**Supplemental File**

**Table Captions**

* **Table S1** Results of EFADE in 10D.
* **Table S2** Results of EFADE in 30D.
* **Table S3** Results of EFADE in 50D.
* **Table S4** Experimental Results of ADE , DE-APC, SaDE, TLBSaDE, b6e6rl, DE-IPS and EFADE over 51 Independent Runs on 28 Test Functions of 10 Variables with 100,000 FES.
* **Table S5** Experimental Results of SPSRDEMMS , DEcfbLS, SMADE, SHADE, jDEsoo ,MDE-PBX and EFADE over 51 Independent Runs on 28 Test Functions of 10 Variables with 100,000 FES
* **Table S6** Experimental Results of GA-TPC, fK-PSO, CDASA, PLES, CMA-ES-RIS, CCPSO2 and EFADE over 51 Independent Runs on 28 Test Functions of 10 Variables with 100,000 FES
* **Table S7** Experimental Results of ADE , DE-APC, SaDE, TLBSaDE, b6e6rl, DE-IPS and EFADE over 51 Independent Runs on 28 Test Functions of 10 Variables with 300,000 FES.
* **Table S8** Experimental Results of SPSRDEMMS , DEcfbLS, SMADE, SHADE, jDEsoo ,MDE-PBX and EFADE over 51 Independent Runs on 28 Test Functions of 10 Variables with 300,000 FES
* **Table S9** Experimental Results of GA-TPC, fK-PSO, CDASA, PLES, CMA-ES-RIS, CCPSO2 and EFADE over 51 Independent Runs on 28 Test Functions of 10 Variables with 300,000 FES
* **Table S10** Experimental Results of ADE , DE-APC, SaDE, TLBSaDE, b6e6rl, DE-IPS and EFADE over 51 Independent Runs on 28 Test Functions of 10 Variables with 500,000 FES.
* **Table S11** Experimental Results of SPSRDEMMS , DEcfbLS, SMADE, SHADE, jDEsoo ,MDE-PBX and EFADE over 51 Independent Runs on 28 Test Functions of 10 Variables with 500,000 FES
* **Table S12** Experimental Results of GA-TPC, fK-PSO, CDASA, PLES, CMA-ES-RIS, CCPSO2 and EFADE over 51 Independent Runs on 28 Test Functions of 10 Variables with 500,000 FES
* **Table S13** Comparison between EFADE , EFADE-1 , EFADE-2 , EFADE-3 and EFADE-4 on 50D problems.

**Figure Captions**

* **Fig.S1.**An illustration of the new triangular mutation scheme in two-dimensional parametric space. (Local Exploitation).
* **Fig.2.**An illustration of the new triangular mutation scheme with collection of convex combinations vectors and the newly generated donor vectors corresponding to the target vectors  in two-dimensional parametric space.(Global Exploration)
* **Fig. S3.** Convergence graph (median curves) of EFADE, EFADE-1, EFADE-2, EFADE-3 and EFADE-4 on 50-dimensional test functions *f1*-*f28*.

**Table S1** Results of EFADE in 10D

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Function** |  | **BEST** | **MEDIAN** | **MEAN** | **WORST** | **SD** |
| **1** | 0 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| **2** | 0 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| **3** | 0 | 0.00E+00 | 3.08E-02 | 7.08E-01 | 6.32E+00 | 1.87E+00 |
| **4** | 0 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| **5** | 0 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| **6** | 0 | 0.00E+00 | 0.00E+00 | 7.70E-01 | 9.81E+00 | 2.66E+00 |
| **7** | 0 | 1.81E-06 | 3.37E-03 | 8.74E-03 | 9.07E-02 | 1.48E-02 |
| **8** | 0 | 2.02E+01 | 2.04E+01 | 2.04E+01 | 2.05E+01 | 6.42E-02 |
| **9** | 0 | 4.14E-05 | 1.09E+00 | 1.15E+00 | 4.26E+00 | 1.13E+00 |
| **10** | 0 | 0.00E+00 | 3.94E-02 | 4.46E-02 | 1.33E-01 | 3.08E-02 |
| **11** | 0 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| **12** | 0 | 2.98E+00 | 6.96E+00 | 7.21E+00 | 1.54E+01 | 3.08E+00 |
| **13** | 0 | 1.99E+00 | 8.98E+00 | 1.03E+01 | 2.42E+01 | 5.23E+00 |
| **14** | 0 | 0.00E+00 | 6.25E-02 | 4.90E-02 | 1.87E-01 | 5.20E-02 |
| **15** | 0 | 7.33E+01 | 8.12E+02 | 7.62E+02 | 1.22E+03 | 3.15E+02 |
| **16** | 0 | 5.33E-01 | 1.10E+00 | 1.09E+00 | 1.46E+00 | 2.13E-01 |
| **17** | 0 | 1.01E+01 | 1.01E+01 | 1.01E+01 | 1.01E+01 | 3.57E-03 |
| **18** | 0 | 2.24E+01 | 3.21E+01 | 3.20E+01 | 3.90E+01 | 4.00E+00 |
| **19** | 0 | 3.04E-01 | 4.85E-01 | 4.72E-01 | 6.41E-01 | 7.20E-02 |
| **20** | 0 | 2.01E+00 | 2.52E+00 | 2.52E+00 | 3.19E+00 | 2.61E-01 |
| **21** | 0 | 1.00E+02 | 4.00E+02 | 3.63E+02 | 4.00E+02 | 8.24E+01 |
| **22** | 0 | 8.84E+00 | 2.73E+01 | 3.06E+01 | 9.52E+01 | 1.58E+01 |
| **23** | 0 | 7.29E+01 | 8.36E+02 | 8.00E+02 | 1.29E+03 | 3.02E+02 |
| **24** | 0 | 1.08E+02 | 2.00E+02 | 1.90E+02 | 2.09E+02 | 2.84E+01 |
| **25** | 0 | 1.04E+02 | 2.00E+02 | 1.95E+02 | 2.00E+02 | 2.14E+01 |
| **26** | 0 | 1.03E+02 | 1.08E+02 | 1.10E+02 | 2.00E+02 | 1.35E+01 |
| **27** | 0 | 3.00E+02 | 3.00E+02 | 3.10E+02 | 4.00E+02 | 3.00E+01 |
| **28** | 0 | 1.00E+02 | 3.00E+02 | 2.61E+02 | 3.00E+02 | 8.02E+01 |

**Table S2** Results of EFADE in 30D

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Function** |  | **BEST** | **MEDIAN** | **MEAN** | **WORST** | **SD** |
| **1** | 0 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| **2** | 0 | 4.95E+03 | 2.50E+04 | 2.67E+04 | 7.04E+04 | 1.53E+04 |
| **3** | 0 | 6.10E-06 | 1.31E+03 | 9.10E+05 | 1.33E+07 | 2.41E+06 |
| **4** | 0 | 1.92E-01 | 2.41E+00 | 3.37E+00 | 2.10E+01 | 3.78E+00 |
| **5** | 0 | 0.00E+00 | 1.14E-13 | 1.05E-13 | 1.14E-13 | 3.09E-14 |
| **6** | 0 | 1.49E+00 | 5.89E+00 | 6.59E+00 | 2.64E+01 | 4.19E+00 |
| **7** | 0 | 5.49E-01 | 3.85E+00 | 5.07E+00 | 1.69E+01 | 3.62E+00 |
| **8** | 0 | 2.08E+01 | 2.10E+01 | 2.10E+01 | 2.10E+01 | 4.65E-02 |
| **9** | 0 | 7.03E+00 | 1.53E+01 | 1.51E+01 | 2.24E+01 | 3.63E+00 |
| **10** | 0 | 7.40E-03 | 2.96E-02 | 3.48E-02 | 1.11E-01 | 2.04E-02 |
| **11** | 0 | 0.00E+00 | 0.00E+00 | 1.00E-14 | 5.68E-14 | 2.19E-14 |
| **12** | 0 | 1.59E+01 | 2.79E+01 | 2.85E+01 | 4.68E+01 | 6.48E+00 |
| **13** | 0 | 1.25E+01 | 5.14E+01 | 5.35E+01 | 9.96E+01 | 2.18E+01 |
| **14** | 0 | 1.25E-01 | 1.39E+00 | 1.29E+00 | 3.71E+00 | 9.16E-01 |
| **15** | 0 | 2.20E+03 | 3.40E+03 | 3.57E+03 | 6.26E+03 | 9.05E+02 |
| **16** | 0 | 1.59E+00 | 2.38E+00 | 2.33E+00 | 2.90E+00 | 3.22E-01 |
| **17** | 0 | 3.05E+01 | 3.08E+01 | 3.09E+01 | 3.23E+01 | 3.71E-01 |
| **18** | 0 | 4.35E+01 | 9.91E+01 | 1.13E+02 | 1.95E+02 | 5.84E+01 |
| **19** | 0 | 2.95E+00 | 3.44E+00 | 3.47E+00 | 4.05E+00 | 2.98E-01 |
| **20** | 0 | 9.04E+00 | 1.12E+01 | 1.10E+01 | 1.22E+01 | 7.74E-01 |
| **21** | 0 | 2.00E+02 | 3.00E+02 | 3.38E+02 | 4.44E+02 | 8.93E+01 |
| **22** | 0 | 1.14E+02 | 2.22E+02 | 2.56E+02 | 6.08E+02 | 1.46E+02 |
| **23** | 0 | 2.38E+03 | 3.58E+03 | 3.84E+03 | 6.91E+03 | 1.08E+03 |
| **24** | 0 | 2.03E+02 | 2.13E+02 | 2.13E+02 | 2.39E+02 | 7.74E+00 |
| **25** | 0 | 2.50E+02 | 2.60E+02 | 2.61E+02 | 2.79E+02 | 6.95E+00 |
| **26** | 0 | 2.00E+02 | 2.00E+02 | 2.00E+02 | 2.00E+02 | 1.04E-03 |
| **27** | 0 | 3.46E+02 | 6.08E+02 | 5.83E+02 | 7.77E+02 | 1.11E+02 |
| **28** | 0 | 3.00E+02 | 3.00E+02 | 3.00E+02 | 3.00E+02 | 3.53E-13 |

**Table S3** Results of EFADE in 50D

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Function** |  | **BEST** | **MEDIAN** | **MEAN** | **WORST** | **SD** |
| **1** | 0 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| **2** | 0 | 6.41E+04 | 1.60E+05 | 1.72E+05 | 3.35E+05 | 5.48E+04 |
| **3** | 0 | 1.22E+05 | 3.56E+06 | 5.70E+06 | 3.35E+07 | 6.70E+06 |
| **4** | 0 | 7.29E-01 | 4.03E+00 | 6.16E+00 | 2.97E+01 | 5.24E+00 |
| **5** | 0 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| **6** | 0 | 4.34E+01 | 4.34E+01 | 4.34E+01 | 4.34E+01 | 0.00E+00 |
| **7** | 0 | 4.94E+00 | 1.60E+01 | 1.80E+01 | 3.65E+01 | 7.26E+00 |
| **8** | 0 | 2.10E+01 | 2.11E+01 | 2.11E+01 | 2.12E+01 | 3.68E-02 |
| **9** | 0 | 2.29E+01 | 3.31E+01 | 3.28E+01 | 4.17E+01 | 4.67E+00 |
| **10** | 0 | 7.40E-03 | 5.67E-02 | 6.98E-02 | 1.58E-01 | 3.74E-02 |
| **11** | 0 | 0.00E+00 | 0.00E+00 | 1.95E-02 | 9.95E-01 | 1.39E-01 |
| **12** | 0 | 3.38E+01 | 6.47E+01 | 6.42E+01 | 9.55E+01 | 1.34E+01 |
| **13** | 0 | 7.70E+01 | 1.52E+02 | 1.56E+02 | 2.41E+02 | 3.82E+01 |
| **14** | 0 | 7.22E+01 | 4.93E+02 | 4.95E+02 | 7.76E+02 | 1.41E+02 |
| **15** | 0 | 5.20E+03 | 7.25E+03 | 8.09E+03 | 1.37E+04 | 2.50E+03 |
| **16** | 0 | 2.42E+00 | 3.27E+00 | 3.24E+00 | 3.95E+00 | 3.13E-01 |
| **17** | 0 | 8.02E+01 | 8.87E+01 | 8.89E+01 | 9.50E+01 | 3.64E+00 |
| **18** | 0 | 7.38E+01 | 9.87E+01 | 1.50E+02 | 3.75E+02 | 1.07E+02 |
| **19** | 0 | 9.02E+00 | 1.01E+01 | 1.01E+01 | 1.13E+01 | 5.18E-01 |
| **20** | 0 | 1.77E+01 | 2.11E+01 | 2.07E+01 | 2.17E+01 | 9.65E-01 |
| **21** | 0 | 2.00E+02 | 2.00E+02 | 3.53E+02 | 1.12E+03 | 3.19E+02 |
| **22** | 0 | 3.45E+01 | 8.37E+02 | 8.84E+02 | 2.40E+03 | 5.22E+02 |
| **23** | 0 | 4.52E+03 | 7.29E+03 | 7.35E+03 | 1.32E+04 | 1.53E+03 |
| **24** | 0 | 2.20E+02 | 2.45E+02 | 2.45E+02 | 2.76E+02 | 1.10E+01 |
| **25** | 0 | 2.97E+02 | 3.28E+02 | 3.27E+02 | 3.46E+02 | 1.15E+01 |
| **26** | 0 | 2.00E+02 | 2.00E+02 | 2.14E+02 | 4.03E+02 | 4.99E+01 |
| **27** | 0 | 6.00E+02 | 1.07E+03 | 1.07E+03 | 1.30E+03 | 1.38E+02 |
| **28** | 0 | 4.00E+02 | 4.00E+02 | 4.00E+02 | 4.00E+02 | 0.00E+00 |

