ICSI 2014 Competition on Single Objective Optimization  
(ICS-2014-BS)  

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Abstract. This is the introduction and instruction to the ICSI 2014  
Competition on Single Objective Optimization.  

Keywords: Single Objective Optimization, Swarm Intelligence  

1 Introduction  

This competition will focus on single objective optimization, because it is the  
key and fundamental problem in the Swarm Intelligence. In this competition, we  
hope to provide a chance for every swarm intelligence algorithm to show its  
performance and to learn from each other. We welcome any swarm intelligence  
algorithm to participate in the competition, such as Particle Swarm Optimization,  
Ant Colony Optimization, Artificial Bee Colony Algorithm, Bat Algorithm,  
Intelligent Water Drops, Fireworks Algorithm, etc.  
The codes for the competition is available at:  
http://www.ic-si.org/competition/file.zip  
If you have any suggestion, please inform us without hesitation.  

2 Definition  

The task is to minimize the evaluation function:  

$$\min_{x \in [-100,100]^D} f(x)$$  

There are 30 functions in this competition, all shifted and rotated, which  
is named as ICSI-2014-Benchmark Suite, i.e., ICSI-2014-BS, for short, and  
certainly they should be treated as black box problems.
2.1 Basic Functions

The following 23 functions are the same in definition as [3], [2] and [1].

1. Bent Cigar Function

\[ f_1(x) = x_1^2 + 10^6 \sum_{i=2}^{D} x_i^2 \]

2. High Conditioned Elliptic Function

\[ f_2(x) = \sum_{i=1}^{D} (10^6)^{\frac{i}{D-1}} x_i^2 \]

3. Neumaire 3 Function

\[ x = D^2 x/100 \]

\[ f_3(x) = \sum_{i=1}^{D} (x_i - 1)^2 + \sum_{i=1}^{D} x_i x_{i-1} + \frac{D(D+1)(D-1)}{6} \]

4. Discus Function

\[ f_4(x) = 10^6 x_i^2 + \sum_{i=2}^{D} x_i^2 \]

5. Different Powers Function

\[ f_5(x) = \sqrt{\sum_{i=1}^{D} |x_i|^{2+4+\frac{i-1}{D-1}}} \]

6. Rosenbrock’s Function

\[ x = 30x/100 \]

\[ f_6(x) = \sum_{i=1}^{D-1} (100(x_i^2 - x_{i+1})^2 + (x_i - 1)^2) \]

7. Alpine Function

\[ x = 10x/100 \]

\[ f_7(x) = \sum_{i=1}^{D} |x_i \sin(x_i) + 0.1x_i| \]
8. Ackley’s Function

\[ f_8(x) = -20 \exp(-0.2 \sqrt{\frac{1}{D} \sum_{i=1}^{D} x_i^2}) - \exp\left(\frac{1}{D} \sum_{i=1}^{D} \cos(2\pi x_i)\right) + 20 + e \]

9. Weierstrass Function

\[ x = x/100 \]

\[ f_9(x) = \sum_{i=1}^{D} \left( \sum_{k=0}^{20} [0.5^k \cos(2\pi \cdot 3^k (x_i + 0.5))] \right) - D \sum_{k=0}^{20} [0.5^k \cos(2\pi \cdot 3^k \cdot 0.5)] \]

10. Griewank’s Function

\[ x = 600x/100 \]

\[ f_{10}(x) = \sum_{i=1}^{D} \frac{x_i^2}{4000} - \prod_{i=1}^{D} \cos\left(\frac{x_i}{\sqrt{i}}\right) + 1 \]

11. Rastrigin’s Function

\[ x = 5.12x/100 \]

\[ f_{11}(x) = \sum_{i=1}^{D} (x_i^2 - 10 \cos(2\pi x_i) + 10) \]

12. Katsuura Function

\[ x = 5x/100 \]

\[ f_{12}(x) = \frac{10}{D^2} \prod_{i=1}^{D} \left( 1 + \sum_{j=1}^{32} \frac{|2^j x_i - 2^j x_{i+1}|}{2^j} \right)^{10/D^2} - \frac{10}{D^2} \]

