00	2.14E+01	1.52E+01	4.05E+01	2.05E+01	4.63E+00	7.31E+00
$g_{22}$	Mean Err.	3.65E+02 (-)	1.49E+03(+)	2.05E+03 (+)	2.50E+03(+)	5.97E+03(+)	6.56E+03(+)	4.78E+03(+)	5.07E+03(+)	1.00E+02(-)	4.72E+02
	Std.	9.24E+02	1.75E+03	1.76E+03	1.61E+03	9.89E+02	6.40E+03	2.04E+03	9.46E+02	6.87E-09	1.16E+03
$g_{23}$	Mean Err.	4.34E+02 (-)	4.30E+02( $\approx$ )	4.23E+02 (-)	4.30E+02(-)	1.06E+03(+)	5.66E+02(+)	6.46E+02(+)	5.99E+02(+)	4.28E+02(-)	4.48E+02
	Std.	8.16E+00	6.24E+00	1.39E+01	5.08E+00	7.09E+01	3.40E+01	5.66E+01	2.73E+01	1.25E+01	7.45E+00
$g_{24}$	Mean Err.	5.06E+02 ( $\approx$ )	5.07E+02( $\approx$ )	4.91E+02 (-)	5.06E+02( $\approx$ )	1.08E+03(+)	6.75E+02(+)	7.31E+02(+)	8.22E+02(+)	4.99E+02(-)	5.15E+02
	Std.	3.85E+00	4.13E+00	5.73E+00	2.33E+00	7.07E+01	4.75E+01	7.36E+01	5.02E+01	8.95E+00	5.95E+00
$g_{25}$	Mean Err.	4.89E+02 ( $\approx$ )	4.81E+02( $\approx$ )	4.81E+02 (-)	4.85E+02( $\approx$ )	5.41E+02(+)	6.16E+02(+)	5.21E+02(+)	5.12E+02(+)	5.48E+02(+)	4.80E+02
	Std.	2.47E+01	2.80E+00	5.18E+00	1.63E+01	2.77E+01	2.68E+01	3.03E+01	2.48E+01	2.35E+01	2.49E-02
$g_{26}$	Mean Err.	7.06E+02 (-)	1.13E+03(-)	6.55E+02 (-)	1.14E+03(-)	5.45E+03(+)	2.93E+03(+)	3.42E+03(+)	2.81E+03(+)	9.99E+02(-)	1.33E+03
	Std.	4.06E+02	5.62E+01	3.01E+02	4.50E+01	2.59E+03	6.02E+02	7.82E+02	1.88E+02	2.05E+02	9.39E+01
$g_{27}$	Mean Err.	5.22E+02 ( $\approx$ )	5.11E+02(-)	6.08E+02 (+)	5.34E+02(+)	1.46E+03(+)	8.68E+02(+)	6.72E+02(+)	6.76E+02(+)	5.69E+02(+)	5.21E+02
	Std.	7.75E+00	1.11E+01	5.86E+01	1.92E+01	1.70E+02	1.76E+02	7.26E+01	3.85E+01	3.23E+01	7.83E+00
$g_{28}$	Mean Err.	4.67E+02 ( $\approx$ )	4.60E+02( $\approx$ )	4.70E+02 (+)	4.73E+02(+)	4.89E+02(+)	6.11E+02(+)	4.80E+02(+)	4.86E+02(+)	4.83E+02(+)	4.57E+02
	Std.	1.79E+01	6.84E+00	1.94E+01	2.25E+01	1.79E+01	4.22E+01	2.49E+01	1.90E+01	2.63E+01	3.20E-01
$g_{29}$	Mean Err.	3.47E+02 (-)	3.63E+02(-)	6.69E+02 (+)	3.51E+02(-)	1.52E+03(+)	1.02E+03(+)	9.82E+02(+)	9.65E+02(+)	3.50E+02(-)	3.77E+02
	Std.	1.97E+01	1.32E+01	1.99E+02	1.04E+01	2.09E+02	2.48E+02	3.06E+02	2.05E+02	3.25E+01	9.83E+00
$g_{30}$	Mean Err.	6.18E+05 (-)	6.01E+05(-)	6.46E+06 (+)	6.54E+05(+)	7.81E+05(+)	1.16E+06(+)	1.54E+06(+)	8.21E+05(+)	1.02E+06(+)	6.26E+05
	Std.	3.62E+04	2.99E+04	5.07E+06	7.33E+04	4.82E+04	3.15E+05	3.23E+05	1.57E+05	1.07E+05	4.27E+04
	+/-/-	4/10/15	4/14/11	16/2/11	12/8/9	29/0/0	29/0/0	29/0/0	27/2/0	18/2/9	

TABLE S-XIII  
COMPARISON RESULTS FOR PSO-HV, DE-HL AND TOP-RANK ALGORITHMS ON CEC 2013 ON 50-D.