**TABLE S4** Experimental Results of ADE , DE-APC, SaDE, TLBSaDE, b6e6rl, DE-IPS and EFADE over 51 Independent Runs on 28 Test Functions of 10 Variables with 100,000 FES

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Function | ADE [7]  Mean Error ±Std Dev | DE-APC [14]  Mean Error ±Std Dev | SaDE [40]  Mean Error ±Std Dev | TLBSaDE [2]  Mean Error ±Std Dev | b6e6rl [46]  Mean Error ±Std Dev | DE-IPS [32]  Mean Error ±Std Dev | EFADE  Mean Error ±Std Dev |
| *F*1 | **0.00E+00±0.00E+00** | **0.00E+00±0.00E+00** | **0.00E+00±0.00E+00** | **0.00E+00±0.00E+00** | **0.00E+00±0.00E+00** | 2.33E-04±7.10E-05 | **0.00E+00±0.00E+00** |
| *F*2 | 1.90E-02±1.35E-01 | **0.00E+00±0.00E+00** | 1.66E-03±9.12E-03 | **0.00E+00±0.00E+00** | 1.82E-04±1.28E-03 | 2.56E-04±8.12E-05 | **0.00E+00±0.00E+00** |
| *F*3 | 2.17E-01±9.11E-01 | **0.00E+00±0.00E+00** | 1.24E+01±7.65E+01 | 9.58E-01±5.79E-01 | 3.94E-01±1.50E+00 | 1.33E-01±8.83E-01 | 7.08E-01±1.87E+00 |
| *F*4 | 1.26E+03±2.81E+03 | **0.00E+00±0.00E+00** | 1.83E-04±6.37E-04 | **0.00E+00±0.00E+00** | 2.12E-09±1.07E-08 | 3.30E-04±2.07E-04 | **0.00E+00±0.00E+00** |
| *F*5 | 0.00E+00±0.00E+00 | **0.00E+00±0.00E+00** | 0.00E+00±0.00E+00 | **0.00E+00±0.00E+00** | **0.00E+00±0.00E+00** | 2.10E-04±8.51E-05 | **0.00E+00±0.00E+00** |
| *F*6 | 3.27E+00±4.67E+00 | **0.00E+00±0.00E+00** | 5.77E+00±4.88E+00 | **0.00E+00±0.00E+00** | 4.23E+00±4.91E+00 | 2.47E+00±4.14E+00 | 7.70E-01±2.66E+00 |
| *F*7 | 2.67E-02±1.51E-01 | 2.05E-02±2.87E-03 | 1.30E-01±5.91E-01 | 4.54E-01±1.56E-01 | **2.96E-03±6.41E-03** | 8.88E-01±2.13E+00 | 8.74E-03±1.48E-02 |
| *F*8 | 2.04E+01±9.06E-02 | 2.05E+01±8.02E-02 | 2.04E+01±6.65E-02 | **2.02E+01±4.06E-02** | 2.04E+01±7.90E-02 | 2.03E+01±7.74E-02 | 2.04E+01±6.42E-02 |
| *F*9 | 1.90E+00±2.04E+00 | 9.96E+00±3.72E+00 | 1.40E+00±1.25E+00 | 4.28E+00±3.34E-01 | 1.78E+00±1.87E+00 | 2.09E+00±1.23E+00 | **1.15E+00±1.13E+00** |
| *F*10 | 5.70E-02±3.32E-02 | 1.06E-01±2.72E-02 | 2.28E-02±1.61E-02 | **4.88E-03±3.74E-03** | 3.51E-02±2.54E-02 | 1.51E-01±7.67E-02 | 4.46E-02±3.08E-02 |
| *F*11 | 4.98E+00±3.07E+00 | **0.00E+00±0.00E+00** | **0.00E+00±0.00E+00** | **0.00E+00±0.00E+00** | **0.00E+00±0.00E+00** | 7.88E+00±3.92E+00 | **0.00E+00±0.00E+00** |
| *F*12 | 7.69E+00±3.62E+00 | 1.49E+01±3.14E+00 | **4.48E+00±1.57E+00** | 5.44E+00±6.53E-01 | 8.07E+00±2.25E+00 | 1.14E+01±4.66E+00 | 7.21E+00±3.08E+00 |
| *F*13 | 9.52E+00±5.20E+00 | 2.74E+01±6.54E+00 | **5.47E+00±3.06E+00** | 5.67E+00±1.79E+00 | 9.57E+00±3.41E+00 | 1.78E+01±9.78E+00 | 1.03E+01±5.23E+00 |
| *F*14 | 1.51E+02±8.12E+01 | 1.15E+02±2.37E+01 | **1.59E-02±3.02E-02** | 1.61E+00±6.30E-01 | 7.10E-02±6.37E-02 | 2.43E+02±2.20E+02 | 4.90E-02±5.20E-02 |
| *F*15 | 8.71E+02±1.32E+02 | 1.64E+03±3.64E+02 | 6.86E+02±1.99E+02 | **5.61E+02±6.16E+01** | 6.99E+02±1.72E+02 | 7.52E+02±3.14E+02 | 7.62E+02±3.15E+02 |
| *F*16 | 9.09E-01±1.87E-01 | 1.35E+00±1.95E-01 | 1.12E+00±1.93E-01 | **7.75E-01±8.93E-02** | 9.48E-01±2.49E-01 | 8.57E-01±3.64E-01 | 1.09E+00±2.13E-01 |
| *F*17 | 1.59E+01±2.92E+00 | 1.03E+01±2.20E-02 | 1.01E+01±2.76E-03 | 1.05E+01±9.60E-02 | 1.01E+01±1.26E-14 | 1.68E+01±4.45E+00 | **1.01E+01±3.57E-03** |
| *F*18 | 2.76E+01±3.08E+00 | 4.05E+01±7.78E+00 | 2.28E+01±3.26E+00 | **1.90E+01±1.09E+00** | 2.49E+01±4.75E+00 | 3.21E+01±7.60E+00 | 3.20E+01±4.00E+00 |
| *F*19 | 6.42E-01±1.53E-01 | 1.23E+00±2.58E-01 | 3.76E-01±5.65E-02 | 4.82E-01±4.77E-02 | **3.38E-01±4.13E-02** | 8.66E-01±3.33E-01 | 4.72E-01±7.20E-02 |
| *F*20 | 2.35E+00±4.13E-01 | 3.59E+00±4.75E-01 | **2.23E+00±3.53E-01** | 2.59E+00±2.07E-01 | 2.31E+00±2.98E-01 | 2.28E+00±7.63E-01 | 2.52E+00±2.61E-01 |
| *F*21 | 3.69E+02±7.35E+01 | 3.00E+02±2.80E+01 | 3.96E+02±2.80E+01 | **1.65E+02±5.53E+01** | 3.83E+02±6.24E+01 | 3.76E+02±7.37E+01 | 3.63E+02±8.24E+01 |
| *F*22 | 2.62E+02±1.17E+02 | 7.70E+02±1.37E+02 | **1.13E+01±8.67E+00** | 1.01E+02±1.67E+01 | 1.98E+01±2.53E+01 | 2.55E+02±1.79E+02 | 3.06E+01±1.58E+01 |
| *F*23 | 9.04E+02±2.18E+02 | 1.87E+03±4.43E+02 | 6.55E+02±2.36E+02 | 7.95E+02±1.21E+02 | 7.05E+02±2.02E+02 | **6.41E+02±3.72E+02** | 8.00E+02±3.02E+02 |
| *F*24 | 2.05E+02±1.38E+01 | 2.25E+02±7.39E+00 | 1.94E+02±2.44E+01 | **1.75E+02±2.03E+01** | 2.04E+02±3.52E+00 | 2.01E+02±1.91E+01 | 1.90E+02±2.84E+01 |
| *F*25 | 2.04E+02±3.77E+00 | 2.25E+02±6.76E+00 | 1.98E+02±1.29E+01 | 2.09E+02±1.48E+01 | 2.00E+02±1.31E+01 | 2.02E+02±1.21E+01 | **1.95E+02±2.14E+01** |
| *F*26 | 1.84E+02±3.53E+01 | 2.00E+02±6.16E-09 | 1.27E+02±3.93E+01 | **1.09E+02±2.32E+00** | 1.55E+02±4.64E+01 | 1.61E+02±4.44E+01 | 1.10E+02±1.35E+01 |
| *F*27 | 3.77E+02±9.38E+01 | 5.52E+02±6.65E+01 | **3.00E+02±5.45E-02** | 4.06E+02±5.63E+00 | 3.25E+02±6.25E+01 | 3.11E+02±4.22E+01 | 3.10E+02±3.00E+01 |
| *F*28 | 2.88E+02±4.75E+01 | 3.00E+02±3.92E+01 | 2.96E+02±2.80E+01 | 9.61E+01±1.96E+01 | 2.92E+02±3.92E+01 | 3.06E+02±9.39E+01 | **2.61E+02±8.02E+01** |

**TABLE S5** Experimental Results of SPSRDEMMS , DEcfbLS, SMADE, SHADE, jDEsoo , MDE-PBX and EFADE over 51 Independent Runs on 28 Test Functions of 10 Variables with 100,000 FES