13. Expanded Scaffer’s F6 Function

\[ g(x, y) = 0.5 + \frac{(\sin^2(\sqrt{x^2 + y^2}) - 0.5)}{(1 + 0.001(x^2 + y^2))^2} \]

\[ f_{13}(x) = \sum_{i=1}^{D-1} g(x_i, x_{i+1}) + g(x_D, x_1) \]

14. HappyCat Function
\[ f_{14}(x) = \sum_{i=1}^{D} x_i^2 - D|x|^\frac{1}{4} + (0.5 \sum_{i=1}^{D} x_i^2 + \sum_{i=1}^{D} x_i)/D + 0.5 \]

15. HGBat Function

\[ f_{15}(x) = |\left(\sum_{i=1}^{D} x_i^2\right)^2 - \left(\sum_{i=1}^{D} x_i\right)^2| + (0.5 \sum_{i=1}^{D} x_i^2 + \sum_{i=1}^{D} x_i)/D + 0.5 \]

16. Schwefel’s Problem 2.22

\[ x = 10x/100 \]

\[ f_{16}(x) = \sum_{i=1}^{D} |x_i| + \prod_{i=1}^{D} |x_i| \]

17. Schwefel’s Problem 1.2

\[ f_{17}(x) = \sum_{i=1}^{D} (\sum_{j=1}^{i} x_j)^2 \]

18. Schwefel’s Problem 2.26

\[ x = 500x/100 \]

\[ f_{18}(x) = \sum_{i=1}^{D} (x_i \sin(\sqrt{|x_i|})) \]

19. Penalized Function

\[ x = 50x/100 \]

\[ \mu(x_i, a, k, m) = \begin{cases} 
  k(x_i - a)^m & x_i > a \\
  0 & a \leq x_i \leq a \\
  k(-x_i - a)^m & x_i < -a 
\end{cases} \]

\[ f_{19}(x) = 0.1\{\sin^2(3\pi x_1) + \sum_{i=1}^{D-1} (x_i - 1)^2[1 + \sin^2(3\pi x_{i+1})]\} \]

\[ + (x_D - 1)^2[1 + \sin^2(2\pi x_D)]\} + \sum_{i=1}^{D} \mu(x_i, 5, 100, 4) \]

20. Schaffer’s F7 Function

\[ f_{20}(x) = (\frac{1}{D-1} \sum_{i=1}^{D-1} (x_i^2 + x_{i+1}^2)^\frac{1}{4} + (x_i^2 + x_{i+1}^2)^\frac{1}{4} \sin^2(50(x_i^2 + x_{i+1}^2)^{0.1})) \]
21. Salomon Function

\[ f_{21}(x) = 1 - \cos(2\pi \sum_{i=1}^{D} x_i) + 0.1 \sum_{i=1}^{D} x_i^2 \]

2.2 Composition Functions

The following 7 functions are newly generated composition functions.

22. Well Function

\[ f_{22}(x) = \begin{cases} 
\sum_{i=1}^{D} x_i^2 & \text{max}(x) < 20 \\
400 \cdot D & \text{otherwise} 
\end{cases} \]

23. '8'+13'+21'

\[ f_{23}(x) = f_8(x) + f_{13}(x) \cdot 10 + f_{21}(x) \cdot 1e - 2 \]

24. '2'+9'+15'+16'

\[ f_{24}(x) = f_2(x) \cdot 1e - 9 + f_9(x) \cdot 2 + f_{15}(x) \cdot 1e - 1 + f_{16}(x) \cdot 5e - 2 \]

25. '3'+4'+7'+18'

\[ f_{25}(x) = f_3(x) \cdot 0.25 + f_4(x) \cdot 1e - 9 + f_7(x) + f_{18}(x) \cdot 1e - 2 \]

26. '5'+6'+12'

\[ f_{26}(x) = f_5(x) \cdot 1e - 5 + f_6(x) \cdot 1e - 7 + f_{12}(x) \cdot 1e - 2 \]