Func		NBIPOP-ACMA-ES	DRMA-LSCh-CMA	SHADE	MVMO-SH	TLBSaDE	SPSOABC	TPC-GA	PSO-HV	DE-HL
$f_1$	Mean Err.	0.00E+00 ( $\approx$ )	0.00E+00 ( $\approx$ )	0.00E+00 ( $\approx$ )	0.00E+00 ( $\approx$ )	0.00E+00 ( $\approx$ )	0.00E+00 ( $\approx$ )	0.00E+00 ( $\approx$ )	6.33E-13 ( $\approx$ )	0.00E+00
	Std.	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.53E-13	0.00E+00
$f_2$	Mean Err.	0.00E+00 ( $-$ )	0.00E+00 ( $-$ )	2.66E+04 (+)	9.13E-04 ( $-$ )	1.68E+05 (+)	4.95E+05 (+)	4.76E+05 (+)	4.83E+06 (+)	8.81E-03
	Std.	0.00E+00	0.00E+00	1.13E+04	6.81E-04	2.85E+04	1.48E+05	2.14E+05	1.92E+06	1.38E-02
$f_3$	Mean Err.	1.82E+01 ( $-$ )	9.95E+03 ( $\approx$ )	8.80E+05 (+)	3.64E-04 ( $-$ )	7.08E+05 (+)	1.21E+08 (+)	1.06E+08 (+)	1.19E+07 (+)	8.16E+01
	Std.	1.21E+02	3.97E+04	1.96E+06	1.62E-03	3.59E+05	1.18E+08	1.49E+08	2.61E+07	1.28E+02
$f_4$	Mean Err.	0.00E+00 ( $-$ )	1.21E+02 ( $\approx$ )	1.61E-03 (+)	2.14E-06 ( $\approx$ )	6.58E+02 (+)	4.88E+03 (+)	3.33E+00 (+)	4.02E+04 (+)	9.77E-07
	Std.	0.00E+00	5.34E+02	1.41E-03	1.17E-06	1.76E+02	1.20E+03	4.88E+00	8.72E+03	9.83E-07
$f_5$	Mean Err.	0.00E+00 ( $\approx$ )	4.95E-04 (+)	0.00E+00 ( $\approx$ )	1.98E-08 (+)	0.00E+00 ( $\approx$ )	0.00E+00 ( $\approx$ )	0.00E+00 ( $\approx$ )	3.21E-11 ( $\approx$ )	0.00E+00
	Std.	0.00E+00	2.31E-04	0.00E+00	1.09E-08	0.00E+00	0.00E+00	0.00E+00	5.93E-11	0.00E+00
$f_6$	Mean Err.	0.00E+00 ( $-$ )	4.34E+01 (+)	4.28E+01 ( $-$ )	3.76E+01 ( $\approx$ )	4.07E+01 ( $-$ )	4.05E+01 ( $-$ )	4.72E+01 ( $\approx$ )	4.72E+01 (+)	4.34E+01