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Function | SPSRDEMMS [51]  Mean Error ±Std Dev | DEcfbLS [37]  Mean Error ±Std Dev | SMADE [6]  Mean Error ±Std Dev | SHADE [45]  Mean Error ±Std Dev | jDEsoo [3]  Mean Error ±Std Dev | MDE-PBX [6]  Mean Error ±Std Dev | EFADE  Mean Error ±Std Dev |
| *F*1 | 0.00E+00±0.00E+00 | 0.00E+00±0.00E+00 | 0.00E+00±0.00E+00 | 0.00E+00±0.00E+00 | 0.00E+00±0.00E+00 | 0.00E+00±0.00E+00 | **0.00E+00±0.00E+00** |
| *F*2 | 6.89E+02±1.02E+03 | 1.01E+02±6.09E+02 | 0.00E+00±0.00E+00 | 0.00E+00±0.00E+00 | 1.72E+03±1.71E+03 | 4.15E+02±9.60E+02 | **0.00E+00±0.00E+00** |
| *F*3 | 5.97E+00±1.76E+01 | 1.14E+00±2.00E+00 | 2.48E−01±1.23E+00 | **1.27E-01±8.84E-01** | 1.61E+00±2.99E+00 | 4.96E+03±4.66E+04 | 7.08E-01±1.87E+00 |
| *F*4 | 3.87E-02±7.87E-02 | 8.19E-01±4.57E+00 | **0.00E+00±0.00E+00** | **0.00E+00±0.00E+00** | 1.24E-01±3.80E-01 | 6.50E−02±6.38E−01 | **0.00E+00±0.00E+00** |
| *F*5 | **0.00E+00±0.00E+00** | **0.00E+00±0.00E+00** | **0.00E+00±0.00E+00** | **0.00E+00±0.00E+00** | **0.00E+00±0.00E+00** | **0.00E+00±0.00E+00** | **0.00E+0±0.00E+00** |
| *F*6 | 8.66E+00±3.19E+00 | 1.35E+00±3.38E+00 | 5.41E+00±4.76E+00 | 7.89E+00±3.93E+00 | 8.50E+00±3.33E+00 | 6.18E+00±4.73E+00 | **7.70E-01±2.66E+00** |
| *F*7 | 1.87E-01±2.74E-01 | 8.71E-01±8.21E-01 | 2.27E+00±4.45E+00 | **3.26E-03±4.54E-03** | 9.48E-01±3.28E+00 | 5.63E+00±7.94E+00 | 8.74E-03±1.48E-02 |
| *F*8 | **2.03E+01±7.71E-02** | **2.03E+01±1.12E-01** | **2.03E+01±1.03E−01** | 2.04E+01±8.95E-02 | **2.03E+01±7.62E-02** | 2.05E+01±1.06E−01 | 2.04E+01±6.42E-02 |
| *F*9 | 2.73E+00±1.13E+00 | 3.54E+00±1.09E+00 | 2.29E+00±7.19E−01 | 3.39E+00±7.35E-01 | 2.75E+00±1.39E+00 | 2.37E+00±1.41E+00 | **1.15E+00±1.13E+00** |
| *F*10 | **1.03E-01±6.29E-02** | 3.29E-02±1.71E-02 | 1.42E−02±9.58E−03 | 1.20E-02±8.99E-03 | 7.10E-02±3.52E-02 | 1.25E−01±9.20E−02 | 4.46E-02±3.08E-02 |
| *F*11 | **0.00E+00±0.00E+00** | 1.95E-02±1.38E-01 | 9.75E−02±2.96E−01 | **0.00E+00±0.00E+00** | **0.00E+00±0.00E+00** | 2.48E+00±1.61E+00 | **0.00E+00±0.00E+00** |
| *F*12 | 7.58E+00±2.81E+00 | 6.15E+00±1.88E+00 | 7.80E+00±4.10E+00 | **3.14E+00±9.73E-01** | 6.11E+00±3.26E+00 | 1.06E+01±4.76E+00 | 7.21E+00±3.08E+00 |
| *F*13 | 1.10E+01±5.44E+00 | 1.19E+01±4.39E+00 | 1.21E+01±6.40E+00 | **3.77E+00±1.85E+00** | 7.81E+00±4.83E+00 | 2.01E+01±7.94+00 | 1.03E+01±5.23E+00 |
| *F*14 | 8.33E-02±7.25E-02 | 1.84E-02±3.10E-02 | 3.64E+00±4.39E+00 | **4.90E-03±1.70E-02** | 5.02E-02±5.73E-02 | 1.25E+02±1.12E+02 | 4.90E-02±5.20E-02 |
| *F*15 | 7.63E+02±2.71E+02 | 5.27E+02±1.38E+02 | 7.36E+02±2.60E+02 | **4.21E+02±1.14E+02** | 8.40E+02±2.34E+02 | 7.26E+02±2.61E+02 | 7.62E+02±3.15E+02 |
| *F*16 | 1.10E+00±2.42E-01 | 2.79E-01±1.99E-01 | **4.04E−01±3.14E−01** | 7.08E-01±2.12E-01 | 1.10E+00±2.35E-01 | 5.43E−01±4.49E−01 | 1.09E+00±2.13E-01 |
| *F*17 | 1.01E+01±8.71E-03 | **9.80E+00±1.51E+00** | 1.03E+01±1.55E−01 | 1.01E+01±0.00E+00 | 9.92E+00±1.42E+00 | 1.32E+01±1.85E+00 | 1.01E+01±3.57E-03 |
| *F*18 | 2.14E+01±5.63E+00 | **1.65E+01±2.66E+00** | 2.46E+01±4.68E+00 | 1.69E+01±1.54E+00 | 2.77E+01±5.43E+00 | 1.93E+01±4.67E+00 | 3.20E+01±4.00E+00 |
| *F*19 | **2.90E-01±5.95E-02** | **2.90E-01±6.21E-02** | 3.95E−01±1.25E−01 | 3.44E-01±4.90E-02 | 3.20E-01±1.05E-01 | 6.44E−01±2.09E−01 | 4.72E-01±7.20E-02 |
| *F*20 | 2.50E+00±3.93E-01 | 2.56E+00±4.01E-01 | 2.65E+00±4.48E−01 | **2.16E+00±3.52E-01** | 2.72E+00±4.88E-01 | 2.87E+00±5.25E−01 | 2.52E+00±2.61E-01 |
| *F*21 | 3.92E+02±3.92E+01 | 4.00E+02±0.00E+00 | 3.83E+02±5.50E+01 | 4.00E+02±0.00E+00 | **3.51E+02±9.04E+01** | 3.98E+02±1.99E+01 | 3.63E+02±8.24E+01 |
| *F*22 | 6.62E+01±4.25E+01 | 3.08E+01±1.89E+01 | 4.93E+01±5.33E+01 | **4.84E+00±6.20E+00** | 9.19E+01±2.96E+01 | 1.33E+02±1.04E+02 | 3.06E+01±1.58E+01 |
| *F*23 | 9.31E+02±2.72E+02 | 6.56E+02±1.59E+02 | 5.78E+02±3.16E+02 | **4.61E+02±1.78E+02** | 8.11E+02±2.22E+02 | 8.82E+02±3.08E+02 | 8.00E+02±3.02E+02 |
| *F*24 | 2.04E+02±1.98E+01 | **1.13E+02±2.19E+01** | 2.02E+02±1.76E+01 | 1.93E+02±2.46E+01 | 2.09E+02±1.38E+01 | 2.02E+02±1.56E+01 | 1.90E+02±2.84E+01 |
| *F*25 | 2.05E+02±1.63E+01 | **1.82E+02±3.70E+01** | 2.02E+02±1.91E+00 | 2.00E+02±7.02E-01 | 2.10E+02±4.33E+00 | 2.00E+02±1.23E+01 | 1.95E+02±2.14E+01 |
| *F*26 | 1.69E+02±3.84E+01 | **1.10E+02±1.31E+01** | 1.26E+02±3.69E+01 | 1.33E+02±4.36E+01 | 1.93E+02±4.38E+01 | 1.47E+02±4.36E+01 | **1.10E+02±1.35E+01** |
| *F*27 | 4.73E+02±4.70E+01 | 3.90E+02±2.97E+01 | 3.37E+02±5.23E+01 | **3.00E+02±1.46E-08** | 4.94E+02±5.25E+01 | 3.06E+02±2.76E+01 | 3.10E+02±3.00E+01 |
| *F*28 | 2.84E+02±5.43E+01 | **2.41E+02±9.11E+01** | 3.17E+02±6.87E+01 | 3.00E+02±0.00E+00 | 2.88E+02±4.75E+01 | 3.07E+02±5.78E+01 | 2.61E+02±8.02E+01 |

**TABLE S6** Experimental Results of GA-TPC, fK-PSO, CDASA, PLES, CMA-ES-RIS, CCPSO2 and EFADE over 51 Independent Runs on 28 Test Functions of 10 Variables with 100,000 FES

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Function | GA-TPC [13]  Mean Error ±Std Dev | fk-PSO[30]  Mean Error ±Std Dev | CDASA [22]  Mean Error ±Std Dev | PLES [35]  Mean Error ±Std Dev | CMA-ES-RIS [5]  Mean Error ±Std Dev | CCPSO2 [6]  Mean Error ±Std Dev | EFADE  Mean Error ±Std Dev |
| *F*1 | **0.00E+00±0.00E+00** | **0.00E+00±0.00E+00** | **0.00E+00±0.00E+00** | **0.00E+00±0.00E+00** | **0.00E+00±0.00E+00** | 1.92E−04±1.16E−03 | **0.00E+00±0.00E+00** |
| *F*2 | **0.00E+00±0.00E+00** | 1.44E+05±1.04E+05 | 2.05E+06±1.30E+07 | 2.42E+06±1.66E+06 | **0.00E+00±0.00E+00** | 9.93E+05±7.58E+05 | **0.00E+00±0.00E+00** |
| *F*3 | **0.00E+00±0.00E+00** | 6.75E+05±1.96E+06 | 1.98E+11±1.39E+12 | 2.21E+08±8.30E+08 | 7.04E-01±4.57E+00 | 2.13E+07±3.13E+07 | 7.08E-01±1.87E+00 |
| *F*4 | **0.00E+00±0.00E+00** | 4.16E+02±3.37E+02 | 1.32E+03±9.27E+03 | 1.34E+04±7.59E+03 | **0.00E+00±0.00E+00** | 8.80E+03±2.50E+03 | **0.00E+00±0.00E+00** |
| *F*5 | **0.00E+00±0.00E+00** | **0.00E+00±0.00E+00** | 7.52E-06±6.80E-06 | **0.00E+00±0.00E+00** | **0.00E+00±0.00E+00** | 2.94E−03±8.06E−03 | **0.00E+00±0.00E+00** |
| *F*6 | **0.00E+00±0.00E+00** | 2.64E+00±2.05E+00 | 5.05E+00±5.60E+00 | 1.64E+01±2.58E+01 | 1.10E+00±2.85E+00 | 1.52E+00±2.91E+00 | 7.70E-01±2.66E+00 |
| *F*7 | 1.49E+00±2.10E-01 | 1.92E+00±2.70E+00 | 1.15E+02±3.43E+02 | 4.70E+01±2.14E+01 | 5.33E+01±4.63E+01 | 3.27E+01±8.31E+00 | **8.74E-03±1.48E-02** |
| *F*8 | 2.06E+01±8.64E-02 | **2.03E+01±8.71E-02** | **2.03E+01±1.17E-01** | 2.04E+01±1.02E-01 | **2.03E+01±1.36E-01** | 2.04E+01±7.66E−02 | 2.04E+01±6.42E-02 |
| *F*9 | 1.05E+01±2.90E+00 | 2.75E+00±1.09E+00 | 5.05E+00±2.37E+00 | 6.81E+00±1.26E+00 | 3.59E+00±1.03E+00 | 4.98E+00±9.13E−01 | **1.15E+00±1.13E+00** |
| *F*10 | 1.55E-01±2.82E-02 | 5.13E-01±3.15E-01 | 2.66E-01±1.38E-01 | 1.06E+01±7.95E+00 | **1.24E-02±1.33E-02** | 1.47E+00±6.44E−01 | 4.46E-02±3.08E-02 |
| *F*11 | 1.99E+00±4.91E-01 | 1.76E-01±3.79E-01 | 4.68E-01±7.46E-01 | 1.71E+01±7.91E+00 | 3.57E+00±1.46E+00 | 1.97E+00±1.18E+00 | **0.00E+00±0.00E+00** |
| *F*12 | 1.19E+01±2.29E+00 | **7.04E+00±2.95E+00** | 2.19E+01±7.38E+00 | 2.34E+01±1.15E+01 | 1.29E+01±5.36E+00 | 2.64E+01±7.93E+00 | 7.21E+00±3.08E+00 |
| *F*13 | 3.40E+01±6.30E+00 | 1.15E+01±4.77E+00 | 3.45E+01±1.21E+01 | 4.32E+01±1.39E+01 | 2.56E+01±1.07E+01 | 3.56E+01±8.30E+00 | **1.03E+01±5.23E+00** |
| *F*14 | 1.39E+02±2.75E+01 | 3.78E+01±4.21E+01 | 2.05E+02±1.47E+02 | 5.24E+02±2.12E+02 | 1.02E+02±7.32E+01 | 5.27E+01±3.86E+01 | **4.90E-02±5.20E-02** |
| *F*15 | 1.46E+03±2.58E+02 | **4.54E+02±1.67E+02** | 1.08E+03±3.77E+02 | 1.06E+03±3.56E+02 | 6.17E+02±1.72E+02 | 8.92E+02±2.18E+02 | 7.62E+02±3.15E+02 |
| *F*16 | 1.88E+00±3.26E-01 | 4.07E-01±1.36E-01 | 2.62E-01±2.15E-01 | 7.29E-01±3.24E-01 | **1.64E-01±7.49E-02** | 1.18E+00±2.19E−01 | 1.09E+00±2.13E-01 |
| *F*17 | 1.35E+01±7.73E-01 | 1.10E+01±3.28E+00 | 1.04E+01±3.22E+00 | 2.77E+01±8.51E+00 | 1.04E+01±3.70E+00 | 1.60E+01±2.07E+00 | **1.01E+01±3.57E-03** |
| *F*18 | 4.81E+01±5.22E+00 | **1.56E+01±2.33E+00** | 3.05E+01±1.07E+01 | 3.43E+01±1.01E+01 | 2.98E+01±6.10E+00 | 5.41E+01±6.33E+00 | 3.20E+01±4.00E+00 |
| *F*19 | 9.16E-01±1.48E-01 | 5.01E-01±1.38E-01 | 6.29E-01±2.40E-01 | 1.59E+00±7.66E-01 | 8.14E-01±2.71E-01 | 7.65E−01±2.52E−01 | **4.72E-01±7.20E-02** |
| *F*20 | 4.13E+00±5.05E-01 | **2.52E+00±4.77E-01** | 4.02E+00±7.54E-01 | 3.59E+00±4.71E-01 | 4.16E+00±3.95E-01 | 3.50E+00±1.96E−01 | **2.52E+00±2.61E-01** |
| *F*21 | 3.00E+02±5.00E+01 | 3.75E+02±7.10E+01 | 3.43E+02±9.56E+01 | 3.92E+02±3.92E+01 | **1.61E+02±5.97E+01** | 3.73E+02±6.75E+01 | 3.63E+02±8.24E+01 |
| *F*22 | 3.25E+02±6.28E+01 | 1.22E+02±7.57E+01 | 2.65E+02±1.67E+02 | 6.50E+02±2.59E+02 | 2.44E+02±1.07E+02 | 7.27E+01±4.98E+01 | **3.06E+01±1.58E+01** |
| *F*23 | 1.83E+03±3.32E+02 | **5.15E+02±1.97E+02** | 1.47E+03±4.72E+02 | 1.27E+03±3.02E+02 | 8.35E+02±1.89E+02 | 1.15E+03±2.58E+02 | 8.00E+02±3.02E+02 |
| *F*24 | 2.25E+02±6.79E+00 | 2.03E+02±1.91E+01 | 2.11E+02±4.49E+01 | 2.18E+02±1.25E+01 | **1.19E+02±5.63E+00** | 2.01E+02±2.54E+01 | 1.90E+02±2.84E+01 |
| *F*25 | 2.26E+02±6.71E+00 | 2.05E+02±1.44E+01 | 2.21E+02±2.79E+01 | 2.15E+02±1.61E+01 | **1.93E+02±3.39E+01** | 2.12E+02±1.09E+01 | 1.95E+02±2.14E+01 |
| *F*26 | 2.00E+02±1.81E+01 | 1.89E+02±5.13E+01 | 2.15E+02±8.84E+01 | 1.71E+02±3.61E+01 | 1.61E+02±4.02E+01 | 1.58E+02±2.40E+01 | **1.10E+02±1.35E+01** |
| *F*27 | 5.60E+02±7.42E+01 | 3.70E+02±3.22E+01 | 5.75E+02±1.72E+02 | 4.65E+02±7.76E+01 | 3.13E+02±2.27E+01 | 4.27E+02±4.91E+01 | **3.10E+02±3.00E+01** |
| *F*28 | 3.00E+02±3.92E+01 | 3.26E+02±1.25E+02 | 3.20E+02±7.97E+01 | 4.96E+02±2.62E+02 | 2.06E+02±1.06E+02 | 3.01E+02±1.28E+02 | 2.61E+02±8.02E+01 |