27. ('10'+14'+20')*18'

\[ f_{27}(x) = f_{18}(f_{10}(x), f_{14}(x), f_{20}(x)) \]

28. ('19'+17'+1')*9'

\[ f_{28}(x) = f_9(f_{19}(x), f_{17}(x), f_1(x)) \]

29. ('3'+12'+15')*8'

\[ f_{29}(x) = f_8(f_3(x), f_{12}(x), f_{15}(x)) \]

30. ('6'+21'+14')*13'

\[ f_{30}(x) = f_{13}(f_6(x), f_{21}(x), f_{14}(x)) \]
3 Experiment

1. $D = 2, 10, 30, 50$, Search space: $[-100, 100]^D$, Maximum evaluation times: $D \ast 10000$.

   For each function and each $D$, run 51 times independently and record the best fitness found.

   Note that error smaller than $2^{-52} \approx 2.22e - 16$ (the eps in matlab) is 0.

2. Run the following program 5 times and record the MEAN time consumed as $T1$:
   
   ```
   for i = 1 : 300000
     evaluate(9 , rand(30,1)*200-100);
   end
   ```

   Run your algorithm on function 9 and $D = 30$ for 5 times, and record the MEAN time consumed as $T2$.

4 Format

   The following things should be included in your paper:

   1. Description of your algorithm.
   2. The parameters used in your experiment.
   3. Experimental environment.
   4. $T1, T2$ and $(T2 - T1)/T1$.
   5. For each $D = 2, D = 10, D = 30$ and $D = 50$, show a 30*5 table containing the Max, Min, Mean, Median and Standard deviation of fitness of each function.

   Besides, you also need to submit 4 result files to the organizers: name_2d.csv, name_10d.csv, name_30d.csv and name_50d.csv(for example:pso_2d.csv, pso_10d.csv, pso_30d.csv and pso_50d.csv), with each containing a 30*51 matrix, showing the best fitness found in each function and each run.

   The algorithms will be ranked according to their fitness value. The ranking and analysis will be published by the organizers later.

References

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Comparison and Ranking Results of Algorithms in ICSI 2014 Competition on Single Objective Optimization

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Abstract. In this technical report, the analyses, comparison and ranking results of the algorithms participating in the ICSI 2014 Competition on Single Objective Optimization (ICSI-2014-BS) are presented.

Keywords: Single Objective Optimization, Swarm Intelligence

1 Introduction

The Fifth International Conference on Swarm Intelligence (ICSI 2014) organized a competition session on Single Objective Optimization. A benchmark suite of 30 evaluation functions called ICSI-2014-BS is set up for this competition session. The competition requires participants to submit their algorithms’ evaluation results for 2, 10, 30 and 50 dimensions and their time complexity index.

There are in total 9 papers submitted to this competition session and 6 papers accepted at last. They are listed in Table 1.

| #  | Title                                                                 |
|----|----------------------------------------------------------------------|
| 33 | Evaluating a Hybrid DE and BBO with Self Adaptation on ICSI 2014 Benchmark Problems |
| 86 | The Multiple Population Co-evolution PSO Algorithm                   |
| 92 | Performance of Migrating Birds Optimization Algorithm on Continuous Functions |
| 131| Dynamic Search Fireworks Algorithm for Solving ICSI2014 Competition Problems |
| 178| Differential Evolution with Sparks Applied to ICSI 2014 Competition Functions |
| 180| Applying Enhanced Fireworks Algorithm to ICSI 2014 Benchmark Suite    |
The abbreviations of the 6 algorithms are respectively: HSDB, MPCPSO, MBO, dynFWA, DESP and EFWA.