	Std.	0.00E+00	3.51E-09	5.52E+00	1.49E+01	6.96E+00	2.28E+01	1.40E+01	7.32E+00	1.96E-02
$f_7$	Mean Err.	4.97E+00 (+)	1.54E+01 (+)	2.33E+01 (+)	4.32E+01 (+)	4.96E+01 (+)	7.34E+01 (+)	4.17E+01 (+)	9.50E-01 (+)	2.18E-01
	Std.	5.72E+00	1.37E+01	9.32E+00	8.24E+00	5.31E+00	1.17E+01	1.83E+01	5.11E-01	1.17E-01
$f_8$	Mean Err.	2.11E+01 ( $\approx$ )	2.11E+01 ( $\approx$ )	2.09E+01 ( $-$ )	2.10E+01 ( $\approx$ )	2.11E+01 ( $-$ )	2.11E+01 (+)	2.12E+01 ( $\approx$ )	2.11E+01 ( $\approx$ )	2.11E+01
	Std.	4.52E-02	3.45E-02	1.68E-01	2.64E-01	2.71E-02	3.42E-02	3.84E-02	4.61E-02	7.57E-02
$f_9$	Mean Err.	7.22E+00 ( $-$ )	1.76E+01 ( $-$ )	5.54E+01 (+)	3.28E+01 ( $-$ )	6.09E+01 (+)	5.84E+01 (+)	7.30E+01 (+)	1.40E+01 ( $-$ )	5.02E+01
	Std.	2.29E+00	2.81E+00	1.98E+00	4.57E+00	1.66E+00	3.92E+00	3.82E+00	2.88E+00	2.28E+00
$f_{10}$	Mean Err.	0.00E+00 ( $\approx$ )	1.89E-03 ( $\approx$ )	7.37E-02 (+)	2.90E-04 ( $\approx$ )	1.76E-02 (+)	1.55E-01 (+)	1.05E-01 (+)	2.75E-01 (+)	0.00E+00
	Std.	0.00E+00	3.26E-03	3.67E-02	1.45E-03	6.85E-03	8.10E-02	7.09E-02	2.27E-01	0.00E+00
$f_{11}$	Mean Err.	5.52E+00 (+)	6.13E+00 (+)	0.00E+00 ( $-$ )	3.61E+01 (+)	0.00E+00 ( $-$ )	6.65E-02 (+)	5.57E+01 (+)	7.67E+00 (+)	5.16E-07
	Std.	2.97E+00	2.29E+00	0.00E+00	1.00E+01	0.00E+00	2.39E-01	2.23E+01	4.25E+00	7.56E-07
$f_{12}$	Mean Err.	5.37E+00 ( $-$ )	3.33E+01 ( $\approx$ )	5.86E+01 (+)	8.96E+01 (+)	1.20E+02 (+)	1.73E+02 (+)	9.62E+01 (+)	1.70E+01 ( $-$ )	2.63E+01