**TABLE S7** Experimental Results of ADE , DE-APC, SaDE, TLBSaDE, b6e6rl, DE-IPS and EFADE over 51 Independent Runs on 28 Test Functions of 30 Variables with 300,000 FES

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Function | ADE [7]  Mean Error ±Std Dev | DE-APC [14]  Mean Error ±Std Dev | SaDE [40]  Mean Error ±Std Dev | TLBSaDE [2]  Mean Error ±Std Dev | b6e6rl [46]  Mean Error ±Std Dev | DE-IPS [32]  Mean Error ±Std Dev | EFADE  Mean Error ±Std Dev |
| *F*1 | **0.00E+00±0.00E+00** | **0.00E+00±0.00E+00** | **0.00E+00±0.00E+00** | **0.00E+00±0.00E+00** | **0.00E+00±0.00E+00** | 1.89E-03±4.65E-04 | **0.00E+00±0.00E+00** |
| *F*2 | 2.12E+06±1.56E+06 | 1.75E+05±1.33E+05 | 3.40E+04±1.63E+04 | **6.73E+03±2.55E+03** | 6.99E+04±4.41E+04 | 5.52E+04±2.70E+04 | 2.67E+04±1.53E+04 |
| *F*3 | 1.65E+03±2.83E+03 | 3.21E+06±1.19E+07 | 3.32E+06±5.33E+06 | **3.91E+01±6.89E+01** | 4.36E+03±1.36E+04 | 2.16E+06±5.19E+06 | 9.10E+05±2.41E+06 |
| *F*4 | 1.69E+04±2.85E+03 | 2.21E-01±6.03E-01 | 1.03E+02±1.52E+02 | 2.34E+00±1.99E+00 | **1.80E-02±2.88E-02** | 1.32E-01±1.02E-01 | 3.37E+00±3.78E+00 |
| *F*5 | 1.39E-07±1.86E-07 | **0.00E+00±0.00E+00** | **0.00E+00±0.00E+00** | **0.00E+00±0.00E+00** | **0.00E+00±0.00E+00** | 2.48E-03±8.16E-04 | **0.00E+00±0.00E+00** |
| *F*6 | 8.29E+00±5.82E+00 | 9.35E+00±2.06E+00 | 8.72E+00±1.03E+00 | **1.04E-02±2.14E-02** | 5.25E+00±9.90E+00 | 7.82E+00±1.65E+01 | 6.59E+00±4.19E+00 |
| *F*7 | **1.29E+00±1.22E+00** | 2.18E+01±1.89E+01 | 1.92E+01±1.06E+01 | 1.54E+01±3.35E+00 | 2.44E+01±8.96E+00 | 4.89E+01±2.37E+01 | 5.07E+00±3.62E+00 |
| *F*8 | 2.09E+01±4.81E-02 | 2.09E+01±5.24E-02 | 2.09E+01±5.21E-02 | **2.08E+01±5.14E-02** | 2.09E+01±4.73E-02 | 2.09E+01±5.65E-02 | 2.10E+01±4.65E-02 |
| *F*9 | **6.30E+00±3.27E+00** | 3.07E+01±9.47E+00 | 1.69E+01±3.81E+00 | 2.67E+01±3.92E+00 | 2.86E+01±1.15E+00 | 1.59E+01±2.69E+00 | 1.51E+01±3.63E+00 |
| *F*10 | 2.16E-02±1.36E-02 | 6.42E-02±4.82E-02 | 1.52E-01±1.02E-01 | **1.62E-02±6.93E-03** | 1.91E-02±1.34E-02 | 3.24E-02±1.97E-02 | 3.48E-02±2.04E-02 |
| *F*11 | 5.84E+01±1.11E+01 | 3.08E+00±4.50E+00 | 5.85E-02±2.36E-01 | **0.00E+00±0.00E+00** | **0.00E+00±0.00E+00** | 7.88E+01±2.51E+01 | **0.00E+00±0.00E+00** |
| *F*12 | 1.15E+02±1.14E+02 | 3.17E+01±8.51E+00 | 3.34E+01±8.92E+00 | 4.99E+01±3.48E+00 | 8.35E+01±1.29E+01 | 8.14E+01±3.00E+01 | **2.85E+01±6.48E+00** |
| *F*13 | 1.31E+02±1.24E+01 | 7.55E+01±2.65E+01 | 7.21E+01±2.02E+01 | 8.58E+01±8.65E+00 | 1.14E+02±1.40E+01 | 1.61E+02±3.50E+01 | **4.62E+01±2.18E+01** |
| *F*14 | 3.20E+03±4.38E+02 | 3.84E+03±3.85E+02 | 8.34E-02±2.25E-01 | 3.07E+01±1.14E+01 | **2.37E-02±2.50E-02** | 2.38E+03±1.42E+03 | 1.29E+00±9.16E-01 |
| *F*15 | 5.61E+03±3.19E+02 | 4.14E+03±1.08E+03 | 4.82E+03±4.08E+02 | 3.61E+03±2.07E+02 | 4.67E+03±3.39E+02 | 5.19E+03±5.16E+02 | **3.57E+03±9.05E+02** |
| *F*16 | 2.39E+00±2.66E-01 | 2.46E+00±4.45E-01 | 2.38E+00±3.05E-01 | **1.48E+00±2.08E-01** | 1.97E+00±3.85E-01 | 1.97E+00±2.59E-01 | 2.33E+00±3.22E-01 |
| *F*17 | 1.02E+02±1.17E+01 | 5.92E+01±5.56E+00 | **3.04E+01±2.82E-03** | 3.25E+01±7.03E-01 | **3.04E+01±4.15E-5** | 9.29E+01±1.57E+01 | 3.09E+01±3.71E-01 |
| *F*18 | 1.82E+02±1.20E+01 | **6.04E+01±9.80E+00** | 1.25E+02±9.80E+00 | 7.67E+01±7.19E+00 | 1.72E+02±1.34E+01 | 2.34E+02±2.56E+01 | 1.13E+02±5.84E+01 |
| *F*19 | 5.40E+00±8.10E-01 | 2.29E+00±6.24E-01 | 2.08E+00±2.51E-01 | 2.67E+00±2.31E-01 | **1.84E+00±1.46E-01** | 4.51E+00±1.30E+00 | 3.47E+00±2.98E-01 |
| *F*20 | 1.13E+01±3.28E-01 | 1.26E+01±7.40E-01 | 1.09E+01±5.18E-01 | **1.06E+01±3.65E-01** | 1.19E+01±3.24E-01 | 1.43E+01±1.19E+00 | 1.10E+01±7.74E-01 |
| *F*21 | 3.19E+02±6.26E+01 | **2.67E+02±6.59E+01** | 3.04E+02±7.68E+01 | **2.67E+02±4.76E+01** | 2.96E+02±8.55E+01 | 3.20E+02±8.55E+01 | 3.38E+02±8.93E+01 |
| *F*22 | 2.50E+03±3.86E+02 | 4.56E+03±6.07E+02 | **1.14E+02±3.60E+01** | 2.90E+02±1.22E+02 | 1.23E+02±1.63E+01 | 1.72E+03±7.06E+02 | 2.56E+02±1.46E+02 |
| *F*23 | 5.81E+03±5.04E+02 | 4.18E+03±9.22E+02 | 4.82E+03±4.72E+02 | 4.34E+03±3.56E+02 | 5.00E+03±4.06E+02 | 5.28E+03±6.14E+02 | **3.84E+03±1.08E+03** |
| *F*24 | **2.02E+02±1.40E+00** | 2.92E+02±1.90E+01 | 2.26E+02±8.52E+00 | 3.03E+02±2.66E+00 | 2.51E+02±1.38E+01 | 2.47E+02±1.54E+01 | 2.13E+02±7.74E+00 |
| *F*25 | **2.30E+02±2.07E+01** | 2.99E+02±6.89E+00 | 2.62E+02±5.19E+00 | 2.96E+02±2.00E+00 | 2.75E+02±1.76E+01 | 2.80E+02±1.57E+01 | 2.61E+02±6.95E+00 |
| *F*26 | 2.18E+02±4.01E+01 | 3.29E+02±5.48E+01 | 2.10E+02±3.45E+01 | **2.00E+02±5.22E-04** | 2.10E+02±3.93E+01 | 2.52E+02±6.83E+01 | **2.00E+02±1.04E-03** |
| *F*27 | **3.26E+02±1.14E+01** | 1.19E+03±1.87E+02 | 5.66E+02±7.24E+01 | 1.19E+03±1.20E+02 | 1.00E+03±7.44E+01 | 7.64E+02±1.00E+02 | 5.83E+02±1.11E+02 |
| *F*28 | **3.00E+02±2.24E-05** | **3.00E+02±0.00E+00** | **3.00E+02±0.00E+00** | 2.96E+02±2.80E+01 | **3.00E+02±0.00E+00** | 4.02E+02±3.90E+02 | **3.00E+02±3.53E-13** |

**TABLE S8** Experimental Results of SPSRDEMMS , DEcfbLS, SMADE, SHADE, jDEsoo , MDE-PBX and EFADE over 51 Independent Runs on 28 Test Functions of 30 Variables with 300,000 FES