2 Overview of the Results

2.1 Time Complexity

We defined an index to measure the time complexity of the algorithms:
1. Run the following program 5 times and record the MEAN time consumed as $T_1$:
   
   ```
   for i = 1 : 300000
   evaluate(9 , rand(30,1)*200-100);
   end
   ```

2. Run the optimization algorithm on function 9 and $D = 30$ for 5 times, and record the MEAN time consumed as $T_2$.

3. And finally calculate the value $(T_2 - T_1)/T_1$ as the metric of the time complexity of the algorithm.

The results are shown in Table 2. Algorithms with smaller numbers are faster.

| Algorithm | HSDB | MPCPSO | MBO | dynFWA | DESP | EFWA |
|-----------|------|--------|-----|--------|------|------|
| $(T_2 - T_1)/T_1$ | 1.386 | 0.320 | 1.448 | 0.123 | 0.588 | 0.241 |

Table 2. Time Complexity

The index to some extent reveals the efficiency of the algorithms. However, we should note that such kind of metrics are very sensitive to the implementation details. Especially on MATLAB platform, a proper optimization of the codes would significantly reduce the time cost. In addition, time complexity of the algorithms is not the main concern in this competition, because for most real world optimization problems, the evaluation is overwhelmingly expensive.

2.2 Mean Fitness Value

We limit the evaluation times of each function to $10000 \times D$ for each dimensionality $D = 2, 10, 30, 50$. Table 3,4,5 and 6 present the mean fitness value of each dimensionality obtained by the algorithms over 51 independent runs. The best fitness values are highlighted.
| Func \ Alg | HSDB | MPCPSO | MBO | dynFWA | DESP | EFWA |
|-----------|------|--------|-----|--------|------|------|
| 1         | 0.00E+00 | 1.75E-02 | 1.25E+03 | 1.56E+02 | 4.99E+02 | 4.32E+02 |
| 2         | 0.00E+00 | 2.54E+01 | 6.09E+02 | 4.90E+02 | 8.89E+02 | 5.07E+02 |
| 3         | 1.67E+00 | 1.67E+00 | 1.67E+00 | 1.67E+00 | 1.67E+00 | 1.67E+00 |
| 4         | 0.00E+00 | 3.95E+00 | 3.76E+02 | 1.79E+02 | 3.23E+02 | 3.21E+02 |
| 5         | 0.00E+00 | 3.47E-06 | 5.52E-01 | 3.85E-03 | 3.23E+00 | 7.91E-04 |