	Std.	2.54E+00	7.06E+00	1.11E+01	2.17E+01	8.18E+00	3.23E+01	2.15E+01	4.89E+00	2.41E+00
$f_{13}$	Mean Err.	7.60E+00 ( $-$ )	8.29E+01 (+)	1.45E+02 (+)	1.81E+02 (+)	2.19E+02 (+)	2.87E+02 ( $\approx$ )	1.92E+02 (+)	4.09E+01 ( $\approx$ )	4.91E+01
	Std.	5.47E+00	1.91E+01	1.95E+01	3.36E+01	1.74E+01	3.94E+01	5.04E+01	2.13E+01	1.42E+01
$f_{14}$	Mean Err.	1.38E+03 (+)	5.08E+02 (+)	3.45E-02 ( $-$ )	2.40E+03 (+)	8.25E+02 (+)	2.64E+01 (+)	2.55E+03 (+)	3.14E+02 (+)	1.43E+01
	Std.	5.67E+02	2.19E+02	1.93E-02	7.20E+02	1.07E+02	8.03E+00	1.14E+03	1.61E+02	4.66E+00
$f_{15}$	Mean Err.	1.58E+03 ( $-$ )	3.32E+03 ( $-$ )	6.82E+03 (+)	6.16E+03 ( $\approx$ )	7.69E+03 (+)	7.42E+03 (+)	9.40E+03 (+)	2.19E+03 ( $-$ )	6.16E+03
	Std.	5.48E+02	7.58E+02	4.41E+02	5.62E+02	2.86E+02	5.46E+02	2.73E+03	7.21E+02	6.24E+02
$f_{16}$	Mean Err.	8.78E-01 ( $\approx$ )	1.06E-02 ( $-$ )	1.28E+00 ( $\approx$ )	1.14E+00 ( $\approx$ )	1.80E+00 (+)	1.37E+00 (+)	3.38E+00 (+)	4.52E-01 ( $-$ )	1.32E+00
	Std.	1.44E+00	3.32E-03	2.07E-01	2.05E-01	2.00E-01	1.88E-01	3.89E-01	1.67E-01	2.01E-01
$f_{17}$	Mean Err.	5.74E+01 (+)	6.63E+01 (+)	5.08E+01 ( $-$ )	1.04E+02 (+)	7.95E+01 (+)	5.20E+01 (+)	1.15E+02 (+)	5.88E+01 (+)	5.09E+01
	Std.	2.73E+00	4.76E+00	4.57E-14	1.20E+01	1.81E+00	2.40E-01	2.00E+01	1.87E+00	5.55E-02
$f_{18}$	Mean Err.	1.34E+02 ( $\approx$ )	7.83E+01 ( $-$ )	1.37E+02 ( $\approx$ )	1.05E+02 ( $-$ )	1.81E+02 (+)	2.16E+02 (+)	1.68E+02 ( $\approx$ )	8.97E+01 ( $-$ )	1.32E+02