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Function | SPSRDEMMS [51]  Mean Error ±Std Dev | DEcfbLS [37]  Mean Error ±Std Dev | SMADE [6]  Mean Error ±Std Dev | SHADE [45]  Mean Error ±Std Dev | jDEsoo [3]  Mean Error ±Std Dev | MDE-PBX [6]  Mean Error ±Std Dev | EFADE  Mean Error ±Std Dev |
| *F*1 | **0.00E+00±0.00E+00** | **0.00E+00±0.00E+00** | **0.00E+00±0.00E+00** | **0.00E+00±0.00E+00** | **0.00E+00±0.00E+00** | **0.00E+00±0.00E+00** | **0.00E+00±0.00E+00** |
| *F*2 | 1.02E+05±5.30E+04 | 1.99E+05±1.07E+05 | **0.00E+00±0.00E+00** | 9.00E+03±7.47E+03 | 1.29E+05±9.68E+04 | 9.56E+04±6.16E+04 | 2.67E+04±1.53E+04 |
| *F*3 | 1.09E+07±1.39E+07 | 2.11E+06±4.64E+06 | 9.82E+03±4.94E+04 | **4.02E+01±2.13E+02** | 9.84E+06±1.85E+07 | 1.80E+07±3.12E+07 | 9.10E+05±2.41E+06 |
| *F*4 | 2.41E+00±3.28E+00 | 3.82E+02±5.12E+02 | **0.00E+00±0.00E+00** | 1.92E-04±3.01E-04 | 1.97E+04±1.26E+04 | 1.32E+01±5.46E+01 | 3.37E+00±3.78E+00 |
| *F*5 | **0.00E+00±0.00E+00** | **0.00E+00±0.00E+00** | **0.00E+00±0.00E+00** | **0.00E+00±0.00E+00** | 1.26E-08±1.37E-08 | **0.00E+00±0.00E+00** | **0.00E+00±0.00E+00** |
| *F*6 | 1.75E+01±1.14E+01 | 7.08E+00±4.17E+00 | 2.67E+00±7.85E+00 | **5.96E-01±3.73E+00** | 7.93E+00±7.59E+00 | 1.99E+01±2.22E+01 | 6.59E+00±4.19E+00 |
| *F*7 | 1.10E+01±6.18E+00 | 5.68E+01±1.66E+01 | 3.25E+01±1.61E+01 | **4.60E+00±5.39E+00** | 9.82E+00±6.50E+00 | 5.70E+01±1.77E+01 | 5.07E+00±3.62E+00 |
| *F*8 | 2.09E+01±5.01E-02 | 2.09E+01±9.44E-02 | 2.10E+01±4.80E-02 | **2.07E+01±1.76E-01** | 2.09E+01±4.51E-02 | 2.11E+01±5.94E−02 | 2.10E+01±4.65E-02 |
| *F*9 | 2.50E+01±3.45E+00 | 2.40E+01±2.86E+00 | 2.23E+01±3.57E+00 | 2.75E+01±1.77E+00 | 2.09E+01±7.18E+00 | 2.22E+01±4.80E+00 | **1.51E+01±3.63E+00** |
| *F*10 | 5.40E-02±4.02E-02 | 2.01E-02±1.73E-02 | **1.84E-02±1.34E-02** | 7.69E-02±3.58E-02 | 7.91E-02±4.35E-02 | 1.64E−01±1.20E−01 | 3.48E-02±2.04E-02 |
| *F*11 | **0.00E+00±0.00E+00** | 5.85E-02±2.34E-01 | 1.09E+01±4.18E+00 | **0.00E+00±0.00E+00** | **0.00E+00±0.00E+00** | 4.62E+01±1.44E+01 | **0.00E+00±0.00E+00** |
| *F*12 | 4.27E+01±1.36E+01 | 5.42E+01±8.80E+00 | 5.72E+01±1.70E+01 | **2.30E+01±3.73E+00** | 4.28E+01±1.57E+01 | 6.94E+01±2.00E+01 | 2.85E+01±6.48E+00 |
| *F*13 | 7.97E+01±2.09E+01 | 1.01E+02±1.86E+01 | 1.28E+02±3.50E+01 | 5.03E+01±1.34E+01 | 7.08E+01±2.39E+01 | 1.49E+02±3.66E+01 | **4.62E+01±2.18E+01** |
| *F*14 | 3.26E+00±6.13E+00 | 3.29E+01±1.35E+01 | 1.33E+02±1.27E+02 | **3.18E-02±2.33E-02** | 1.33E+00±1.35E+00 | 1.17E+03±3.95E+02 | 1.29E+00±9.16E-01 |
| *F*15 | 4.42E+03±6.98E+02 | 3.43E+03±1.08E+03 | 4.10E+03±8.47E+02 | **3.22E+03±2.64E+02** | 4.83E+03±5.98E+02 | 3.95E+03±6.57E+02 | 3.57E+03±9.05E+02 |
| *F*16 | 2.28E+00±3.74E-01 | 7.27E-01±8.93E-01 | **1.31E-01±7.57E-02** | 9.13E-01±1.85E-01 | 2.28E+00±3.68E-01 | 1.25E+00±6.19E−01 | 2.33E+00±3.22E-01 |
| *F*17 | **3.04E+01±7.58E-03** | 3.53E+01±1.14E+00 | 3.48E+01±1.52E+00 | **3.04E+01±3.83E-14** | **3.04E+01±4.46E-04** | 7.05E+01±1.24E+01 | 3.09E+01±3.71E-01 |
| *F*18 | 8.93E+01±2.07E+01 | 7.94E+01±1.10E+01 | 8.33E+01±2.06E+01 | **7.25E+01±5.58E+00** | 1.23E+02±1.85E+01 | 8.26E+01±1.89E+01 | 1.13E+02±5.84E+01 |
| *F*19 | 1.16E+00±1.79E-01 | 1.50E+00±1.74E-01 | 2.55E+00±5.18E-01 | 1.35E+00±1.20E-01 | **1.09E+00±2.85E-01** | 9.54E+00±5.54E+00 | 3.47E+00±2.98E-01 |
| *F*20 | 1.12E+01±5.24E-01 | 1.17E+01±6.52E-01 | **1.05E+01±8.07E-01** | **1.05E+01±6.04E-01** | 1.16E+01±4.41E-01 | 1.07E+01±7.75E−01 | 1.10E+01±7.74E-01 |
| *F*21 | **2.85E+02±6.94E+01** | 3.36E+02±9.78E+01 | 3.27E+02±8.65E+01 | 3.09E+02±5.65E+01 | 2.94E+02±8.30E+01 | 3.40E+02±7.62E+01 | 3.38E+02±8.93E+01 |
| *F*22 | 7.66E+01±4.88E+01 | 2.56E+03±9.13E+01 | 1.79E+02±4.50E+01 | 9.81E+01±2.52E+01 | **5.16E+01±5.78E+01** | 1.17E+03±4.92E+02 | 2.56E+02±1.46E+02 |
| *F*23 | 4.77E+03±7.75E+02 | 3.59E+03±4.99E+02 | 4.22E+03±8.74E+02 | **3.51E+03±4.11E+02** | 4.60E+03±5.43E+02 | 4.70E+03±7.70E+02 | 3.84E+03±1.08E+03 |
| *F*24 | 2.53E+02±8.97E+00 | 2.64E+02±9.15E+00 | 2.32E+02±2.57E+01 | **2.05E+02±5.29E+00** | 2.48E+02±7.48E+00 | 2.31E+02±8.60E+00 | 2.13E+02±7.74E+00 |
| *F*25 | 2.64E+02±8.34E+00 | 2.83E+02±5.79E+00 | 2.78E+02±9.90E+00 | **2.59E+02±1.96E+01** | 2.60E+02±6.86E+00 | 2.79E+02±1.38E+01 | 2.61E+02±6.95E+00 |
| *F*26 | 2.00E+02±4.94E-03 | 2.00E+02±6.62E-02 | 2.15E+02±5.25E+01 | 2.02E+02±1.48E+01 | 2.57E+02±6.96E+01 | 2.26E+02±5.15E+01 | **2.00E+02±1.04E-03** |
| *F*27 | 8.88E+03±9.19E+01 | 9.38E+02±5.75E+01 | 6.47E+02±1.37E+02 | 3.88E+02±1.09E+02 | 7.21E+02±8.69E+01 | 6.50E+02±1.04E+02 | 5.83E+02±1.11E+02 |
| *F*28 | **3.00E+02±0.00E+00** | **3.00E+02±0.00E+00** | 3.88E+02±3.23E+02 | **3.00E+02±0.00E+00** | **3.00E+02±0.00E+00** | 3.09E+02±1.50E+02 | **3.00E+02±3.53E-13** |

**TABLE S9** Experimental Results of GA-TPC, fK-PSO, CDASA, PLES, CMA-ES-RIS, CCPSO2 and EFADE over 51 Independent Runs on 28 Test Functions of 30 Variables with 300,000 FES

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Function | GA-TPC [13]  Mean Error ±Std Dev | fk-PSO[30]  Mean Error ±Std Dev | CDASA [22]  Mean Error ±Std Dev | PLES [35]  Mean Error ±Std Dev | CMA-ES-RIS [5]  Mean Error ±Std Dev | CCPSO2 [6]  Mean Error ±Std Dev | EFADE  Mean Error ±Std Dev |
| *F*1 | **0.00E+00±0.00E+00** | **0.00E+00±0.00E+00** | **0.00E+00±0.00E+00** | **0.00E+00±0.00E+00** | **0.00E+00±0.00E+00** | **0.00E+00±0.00E+00** | **0.00E+00±0.00E+00** |
| *F*2 | 1.55E+05±1.37E+05 | 1.59E+06±8.03E+05 | 9.52E+05±4.39E+05 | 1.34E+07±4.87E+06 | **0.00E+00±0.00E+00** | 9.95E+05±5.24E+05 | 2.67E+04±1.53E+04 |
| *F*3 | 3.28E+07±7.55E+07 | 2.40E+08±3.71E+08 | 4.54E+07±6.37E+07 | 1.93E+09±1.97E+09 | **2.24E+03±1.09E+04** | 5.59E+08±5.57E+08 | 9.10E+05±2.41E+06 |
| *F*4 | 9.07E-01±1.26E+00 | 4.70E+02±1.96E+02 | 1.83E-01±5.48E-01 | 4.47E+04±1.37E+04 | **0.00E+00±0.00E+00** | 5.57E+04±2.06E+04 | 3.37E+00±3.78E+00 |
| *F*5 | **0.00E+00±0.00E+00** | **0.00E+00±0.00E+00** | 8.19E-06±3.19E-06 | **0.00E+00±0.00E+00** | **0.00E+00±0.00E+00** | 2.62E−08±6.05E-08 | **0.00E+00±0.00E+00** |
| *F*6 | 2.04E+01±7.92E+00 | 2.99E+01±1.76E+01 | 3.54E+01±2.67E+01 | 7.77E+01±2.64E+01 | **6.94E-04±1.99E-03** | 2.19E+01±2.27E+01 | 6.59E+00±4.19E+00 |
| *F*7 | 4.58E+01±2.97E-01 | 6.39E+01±3.09E+01 | 6.95E+01±3.05E+01 | 1.18E+02±3.14E+01 | 4.81E+01±2.93E+01 | 1.15E+02±3.11E+01 | **5.07E+00±3.62E+00** |
| *F*8 | 2.10E+01±5.34E-02 | **2.09E+01±6.28E-02** | **2.09E+01±8.53E-02** | **2.09E+01±8.37E-02** | **2.09E+01±8.11E-02** | 2.10E+01±4.60E−02 | 2.10E+01±4.65E-02 |
| *F*9 | 3.70E+01±6.44E+00 | 1.85E+01±2.69E+00 | 2.34E+01±4.19E+00 | 3.31E+01±3.27E+00 | 2.37E+01±1.93E+00 | 2.84E+01±2.08E+00 | **1.51E+01±3.63E+00** |
| *F*10 | 8.35E-02±4.66E-02 | 2.29E-01±1.32E-01 | 3.54E-02±1.97E-02 | 1.18E+01±7.08E+00 | **8.31E-03±5.41E-03** | 1.48E−01±6.90E−02 | 3.48E-02±2.04E-02 |
| *F*11 | 2.13E+01±1.07E+01 | 2.36E+01±7.60E-01 | 1.71E+00±1.19E+00 | 1.65E+02±4.00E+01 | 2.54E+01±6.30E+00 | 1.19E−01±2.90E−01 | **0.00E+00±0.00E+00** |
| *F*12 | 3.77E+01±9.55E+00 | 5.64E+01±1.51E+01 | 1.17E+02±3.18E+01 | 2.15E+02±5.95E+01 | 7.94E+01±4.35E+1 | 2.12E+02±5.24E+01 | **2.85E+01±6.48E+00** |
| *F*13 | 8.09E+01±1.95E+01 | 1.23E+02±2.19E+01 | 1.86E+02±3.71E+01 | 3.29E+02±6.10E+01 | 1.56E+02±5.36E+01 | 2.44E+02±3.44E+01 | **4.62E+01±2.18E+01** |
| *F*14 | 1.01E+03±4.74E+02 | 7.04E+02±2.38E+02 | 6.64E+02±2.85E+02 | 2.61E+03±5.98E+02 | 7.92E+02±2.19E+02 | 4.48E+00±2.87E+00 | **1.29E+00±9.16E-01** |
| *F*15 | 4.09E+03±6.93E+02 | 3.42E+03±5.16E+02 | 3.87E+03±6.67E+02 | 4.39E+03±7.14E+02 | **3.13E+03±4.53E+02** | 3.85E+03±4.52E+02 | 3.57E+03±9.05E+02 |
| *F*16 | 2.72E+00±5.05E-01 | 8.48E-01±2.20E-01 | 3.26E-01±1.37E-01 | 1.32E+00±5.26E-01 | **1.07E-01±6.71E-02** | 2.16E+00±3.76E−01 | 2.33E+00±3.22E-01 |
| *F*17 | 6.00E+01±1.10E+01 | 5.26E+01±7.11E+00 | 3.39E+01±4.53E+00 | 2.43E+02±6.02E+01 | 5.50E+01±5.19E+00 | **3.07E+01±3.03E+00** | 3.09E+01±3.71E-01 |
| *F*18 | 7.45E+01±1.80E+01 | **6.81E+01±9.68E+00** | 1.96E+02±5.22E+01 | 2.57E+02±6.22E+01 | 1.89E+02±2.71E+01 | 2.31E+02±5.43E+01 | 1.13E+02±5.84E+01 |
| *F*19 | 4.14E+00±1.99E+00 | 3.12E+00±9.83E-01 | 2.10E+00±5.21E-01 | 2.41E+01±1.52E+01 | 2.80E+00±6.35E-01 | **7.77E−01±1.58E−01** | 3.47E+00±2.98E-01 |
| *F*20 | 1.37E+01±4.78E-01 | 1.20E+01±9.26E-01 | 1.48E+01±6.18E-01 | 1.43E+01±7.21E-01 | 1.43E+01±5.69E-01 | 1.35E+01±5.50E−01 | **1.10E+01±7.74E-01** |
| *F*21 | 2.79E+02±7.89E+01 | 3.11E+02±7.92E+01 | 2.77E+02±7.22E+01 | 3.30E+02±8.87E+01 | 1.86E+02±3.97E+01 | **2.37E+02±6.71E+01** | 3.38E+02±8.93E+01 |
| *F*22 | 1.15E+03±3.86E+02 | 8.59E+02±3.10E+02 | 4.89E+02±2.07E+02 | 3.25E+03±6.48E+02 | 1.17E+03±2.90E+02 | **9.87E+01±6.70E+01** | 2.56E+02±1.46E+02 |
| *F*23 | 4.28E+03±6.72E+02 | **3.57E+03±5.90E+02** | 5.41E+03±8.62E+02 | 5.00E+03±9.73E+02 | 4.03E+03±5.38E+02 | 4.99E+03±6.31E+02 | 3.84E+03±1.08E+03 |
| *F*24 | 2.79E+02±1.41E+01 | 2.40E+02±1.10E-01 | 2.98E+02±4.05E+01 | 2.97E+02±1.28E+01 | 2.59E+02±1.74E+01 | 2.80E+02±6.34E+00 | **2.13E+02±7.74E+00** |
| *F*25 | 3.00E+02±8.90E+00 | **2.49E+02±7.82E+00** | 3.15E+02±6.57E+00 | 3.27E+02±1.26E+01 | 2.82E+02±8.41E+00 | 2.98E+02±6.94E+00 | 2.61E+02±6.95E+00 |
| *F*26 | 3.21E+02±6.48E+01 | 2.95E+02±7.06E+01 | 2.91E+02±1.08E+02 | 2.46E+02±7.91E+01 | **1.97E+02±1.20E+01** | 2.00E+02±6.76E−01 | 2.00E+02±1.04E-03 |
| *F*27 | 1.08E+03±1.47E+02 | 7.76E+02±7.11E+01 | 1.08E+03±2.85E+02 | 1.15E+03±9.14E+01 | 7.49E+02±1.85E+02 | 1.04E+03±8.09E+01 | **5.83E+02±1.11E+02** |
| *F*28 | 3.00E+02±0.00E+00 | 4.01E+02±3.48e+02 | 3.87E+02±3.14E+02 | 2.07E+03±5.65E+02 | 5.39E+02±1.32E+03 | 4.35E+02±5.10E+02 | **3.00E+02±0.00E+00** |