| 6         | 0.00E+00 | 5.66E-23 | 1.16E+00 | 1.21E-03 | 1.77E+00 | 2.70E-04 |
| 7         | 0.00E+00 | 1.59E-06 | 2.55E-03 | 9.70E-04 | 4.62E-03 | 6.15E-03 |
| 8         | 0.00E+00 | 1.03E-15 | 3.74E+00 | 2.45E-02 | 3.04E-01 | 8.19E-01 |
| 9         | -4.00E+00 | -4.00E+00 | 2.73E-01 | -3.98E+00 | -3.75E+00 | -3.99E+00 |
| 10        | -9.97E-01 | -9.95E-01 | 2.29E-01 | -9.76E-01 | -7.92E-01 | -9.85E-01 |
| 11        | 0.00E+00 | 6.20E-15 | 3.05E-01 | 7.02E-05 | 7.29E-01 | 1.63E-05 |
| 12        | 4.89E+01 | 4.95E+01 | 5.41E-01 | 4.93E+01 | 6.96E+01 | 5.17E+01 |
| 13        | 6.89E-03 | 1.07E-02 | 2.31E-02 | 1.55E-02 | 7.29E-02 | 2.64E-02 |
| 14        | 4.76E-03 | 5.66E-04 | 7.23E-01 | 6.47E-02 | 6.49E-02 | 1.61E-01 |
| 15        | 7.53E-04 | 2.41E-04 | 9.02E-01 | 1.74E-02 | 2.59E-01 | 3.81E-02 |
| 16        | 0.00E+00 | 6.76E-18 | 7.61E-02 | 2.31E-03 | 1.48E-01 | 5.43E-04 |
| 17        | 0.00E+00 | 0.00E+00 | 1.83E-01 | 3.63E-03 | 1.95E+00 | 8.96E-05 |
| 18        | -8.38E+02 | -7.72E+02 | -8.39E+02 | -8.38E+02 | -6.49E+02 | -6.25E+02 |
| 19        | 0.00E+00 | 4.44E-16 | 1.07E-01 | 1.14E-03 | 2.69E-03 | 9.26E-04 |
| 20        | 0.00E+00 | 0.00E+00 | 2.79E+00 | 0.00E+00 | 1.06E-13 | 0.00E+00 |
| 21        | 0.00E+00 | 0.00E+00 | 4.24E-01 | 1.98E-03 | 1.57E-02 | 3.53E-07 |
| 22        | 0.00E+00 | 5.08E-33 | 3.51E-01 | 2.27E-03 | 9.13E-01 | 5.40E-05 |
| 23        | 8.97E+00 | 8.97E+00 | 6.74E+00 | 8.99E+00 | 1.05E+01 | 9.16E+00 |
| 24        | -4.53E+00 | -4.51E+00 | 5.49E+02 | -4.42E+00 | -3.90E+00 | -4.03E+00 |
| 25        | -1.60E+00 | -1.63E+00 | 4.23E+02 | -1.57E+00 | -9.05E-01 | -1.10E+00 |
| 26        | 5.86E-01 | 6.04E-01 | 2.57E+00 | 6.68E-01 | 8.93E-01 | 7.81E-01 |
| 27        | -3.74E+07 | -3.73E+07 | -3.83E+04 | -3.74E+07 | -2.93E+07 | -2.99E+07 |
| 28        | -5.22E+00 | -5.74E+00 | -8.85E-01 | -5.24E+00 | -5.32E+00 | -5.07E+00 |
| 29        | 2.00E+01 | 2.00E+01 | 1.29E+01 | 2.00E+01 | 2.00E+01 | 2.00E+01 |
| 30        | 3.91E-01 | 3.19E-01 | 3.60E-01 | 3.39E-01 | 8.68E-01 | 6.31E-01 |
Table 4. Mean Fitness ($D = 10$)