	Std.	1.00E+02	4.64E+00	1.29E+01	1.57E+01	7.64E+00	2.63E+01	1.02E+02	1.01E+01	8.36E+00
$f_{19}$	Mean Err.	4.46E+00 (+)	3.39E+00 ( $\approx$ )	2.64E+00 ( $-$ )	3.93E+00 (+)	7.57E+00 (+)	5.19E+00 (+)	8.92E+00 (+)	5.15E+00 (+)	3.02E+00
	Std.	5.93E-01	3.80E-01	2.83E-01	7.34E-01	4.78E-01	1.41E+00	3.17E+00	6.47E-01	1.25E-01
$f_{20}$	Mean Err.	2.25E+01 (+)	1.87E+01 ( $-$ )	1.93E+01 ( $-$ )	1.96E+01 ( $\approx$ )	1.93E+01 ( $-$ )	1.98E+01 ( $-$ )	2.34E+01 (+)	2.28E+01 (+)	2.06E+01
	Std.	1.18E+00	8.18E-01	7.70E-01	6.21E-01	3.55E-01	6.78E-01	7.93E-01	8.04E-01	1.65E+00
$f_{21}$	Mean Err.	1.98E+02 ( $\approx$ )	6.95E+02 (+)	8.45E+02 (+)	2.49E+02 ( $\approx$ )	3.12E+02 ( $\approx$ )	8.96E+02 (+)	7.93E+02 (+)	8.72E+02 (+)	2.58E+02
	Std.	1.40E+01	4.01E+02	3.63E+02	1.91E+02	2.45E+02	2.90E+02	3.63E+02	3.02E+02	1.92E+02
$f_{22}$	Mean Err.	1.45E+03 (+)	2.53E+02 (+)	1.33E+01 ( $\approx$ )	2.76E+03 (+)	2.59E+03 (+)	5.11E+01 (+)	3.51E+03 (+)	2.11E+02 (+)	2.67E+01
	Std.	6.01E+02	1.44E+02	7.12E+00	8.38E+02	3.82E+02	1.40E+01	1.90E+03	8.99E+01	3.91E+00
$f_{23}$	Mean Err.	1.71E+03 ( $-$ )	3.30E+03 ( $-$ )	7.63E+03 (+)	6.78E+03 ( $\approx$ )	9.68E+03 (+)	9.04E+03 (+)	9.93E+03 (+)	2.18E+03 ( $-$ )	6.10E+03
	Std.	8.09E+02	7.24E+02	6.58E+02	5.53E+02	3.99E+02	7.81E+02	3.15E+03	7.06E+02	4.68E+02
$f_{24}$	Mean Err.	2.40E+02 (+)	2.21E+02 (+)	2.34E+02 (+)	2.43E+02 (+)	3.98E+02 (+)	3.08E+02 (+)	3.77E+02 (+)	2.06E+02 (+)	2.01E+02