**TABLE S10** Experimental Results of ADE , DE-APC, SaDE, TLBSaDE, b6e6rl, DE-IPS and EFADE over 51 Independent Runs on 28 Test Functions of 50 Variables with 500,000 FES

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Function | ADE [7]  Mean Error ±Std Dev | DE-APC [14]  Mean Error ±Std Dev | SaDE [40]  Mean Error ±Std Dev | TLBSaDE [2]  Mean Error ±Std Dev | b6e6rl [46]  Mean Error ±Std Dev | DE-IPS [32]  Mean Error ±Std Dev | EFADE  Mean Error ±Std Dev |
| *F*1 | **0.00E+00±0.00E+00** | **0.00E+00±0.00E+00** | **0.00E+00±0.00E+00** | **0.00E+00±0.00E+00** | **0.00E+00±0.00E+00** | 5.20E-03±1.62E-03 | **0.00E+00±0.00E+00** |
| *F*2 | 2.04E+05±7.67E+04 | 3.59E+05±1.67E+05 | 1.93E+05±6.94E+04 | **1.68E+05±2.85E+04** | 3.23E+05±1.56E+05 | 2.99E+05±1.40E+05 | 1.72E+05±5.48E+04 |
| *F*3 | 7.48E+06±7.60E+06 | 6.98E+06±1.27E+07 | 3.33E+07±3.85E+07 | **7.08E+05±3.59E+05** | 8.61E+06±2.33E+07 | 2.40E+07±2.87E+07 | 5.70E+06±6.70E+06 |
| *F*4 | 2.20E+02±9.58E+01 | 1.53E+00±1.42E+00 | 3.45E+02±4.63E+02 | 6.57E+02±1.76E+02 | **2.32E-01±3.12E-01** | 1.08E+02±4.83E+01 | 6.16E+00±5.24E+00 |
| *F*5 | 1.39E-03±1.87E-03 | 2.93E+04±1.21E+05 | **0.00E+00±0.00E+00** | **0.00E+00±0.00E+00** | **0.00E+00±0.00E+00** | 6.89E-03±1.31E-03 | **0.00E+00±0.00E+00** |
| *F*6 | 7.35E+01±2.80E+01 | 3.90E+01±1.54E+00 | 4.51E+01±9.31E+00 | 4.07E+01±6.96E+00 | 4.34E+01±1.43E-14 | **3.42E+01±2.15E+01** | 4.34E+01±7.83E-10 |
| *F*7 | 2.07E+01±9.16E+00 | 3.66E+01±1.61E+01 | 4.84E+01±1.04E+01 | 4.96E+01±5.31E+00 | 8.26E+01±1.55E+01 | 6.49E+01±1.91E+0l | **1.80E+01±7.26E+00** |
| *F*8 | 2.11E+01±3.54E-02 | 2.11E+01±3.16E-02 | 2.11E+01±3.65E-02 | **2.10E+01±2.71E-02** | 2.11E+01±4.65E-02 | 2.11E+01±3.83E-02 | 2.11E+01±3.68E-02 |
| *F*9 | **2.60E+01±3.05E+00** | 6.09E+01±1.66E+01 | 3.63E+01±5.40E+00 | 6.08E+01±1.66E+00 | 5.67E+01±2.57E+00 | 3.49E+01±4.16E+00 | 3.28E+01±4.67E+00 |
| *F*10 | 5.98E-01±3.43E-01 | 6.71E-02±4.18E-02 | 1.62E-01±9.17E-02 | **1.76E-02±6.85E-03** | 3.54E-02±1.85E-02 | 4.78E-02±3.02E-02 | 6.98E-02±3.74E-02 |
| *F*11 | 1.68E+02±4.08E+01 | 3.44E+01±1.45E+01 | 5.85E-01±1.85E+00 | **0.00E+00±0.00E+00** | **0.00E+00±0.00E+00** | 1.94E+02±3.62E+01 | 1.95E-02±1.39E-01 |
| *F*12 | 2.57E+02±2.25E+01 | 5.96E+01±1.69E+01 | 1.03E+02±1.85E+01 | 1.20E+02±8.17E+00 | 1.89E+02±2.40E+01 | 1.85E+02±4.03E+01 | **6.42E+01±1.34E+01** |
| *F*13 | 3.06E+02±2.77E+01 | 1.55E+02±3.58E+01 | 2.04E+02±3.75E+01 | 2.19E+02±1.74E+01 | 2.52E+02±3.07E+01 | 4.09E+02±6.67E+01 | **1.56E+02±3.82E+01** |
| *F*14 | 7.34E+03±5.82E+02 | 9.96E+03±4.32E+02 | 4.34E-01±8.44E-01 | 8.25E+02±1.07E+02 | **3.65E-02±2.06E-02** | 4.56E+03±2.30E+03 | 4.95E+02±1.41E+02 |
| *F*15 | 1.25E+04±5.61E+02 | 9.34E+03±3.33E+03 | 1.02E+04±6.93E+02 | **7.69E+03±2.86E+02** | 9.26E+03±4.57E+02 | 1.03E+04±7.24E+02 | 8.09E+03±2.50E+03 |
| *F*16 | 3.39E+00±3.22E-01 | 3.24E+00±3.74E-01 | 3.20E+00±2.95E-01 | **1.80E+00±2.00E-01** | 2.30E+00±6.41E-01 | 2.52E+00±3.17E-01 | 3.24E+00±3.13E-01 |
| *F*17 | 2.38E+02±2.21E+01 | 1.72E+02±1.59E+01 | 5.08E+01±1.05E-02 | 7.95E+01±1.81E+00 | **5.07E+01±6.46E-14** | 2.19E+02±4.14E+01 | 8.89E+01±3.64E+00 |
| *F*18 | 3.87E+02±1.81E+01 | **1.04E+02±1.41E+01** | 2.64E+02±1.82E+01 | 1.81E+02±7.64E+00 | 3.28E+02±3.84E+01 | 5.08E+02±4.78E+01 | 1.50E+02±1.07E+02 |
| *F*19 | 2.12E+01±4.77E+00 | 5.08E+00±1.81E+00 | 5.78E+00±9.42E-01 | 7.67E+00±4.78E-01 | **3.43E+00±1.87E-01** | 1.43E+01±4.19E+00 | 1.01E+01±5.18E-01 |
| *F*20 | 2.07E+01±4.07E-01 | 2.23E+01±9.04E-01 | 2.04E+01±6.98E-01 | **1.93E+01±3.55E-01** | 2.14E+01±3.86E-01 | 2.26E+01±1.55E+00 | 2.07E+01±9.65E-01 |
| *F*21 | 9.65E+02±1.44E+02 | 6.81E+02±4.24E+02 | 7.74E+02±3.77E+02 | **3.12E+02±2.45E+02** | 4.60E+02±4.10E+02 | 8.71E+02±3.20E+02 | 3.53E+02±3.19E+02 |
| *F*22 | 7.72E+03±8.46E+02 | 1.06E+04±4.90E+02 | 7.72E+01±1.18E+02 | 2.58E+03±3.82E+02 | **3.60E+01±2.44E+01** | 4.70E+03±1.46E+03 | 8.84E+02±5.22E+02 |
| *F*23 | 1.176E+04±1.47E+03 | 9.09E+03±3.22E+03 | 1.03E+04±8.44E+02 | 9.68E+03±3.99E+02 | 9.77E+03±5.33E+02 | 1.04E+04±8.15E+02 | **7.35E+03±1.53E+03** |
| *F*24 | 2.78E+02±1.82E+01 | 3.84E+02±8.07E+00 | 2.76E+02±1.23E+01 | 3.98E+02±2.27E+00 | 3.33E+02±1.54E+01 | 3.12E+02±1.71E+01 | **2.45E+02±1.10E+01** |
| *F*25 | 3.54E+02±1.72E+01 | 3.83E+02±4.00E+00 | **3.23E+02±1.08E+00** | 3.79E+02±2.88E+00 | 3.64E+02±2.08E+01 | 3.87E+02±1.90E+01 | 3.27E+02±1.15E+01 |
| *F*26 | 3.47E+02±6.00E+01 | 4.09E+02±4.81E+01 | 2.83E+02±8.98E+01 | **2.01E+02±1.72E+00** | 3.28E+02±1.21E+02 | 3.91E+02±3.04E+01 | 2.14E+02±4.99E+01 |
| *F*27 | 1.10E+03±1.19E+01 | 2.14E+03±4.54E+01 | 1.16E+03±1.01E+02 | 2.17E+03±3.21E+01 | 1.73E+03±1.07E+02 | 1.35E+03±1.15E+02 | **1.07E+03±1.38E+02** |
| *F*28 | 4.62E+02±4.39E+02 | 7.47E+02±9.61E+02 | 5.23E+02±6.14E+02 | **4.00E+02±4.37E-13** | **4.00E+02±0.00E+00** | 8.44E+02±1.12E+03 | **4.00E+02±2.76E-13** |