| Func | Alg  | HSDB  | MPCSPO | MBO    | dynFW  | DESP   | EFW   |
|------|------|-------|--------|--------|--------|--------|-------|
| 1    | 5.91E+00 | 4.16E+03 | 5.74E+07 | 3.18E+04 | 9.12E+05 | 5.86E+04 |       |
| 2    | 2.87E+01 | 3.11E+03 | 8.60E+02 | 9.49E+03 | 1.04E+03 | 7.52E+03 |       |
| 3    | 1.70E+02 | 1.70E+02 | 2.44E+02 | 1.70E+02 | 1.71E+02 | 1.70E+02 |       |
| 4    | 3.00E-01 | 7.86E+01 | 1.02E+03 | 6.48E+01 | 5.93E+00 | 1.89E+01 |       |
| 5    | 9.36E-03 | 2.51E+00 | 1.36E+00 | 6.31E-02 | 2.86E+00 | 1.12E-01 |       |
| 6    | 5.02E+00 | 5.37E+00 | 1.90E+03 | 6.56E+00 | 5.83E+01 | 7.81E+00 |       |
| 7    | 1.30E-04 | 8.02E-03 | 8.04E-01 | 1.64E-02 | 9.09E-02 | 8.51E-01 |       |
| 8    | 1.55E-01 | 2.48E+00 | 9.38E+00 | 2.03E+00 | 4.00E+00 | 1.66E+01 |       |
| 9    | -1.99E+01 | -1.85E+01 | 4.72E+00 | -1.84E+01 | -1.77E+01 | -1.48E+01 |       |
| 10   | -8.35E+00 | -7.91E+00 | 1.69E+00 | -7.24E+00 | -6.80E+00 | -2.16E+00 |       |
| 11   | 1.05E+00 | 5.40E+00 | 2.64E+01 | 6.54E+00 | 1.18E+01 | 2.04E+01 |       |
| 12   | 4.52E-01 | 4.76E-01 | 1.52E+00 | 4.70E-01 | 4.62E-01 | 4.96E-01 |       |
| 13   | 4.00E-01 | 6.23E-01 | 2.15E+00 | 9.80E-01 | 1.16E+00 | 2.11E+00 |       |
| 14   | 5.16E-02 | 5.82E-02 | 7.99E+00 | 8.83E-02 | 1.21E-01 | 7.24E-01 |       |
| 15   | 4.85E-02 | 1.66E-01 | 1.20E+02 | 1.03E-01 | 2.32E-01 | 3.02E-01 |       |
| 16   | 5.50E-03 | 2.16E-01 | 2.66E+00 | 2.67E-01 | 2.29E-01 | 2.45E-01 |       |
| 17   | 7.46E-04 | 3.04E-02 | 1.77E+03 | 2.57E-03 | 1.30E-01 | 2.44E-02 |       |
| 18   | -2.27E+03 | -1.94E+03 | -2.91E+03 | -2.31E+03 | -1.97E+03 | -3.00E+03 |       |
| 19   | 6.86E-04 | 8.28E-03 | 4.22E+00 | 2.42E-02 | 3.51E-02 | 8.23E-01 |       |
| 20   | 5.11E-03 | 1.31E-03 | 1.03E+01 | 3.95E-01 | 2.89E-01 | 9.57E+00 |       |
| 21   | 9.99E-02 | 2.94E-01 | 1.48E+01 | 2.88E-01 | 5.98E-01 | 2.29E-01 |       |
| 22   | 6.69E-04 | 3.46E-03 | 1.17E+02 | 4.80E-02 | 3.47E+00 | 9.16E-02 |       |
| 23   | 1.94E+01 | 2.47E+01 | 3.83E+01 | 2.90E+01 | 3.03E+01 | 3.89E+01 |       |
| 24   | -3.53E+01 | -3.16E+01 | 1.03E+03 | -3.29E+01 | -3.04E+01 | -2.18E+01 |       |
| 25   | 4.29E+01 | 4.29E+01 | 1.44E+03 | 4.36E+01 | 4.48E+01 | 4.37E+01 |       |
| 26   | 6.71E-03 | 8.40E-03 | 2.33E+03 | 7.92E-03 | 8.95E-03 | 9.84E-03 |       |
| 27   | -1.02E+08 | -2.82E+07 | -1.37E+04 | -7.83E+07 | -5.25E+07 | -9.75E+07 |       |
| 28   | -5.83E-00 | -5.64E+00 | 1.51E+01 | -5.77E+00 | -5.40E+00 | -5.37E+00 |       |
| 29   | 2.00E+01 | 2.00E+01 | 2.14E+01 | 2.00E+01 | 2.00E+01 | 2.00E+01 |       |
| 30   | 1.01E+00 | 1.02E+00 | 1.25E+00 | 1.02E+00 | 1.04E+00 | 1.04E+00 |       |
Table 5. Mean Fitness $(D = 30)$