	Std.	2.04E+01	1.41E+01	1.01E+01	7.77E+00	2.27E+00	2.13E+01	1.98E+01	9.91E+00	2.61E-01
$f_{25}$	Mean Err.	2.48E+02 ( $-$ )	2.94E+02 ( $\approx$ )	3.40E+02 (+)	3.24E+02 (+)	3.79E+02 (+)	3.65E+02 (+)	3.86E+02 (+)	2.96E+02 ( $\approx$ )	2.84E+02
	Std.	5.06E+00	8.71E+00	3.09E+01	1.18E+01	2.88E+00	1.86E+01	4.06E+00	9.03E+00	1.66E+01
$f_{26}$	Mean Err.	1.96E+02 ( $-$ )	2.91E+02 (+)	2.58E+02 (+)	2.03E+02 (+)	2.01E+02 (+)	3.97E+02 (+)	4.22E+02 (+)	2.78E+02 (+)	2.00E+02
	Std.	1.43E+01	6.28E+01	8.08E+01	2.49E+01	1.72E+00	9.87E+01	3.51E+01	4.82E+01	8.84E-06
$f_{27}$	Mean Err.	7.28E+02 (+)	6.39E+02 (+)	9.36E+02 (+)	1.03E+03 (+)	2.17E+03 (+)	1.63E+03 (+)	2.03E+03 (+)	4.61E+02 ( $\approx$ )	3.47E+02
	Std.	1.44E+02	1.56E+02	3.07E+02	1.33E+02	3.22E+01	1.99E+02	2.29E+02	1.83E+02	2.26E+01
$f_{28}$	Mean Err.	4.00E+02 ( $\approx$ )	4.59E+02 ( $\approx$ )	4.58E+02 ( $\approx$ )	4.59E+02 ( $\approx$ )	4.00E+02 ( $\approx$ )	8.52E+02 (+)	4.59E+02 ( $\approx$ )	4.00E+02 (+)	4.00E+02
	Std.	0.00E+00	4.20E+02	4.13E+02	4.21E+02	0.00E+00	1.15E+03	4.24E+02	3.86E-09	7.19E-14
	+/-/-	9/8/11	12/9/7	15/6/7	13/11/4	20/4/4	23/3/2	22/6/0	16/6/6	

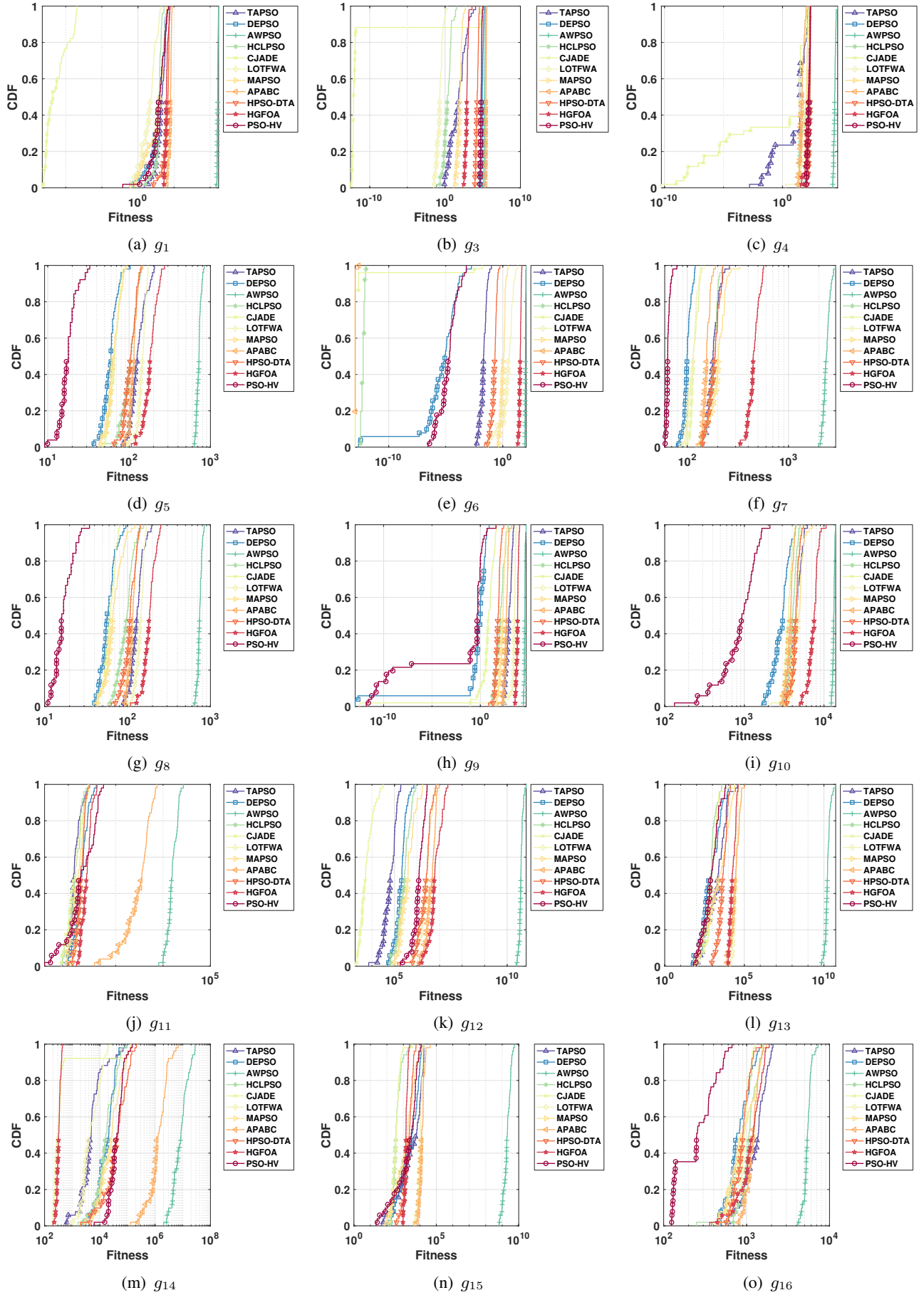
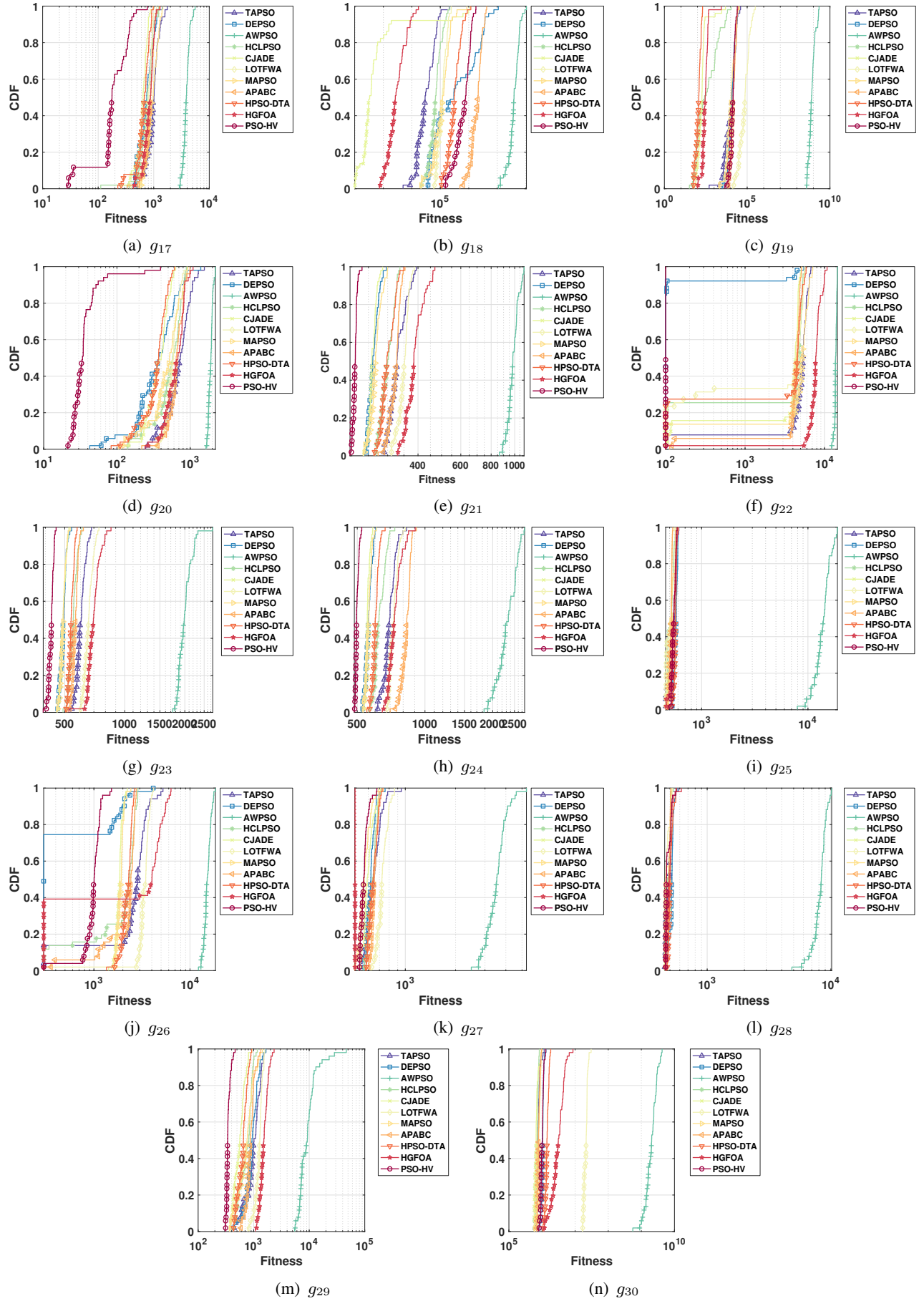


Fig. S-1. The cumulative distribution curves of comparison algorithms on  $g_1$ ,  $g_3$ - $g_{16}$ .

Fig. S-2. The cumulative distribution curves of comparison algorithms on  $g_{17}$ - $g_{30}$ .