**TABLE S11**Experimental Results of SPSRDEMMS, DEcfbLS, SMADE, SHADE, jDEsoo , MDE-PBX and EFADE over 51 Independent Runs on 28 Test Functions of 50 Variables with 500,000 FES

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Function | SPSRDEMMS [51]  Mean Error ±Std Dev | DEcfbLS [37]  Mean Error ±Std Dev | SMADE [6]  Mean Error ±Std Dev | SHADE [45]  Mean Error ±Std Dev | jDEsoo [3]  Mean Error ±Std Dev | MDE-PBX [6]  Mean Error ±Std Dev | EFADE  Mean Error ±Std Dev |
| *F*1 | **0.00E+00±0.00E+00** | **0.00E+00±0.00E+00** | **0.00E+00±0.00E+00** | **0.00E+00±0.00E+00** | 2.76E-08±3.24E-08 | **0.00E+00±0.00E+00** | **0.00E+00±0.00E+00** |
| *F*2 | 5.65E+05±2.56E+05 | 6.55E+05±3.74E+05 | **0.00E+00±0.00E+00** | 2.65E+04±1.13E+04 | 6.05E+05±2.46E+05 | 4.37E+05±1.64E+05 | 1.72E+05±5.48E+04 |
| *F*3 | 4.44E+07±4.56E+07 | 2.20E+08±2.14E+08 | **3.81E+05±1.35E+06** | 8.79E+05±1.96E+06 | 4.78E+07±6.86E+07 | 8.45E+07±1.46E+08 | 5.70E+06±6.70E+06 |
| *F*4 | 5.17E+00±4.72E+00 | 1.21E+03±1.94E+03 | 0.00E+00±0.00E+00 | **1.61E-03±1.41E-03** | 8.34E+04±1.56E+04 | 3.05E+01±6.62E+01 | 6.16E+00±5.24E+00 |
| *F*5 | **0.00E+00±0.00E+00** | **0.00E+00±0.00E+00** | **0.00E+00±0.00E+00** | **0.00E+00±0.00E+00** | 2.43E-06±1.14E-06 | **0.00E+00±0.00E+00** | **0.00E+00±0.00E+00** |
| *F*6 | 4.37E+01±1.11E+00 | 4.34E+01±0.00E+00 | 4.30E+01±6.28E+00 | **4.28E+01±5.52E+00** | 4.29E+01±3.71E+00 | 5.48E+01±2.12E+01 | 4.34E+01±7.83E-10 |
| *F*7 | 3.17e+01±9.20E+00 | 1.05E+02±9.53E+00 | 4.32E+01±1.66E+01 | 2.33E+01±9.32E+00 | 2.94E+01±1.29E+01 | 6.59E+01±1.06E+01 | **1.80E+01±7.26E+00** |
| *F*8 | 2.11E+01±4.19E-02 | 2.11E+01±9.52E-02 | 2.11E+01±3.85E-02 | **2.09E+01±1.68E-01** | 2.11E+01±3.83E-02 | 2.12E+01±4.44E−02 | 2.11E+01±3.68E-02 |
| *F*9 | 5.12E+01±4.97E+00 | 4.71E+01±3.17E+00 | 4.36E+01±4.06E+00 | 5.54E+01±1.98E+00 | 5.33E+01±9.78E+00 | 4.32E+01±7.71E+00 | **3.28E+01±4.67E+00** |
| *F*10 | 5.86E-02±3.89E-02 | 3.21E-02±1.67E-02 | **2.47E-02±1.48E-02** | 7.36E-02±3.67E-02 | 1.47E-01±7.65E-02 | 1.34E−01±1.23E−01 | 6.98E-02±3.74E-02 |
| *F*11 | **0.00E+00±0.00E+00** | 4.64E+00±4.38E+00 | 4.81E+01±1.49E+01 | **0.00E+00±0.00E+00** | 1.95E-02±1.39E-01 | 1.24E+02±2.87E+01 | 1.95E-02±1.39E-01 |
| *F*12 | 8.74E+01±2.16E+01 | 1.34E+02±3.55E+01 | 1.57E+02±4.52E+01 | **5.86E+01±1.11E+01** | 9.71E+01±2.56E+01 | 1.58E+02±3.25E+01 | 6.42E+01±1.34E+01 |
| *F*13 | 1.58E+02±2.60E+01 | 2.47E+02±4.87E+01 | 3.35E+02±5.63E+01 | **1.45E+02±1.95E+01** | 1.76E+02±2.37E+01 | 3.24E+02±4.74E+01 | 1.56E+02±3.82E+01 |
| *F*14 | 2.07E+01±1.35E+01 | 2.31E+02±8.64E+01 | 3.41E+02±2.05E+02 | **3.45E-02±1.93E-02** | 8.01E+00±6.76E+00 | 2.65E+03±8.86E+02 | 4.95E+02±1.41E+02 |
| *F*15 | 8.63E+03±8.47E+02 | **6.25E+03±1.40E+03** | 8.54E+03±9.77E+02 | 6.82E+03±4.41E+02 | 9.48E+03±1.06E+03 | 7.46E+03±7.95E+02 | 8.09E+03±2.50E+03 |
| *F*16 | 2.83E+00±6.01E-01 | 1.63E+00±0.00E+00 | **8.96E-02±4.24E-02** | 1.28E+00±2.07E-01 | 3.13E+00±3.94E-01 | 1.75E+00±7.40E−01 | 3.24E+00±3.13E-01 |
| *F*17 | 5.08E+01±2.44E-02 | 6.58E+01±2.31E+00 | 6.57E+01±5.27E+00 | **5.07E+01±4.27E-14** | 5.08E+01±3.24E-01 | 1.75E+02±3.72E+01 | 8.89E+01±3.64E+00 |
| *F*18 | 1.57E+02±3.64E+01 | 1.57E+02±2.09E+01 | 1.93E+02±3.46E+01 | **1.37E+02±1.29E+01** | 2.18E+02±3.11E+01 | 1.85E+02±3.40E+01 | 1.50E+02±1.07E+02 |
| *F*19 | **1.96E+00±3.13E-01** | 2.95E+00±2.89E-01 | 5.43E+00±1.07E+00 | 2.64E+00±2.83E-01 | 2.24E+00±5.46E-01 | 4.25E+01±2.66E+01 | 1.01E+01±5.18E-01 |
| *F*20 | 2.05E+01±7.92E-01 | 2.17E+01±8.51E-01 | 1.92E+01±8.86E-01 | **1.92E+01±7.70E-01** | 2.15E+01±4.31E-01 | 2.00E+01±9.04E−01 | 2.07E+01±9.65E-01 |
| *F*21 | 6.06E+02±4.42E+02 | 5.24E+02±3.98E+02 | 8.46E+02±3.43E+02 | 8.45E+02±3.63E+02 | 8.24E+02±4.01E+02 | 9.22E+02±3.06E+02 | **3.53E+02±3.19E+02** |
| *F*22 | 3.94E+01±2.97E+01 | 6.89E+02±1.50E+02 | 3.39E+02±2.24E+02 | **1.33E+01±7.12E+00** | 3.10E+01±3.89E+01 | 3.09E+03±9.98E+02 | 8.84E+02±5.22E+02 |
| *F*23 | 8.90E+03±9.56E+02 | 7.77E+03±2.18E+03 | 9.89E+03±1.90E+03 | 7.63E+03±6.58E+02 | 9.47E+03±1.02E+03 | 8.88E+03±1.20E+03 | **7.35E+03±1.53E+03** |
| *F*24 | 3.11E+02±1.43E+01 | 3.31E+02±7.40E+00 | 3.00E+02±1.20E+01 | **2.34E+02±1.01E+01** | 2.88E+02±1.20E+01 | 2.87E+02±1.47E+01 | 2.45E+02±1.10E+01 |
| *F*25 | 3.35E+02±1.29E+01 | 3.60E+02±9.94E+00 | 3.68E+02±1.36E+01 | 3.40E+02±3.08E+01 | **3.16E+02±1.09E+01** | 3.69E+02±1.78E+01 | 3.27E+02±1.15E+01 |
| *F*26 | 2.87E+02±1.09E+02 | **2.00E+02±3.37E-02** | 2.91E+02±9.70E+01 | 2.57E+02±8.07E+01 | 3.97E+02±2.36E+01 | 3.50E+02±7.93E+01 | 2.14E+02±4.99E+01 |
| *F*27 | 1.53E+03±1.45E+02 | 1.55E+03±9.50E+01 | 1.18E+03±1.67E+02 | **9.35E+02±3.07E+02** | 1.16E+03±1.24E+02 | 1.24E+03±1.56E+02 | 1.07E+03±1.38E+02 |
| *F*28 | 7.54E+02±9.78E+02 | **4.00E+02±0.00E+00** | 1.07E+03±1.27E+03 | 4.58E+02±4.13E+02 | 9.43E+02±1.18E+03 | 4.33E+02±3.26E+02 | **4.00E+02±0.00E+00** |

**TABLE S12** Experimental Results of GA-TPC, fK-PSO, CDASA, PLES, CMA-ES-RIS , CCPSO2 and EFADE over 51 Independent Runs on 28 Test Functions of 50 Variables with 500,000 FES

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Function | GA-TPC [13]  Mean Error ±Std Dev | fk-PSO[30]  Mean Error ±Std Dev | CDASA [22]  Mean Error ±Std Dev | PLES [35]  Mean Error ±Std Dev | CMA-ES-RIS [5]  Mean Error ±Std Dev | CCPSO2 [6]  Mean Error ±Std Dev | EFADE  Mean Error ±Std Dev |
| *F*1 | **0.00E+00±0.00E+00** | **0.00E+00±0.00E+00** | **0.00E+00±0.00E+00** | **0.00E+00±0.00E+00** | **0.00E+00±0.00E+00** | **0.00E+00±0.00E+00** | **0.00E+00±0.00E+00** |
| *F*2 | 4.76E+05±2.14E+05 | 2.76E+06±9.64E+05 | 1.93E+06±6.60E+05 | 1.58E+07±5.97E+06 | 0.00E+00±0.00E+00 | 1.85E+06±9.33E+05 | 1.72E+05±5.48E+04 |
| *F*3 | 1.05E+08±1.49E+08 | 9.68E+08±9.65E+08 | 2.18E+08±2.05E+08 | 5.06E+09±4.59E+09 | **2.83E+05±7.80E+05** | 1.98E+09±2.09E+09 | 5.70E+06±6.70E+06 |
| *F*4 | 3.33E+00±4.88E+00 | 5.25E+02±1.82E+02 | 1.58E-02±3.95E-02 | 5.43E+04±1.23E+04 | **0.00E+00±0.00E+00** | 1.00E+05±3.57E+04 | 6.16E+00±5.24E+00 |
| *F*5 | 4.77E+04±1.70E+05 | 0.00E+00±0.00E+00 | 8.39E-06±2.08E-06 | **0.00E+00±0.00E+00** | 3.54E-08±1.44E-08 | **0.00E+00±0.00E+00** | **0.00E+00±0.00E+00** |
| *F*6 | 4.72E+01±1.40E+01 | 5.51E+01±2.25E+01 | 4.80E+01±1.49E+01 | 9.70E+01±4.30E+01 | **9.51E+00±1.41E+01** | 4.35E+01±1.36E+01 | 4.34E+01±7.83E-10 |
| *F*7 | 4.16E+01±1.83E+01 | 7.81E+01±2.21E+01 | 1.04E+02±1.73E+01 | 1.28E+02±2.18E+01 | 4.81E+01±2.16E+01 | 1.37E+02±2.31E+01 | **1.80E+01±7.26E+00** |
| *F*8 | 2.12E+01±3.98E-02 | 2.11E+01±4.81E-02 | 2.11E+01±7.10E-02 | 2.11E+01±5.99E-02 | **2.10E+01±6.02E-02** | 2.11E+01±4.49E−02 | 2.11E+01±3.68E-02 |
| *F*9 | 7.43E+01±3.97E+00 | 3.85E+01±5.31E+00 | 4.66E+01±4.81E+00 | 6.15E+01±4.53E+00 | 4.72E+01±2.76E+00 | 5.79E+01±4.39E+00 | **3.28E+01±4.67E+00** |
| *F*10 | 1.05E-01±7.09E-02 | 2.13E-01±1.33E-01 | 4.66E-02±2.72E-02 | 2.99E+01±1.41E+01 | **8.60E-03±5.86E-03** | 1.24E−01±4.62E−02 | 6.98E-02±3.74E-02 |
| *F*11 | 5.57E+01±2.23E+01 | 8.61E+01±1.99E+01 | 2.15E+00±1.62E+00 | 3.53E+02±6.47E+01 | 5.36E+01±1.31E+01 | 4.31E−01±5.74E−01 | **1.95E-02±1.39E-01** |
| *F*12 | 9.83E+01±2.45E+01 | 1.45E+02±2.88E+01 | 2.67E+02±6.06E+01 | 4.41E+02±7.76E+01 | 2.66E+02±1.02E+02 | 4.46E+02±7.92E+01 | **6.42E+01±1.34E+01** |
| *F*13 | 1.93E+02±5.30E+01 | 2.74E+02±4.53E+01 | 4.11E+02±5.09E+01 | 6.38E+02±8.99E+01 | 4.56E+02±8.54E+01 | 5.49E+02±6.67E+01 | **1.56E+02±3.82E+01** |
| *F*14 | 2.55E+03±1.14E+03 | 1.96E+03±4.60E+02 | 1.07E+03±3.74E+02 | 5.06E+03±8.48E+02 | 1.49E+03±3.07E+02 | **6.45E+00±3.20E+00** | 4.95E+02±1.41E+02 |
| *F*15 | 9.84E+03±3.19E+03 | 6.63E+03±8.09E+02 | 7.33E+03±8.08E+02 | 8.51E+03±1.07E+03 | **6.30E+03±6.74E+02** | 7.95E+03±7.11E+02 | 8.09E+03±2.50E+03 |
| *F*16 | 3.67E+00±3.88E-01 | **1.30E+00±3.04E-01** | 4.97E-01±1.48E-01 | 2.07E+00±5.77E-01 | 8.66E-02±4.20E-02 | 2.39E+00±5.90E−01 | 3.24E+00±3.13E-01 |
| *F*17 | 1.15E+02±2.00E+01 | 1.16E+02±1.58E+01 | 5.81E+01±7.36E+00 | 6.00E+02±1.01E+02 | 1.02E+02±1.04E+01 | **5.14E+01±2.84E−01** | 8.89E+01±3.64E+00 |
| *F*18 | **1.15E+02±1.02E+02** | 1.32E+02±1.62E+01 | 4.43E+02±1.01E+02 | 6.33E+02±1.32E+02 | 4.18E+02±5.24E+01 | 4.94E+02±1.08E+02 | 1.50E+02±1.07E+02 |
| *F*19 | 1.68E+02±3.17E+00 | 7.82E+00±2.34E+00 | **3.69E+00±7.05E-01** | 1.27E+02±9.07E+01 | 5.04E+00±9.33E-01 | 1.40E+00±2.19E−01 | 1.01E+01±5.18E-01 |
| *F*20 | 8.92E+00±8.02E-01 | 2.06E+01±1.08E+00 | 2.43E+01±9.88E-01 | 2.37E+01±9.33E-01 | 2.43E+01±5.49E-01 | 2.28E+01±7.85E−01 | 2.07E+01±9.65E-01 |
| *F*21 | **2.35E+01±3.63E+02** | 8.34E+02±3.55E+02 | 6.86E+02±3.79E+02 | 7.58E+02±4.03E+02 | 2.85E+02±2.20E+02 | 3.27E+02±2.64E+02 | 3.53E+02±3.19E+02 |
| *F*22 | 7.93E+02±1.89E+03 | 2.22E+03±6.06E+02 | 7.32E+02±2.79E+02 | 6.49E+03±1.15E+03 | 2.39E+03±3.67E+02 | 7.58E+01±8.58E+01 | 8.84E+02±5.22E+02 |
| *F*23 | **3.51E+03±3.70E+03** | 7.40E+03±8.61E+02 | 1.01E+04±1.31E+03 | 1.02E+04±1.27E+03 | 8.37E+03±1.01E+03 | 1.05E+04±1.11E+03 | 7.35E+03±1.53E+03 |
| *F*24 | 1.08E+04±2.18E+01 | 3.00E+02±1.47E+01 | 3.74E+02±6.58E+1 | 3.82E+02±1.33E+01 | 3.22E+02±1.95E+01 | 3.56E+02±9.89E+00 | **2.45E+02±1.10E+01** |
| *F*25 | 3.79E+02±4.42E+00 | **3.00E+02±1.27E+01** | 4.03E+02±6.16E+00 | 4.44E+02±1.91E+01 | 3.66E+02±9.94E+00 | 3.96E+02±1.19E+01 | 3.27E+02±1.15E+01 |
| *F*26 | 3.89E+02±4.11E+01 | 3.90E+02±4.04E+01 | 3.44E+02±1.08+02 | 4.26E+02±9.14E+01 | **2.00E+02±3.25E-02** | 2.09E+02±3.92E+01 | 2.14E+02±4.99E+01 |
| *F*27 | **4.27E+02±2.36E+02** | 1.32E+03±1.23E+02 | 1.59E+03±3.07E+02 | 2.03E+03±1.11E+02 | 1.25E+03±2.08E+02 | 1.79E+03±8.78E+01 | 1.07E+03±1.38E+02 |
| *F*28 | 2.08E+03±4.23E+02 | 1.63E+03±1.53e+03 | 1.03E+03±1.28E+03 | 4.01E+03±1.69E+03 | 1.24E+03±1.53E+03 | 6.33E+02±8.95E+02 | **4.00E+02±0.00E+00** |

Table S13 Comparison between EFADE , EFADE-1, EFADE-2, EFADE-3 and EFADE-4 on 50D problems.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Function** |  | **EFADE** | **EFADE-1** | **EFADE-2** | **EFADE-3** | **EFADE-4** |
| **1** | 0 | **0.00E+00±0.00E+00** | **0.00E+00±0.00E+00** | **0.00E+00±0.00E+00** | **0.00E+00±0.00E+00** | **0.00E+00±0.00E+00** |
| **2** | 0 | 1.72E+05±5.48E+04 | **1.64E+05±6.06E+04** | 1.44E+06±5.92E+05 | 2.13E+05±7.36E+04 | 2.51E+05±1.09E+05 |
| **3** | 0 | 5.70E+06±6.70E+06 | 2.40E+07±2.42E+07 | 1.50E+10±3.94E+09 | **3.39E+06±3.37E+06** | 8.96E+06±1.10E+07 |
| **4** | 0 | 6.16E+00±5.24E+00 | **5.84E+00±4.95E+00** | 2.29E+03±2.23E+03 | 1.79E+01±1.22E+01 | 1.54E+03±8.58E+02 |
| **5** | 0 | **0.00E+00±0.00E+00** | **0.00E+00±0.00E+00** | **0.00E+00±0.00E+00** | **0.00E+00±0.00E+00** | **0.00E+00±0.00E+00** |
| **6** | 0 | **4.34E+01±7.83E-10** | 4.61E+01±2.14E+01 | **4.34E+01±2.77E-07** | **4.34E+01±3.17E-12** | **4.38E+01±1.35E+00** |
| **7** | 0 | 1.80E+01±7.26E+00 | 6.82E+01±1.23E+01 | 1.23E+02±1.18E+01 | 1.75E+01±5.40E+00 | **1.20E+01±4.56E+00** |
| **8** | 0 | **2.11E+01±3.68E-02** | **2.11E+01±3.31E-02** | **2.11E+01±3.65E-02** | **2.11E+01±3.96E-02** | **2.11E+01±5.01E-02** |
| **9** | 0 | 3.28E+01±4.67E+00 | 3.66E+01±4.21E+00 | 6.02E+01±2.35E+00 | **3.25E+01±4.94E+00** | 3.63E+01±4.90E+00 |
| **10** | 0 | 6.98E-02±3.74E-02 | 9.95E-02±4.97E-02 | 1.09E+00±7.11E-02 | **6.86E-02±3.25E-02** | 6.93E-02±3.04E-02 |
| **11** | 0 | **1.95E-02±1.39E-01** | 4.00E+01±3.13E+01 | 3.90E-02±1.95E-01 | 3.90E-02±1.95E-01 | 5.25E+01±1.07E+01 |
| **12** | 0 | 6.42E+01±1.34E+01 | 2.17E+02±4.59E+01 | 4.07E+02±2.20E+01 | 7.24E+01±1.78E+01 | **6.41E+01±1.33E+01** |
| **13** | 0 | 1.56E+02±3.82E+01 | 3.20E+02±6.48E+01 | 4.26E+02±2.28E+01 | 1.56E+02±3.92E+01 | **1.47E+02±3.98E+01** |
| **14** | 0 | 4.95E+02±1.41E+02 | **1.70E+01±2.96E+01** | 8.07E+02±1.06E+02 | 1.09E+03±1.24E+02 | 1.98E+03±5.99E+02 |
| **15** | 0 | 8.09E+03±2.50E+03 | **6.82E+03±8.79E+02** | 1.32E+04±3.66E+02 | 1.12E+04±2.92E+03 | 1.42E+04±3.02E+02 |
| **16** | 0 | **3.24E+00±3.13E-01** | 3.27E+00±3.03E-01 | **3.24E+00±2.76E-01** | 3.25E+00±2.79E-01 | 3.33E+00±2.55E-01 |
| **17** | 0 | 8.89E+01±3.64E+00 | **7.92E+01±3.22E+00** | 9.43E+01±3.41E+00 | 9.63E+01±3.44E+00 | 9.72E+01±1.04E+01 |
| **18** | 0 | **1.50E+02±1.07E+02** | 1.55E+02±3.01E+01 | 4.73E+02±3.45E+01 | 3.41E+02±9.41E+01 | 3.92E+02±1.37E+01 |
| **19** | 0 | 1.01E+01±5.18E-01 | 8.55E+00±2.28E+00 | 1.04E+01±8.02E-01 | 1.08E+01±8.30E-01 | **5.36E+00±1.45E+00** |
| **20** | 0 | **2.07E+01±9.65E-01** | 2.43E+01±2.01E+00 | 2.25E+01±2.43E-01 | 2.16E+01±4.24E-01 | 2.15E+01±4.12E-01 |
| **21** | 0 | **3.53E+02±3.19E+02** | 9.27E+02±2.55E+02 | 4.54E+02±4.03E+02 | 3.72E+02±3.20E+02 | 5.64E+02±4.31E+02 |
| **22** | 0 | 8.84E+02±5.22E+02 | **9.47E+01±3.07E+02** | 2.24E+03±3.27E+02 | 2.00E+03±4.41E+02 | 2.09E+03±5.69E+02 |
| **23** | 0 | 7.35E+03±1.53E+03 | **7.05E+03±1.09E+03** | 1.37E+04±5.11E+02 | 1.11E+04±2.98E+03 | 1.45E+04±4.71E+02 |
| **24** | 0 | 2.45E+02±1.10E+01 | 2.86E+02±1.47E+01 | 3.51E+02±6.98E+00 | 2.44E+02±1.26E+01 | **2.36E+02±9.53E+00** |
| **25** | 0 | 3.27E+02±1.15E+01 | 3.33E+02±1.04E+01 | 3.92E+02±5.20E+00 | 3.22E+02±1.41E+01 | **3.16E+02±1.07E+01** |
| **26** | 0 | 2.14E+02±4.99E+01 | 3.40E+02±8.36E+01 | **2.06E+02±3.59E+01** | 2.14E+02±4.75E+01 | 2.38E+02±6.63E+01 |
| **27** | 0 | 1.07E+03±1.38E+02 | 1.22E+03±1.29E+02 | 1.85E+03±5.35E+01 | 1.03E+03±1.40E+02 | **8.28E+02±1.33E+02** |
| **28** | 0 | **4.00E+02±0.00E+00** | 1.12E+03±1.39E+03 | **4.00E+02±0.00E+00** | **4.00E+02±0.00E+00** | 4.59E+02±4.20E+02 |









**Fig.S1.**An illustration of the new triangular mutation scheme in two-dimensional parametric space.(Local Exploitation).

The difference vector 

The target vector 

The scaled difference vector



Other vectors in parametric space (feasible region)

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The newly generated donor vector corresponding to the target vector 

The scaled difference vector 

The difference vector 

The difference vector 



The scaled difference vector



Local Exploitation around convex combination vectorin the direction  , is the best vector and is the worst vector.

The sum of the three scaled difference vectors









**Fig.S2.**An illustration of the new triangular mutation scheme with collection of convex combinations vectors and the newly generated donor vectors corresponding to the target vectors  in two-dimensional parametric space.(Global Exploration)

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**Fig. S3.** Convergence graph (median curves) of EFADE, EFADE-1, EFADE-2, EFADE-3 and EFADE-4 on 50-dimensional test functions *f1*-*f28*.