| Func\Alg | HSDB  | MPCPSO | MBO  | dynFWA | DESP | EFWA |
|----------|-------|--------|------|--------|------|------|
| 1        | 7.64E+04 | 4.01E+04 | 2.78E+08 | 5.48E+04 | 1.37E+07 | 6.64E+04 |
| 2        | 5.05E+03 | 9.24E+03 | 7.70E+02 | 1.26E+04 | 1.21E+03 | 2.13E+04 |
| 3        | 4.52E+03 | 4.52E+03 | 2.75E+04 | 4.52E+03 | 4.99E+03 | 4.52E+03 |
| 4        | 7.46E+00 | 6.72E+01 | 1.03E+03 | 3.03E+01 | 1.67E+00 | 8.91E+00 |
| 5        | 3.75E-02 | 4.04E-02 | 1.11E+00 | 7.79E-02 | 5.29E+00 | 7.12E-02 |
| 6        | 2.91E+01 | 2.91E+01 | 8.60E+03 | 3.64E+01 | 2.04E+02 | 3.03E+01 |
| 7        | 7.91E-03 | 1.83E-02 | 2.64E+00 | 1.20E-02 | 7.88E-02 | 2.12E+00 |
| 8        | 9.06E-01 | 3.04E+00 | 1.08E+01 | 2.75E+00 | 4.39E+00 | 1.93E+01 |
| 9        | -5.83E+01 | -5.35E+01 | 1.58E+01 | -5.33E+01 | -5.29E+01 | -1.07E+01 |
| 10       | -2.48E+01 | -2.39E+01 | 3.77E+00 | -2.22E+01 | -2.05E+01 | -1.27E+01 |
| 11       | 2.92E-02 | 1.47E+00 | 1.15E+02 | 1.07E+01 | 2.45E+01 | 7.82E+01 |
| 12       | 1.43E-02 | 1.40E-02 | 3.60E+00 | 1.41E-02 | 1.33E-02 | 1.41E-02 |
| 13       | 3.04E+00 | 1.91E+00 | 9.16E+00 | 2.98E+00 | 3.53E+00 | 7.32E+00 |
| 14       | 7.32E-03 | 2.11E-02 | 8.85E+00 | 4.61E-02 | 5.50E-02 | 1.94E+00 |
| 15       | 9.48E-02 | 4.55E-01 | 2.95E+02 | 2.41E-01 | 3.65E-01 | 8.91E-01 |
| 16       | 2.57E-01 | 7.66E-01 | 7.50E+00 | 6.31E-01 | 1.62E+00 | 4.92E-01 |
| 17       | 2.02E+00 | 7.11E+00 | 5.47E+04 | 2.17E+00 | 1.75E-01 | 1.07E+00 |
| 18       | -5.82E+03 | -2.50E+03 | -4.49E+03 | -5.03E+03 | -4.53E+03 | -9.01E+03 |
| 19       | 5.04E-03 | 2.50E-02 | 1.18E+01 | 1.95E-01 | 1.19E-01 | 1.27E+00 |
| 20       | 2.01E-01 | 6.43E-01 | 8.06E+00 | 2.76E+00 | 4.19E+00 | 1.15E-05 |
| 21       | 2.14E-01 | 7.23E-01 | 3.07E+01 | 8.87E-01 | 1.41E+00 | 6.86E-01 |
| 22       | 1.00E-01 | 4.81E-02 | 3.21E+02 | 7.58E-02 | 1.63E+01 | 6.73E-02 |
| 23       | 4.43E+01 | 3.96E+01 | 1.09E+02 | 4.98E+01 | 5.35E+01 | 9.27E+01 |
| 24       | -1.15E+02 | -1.06E+02 | 9.04E+02 | -1.04E+02 | -1.03E+02 | -8.55E+01 |
| 25       | 1.13E+03 | 1.13E+03 | 1.93E+04 | 1.13E+03 | 1.26E+03 | 1.13E+03 |
| 26       | 4.38E-04 | 4.65E-04 | 8.21E+03 | 4.23E-04 | 6.31E-04 | 4.31E-04 |
| 27       | -4.78E+08 | -1.09E+08 | -5.16E+03 | -2.64E+08 | -2.45E+08 | -6.11E+08 |
| 28       | -5.48E+00 | -5.74E+00 | 5.52E+01 | -5.80E+00 | -5.49E+00 | -5.52E+00 |
| 29       | 2.00E+01 | 2.00E+01 | 2.16E+01 | 2.00E+01 | 2.00E+01 | 2.00E+01 |
| 30       | 1.02E+00 | 1.04E+00 | 1.42E+00 | 1.06E+00 | 1.08E+00 | 1.09E+00 |
### Table 6. Mean Fitness \((D = 50)\)

| Func \ Alg     | HSDB | MPCPSO | MBO | dynFWA | DESP | EFWA |
|---------------|------|--------|-----|--------|------|------|
| 1             | 5.60E+04 | 1.62E+05 | 3.87E+08 | 6.22E+04 | 4.03E+06 | 9.01E+04 |
| 2             | 9.04E+03 | 7.11E+04 | 8.31E+02 | 1.33E+04 | 1.06E+06 | 1.42E+04 |
| 3             | 2.09E+04 | 2.10E+04 | 2.69E+05 | 2.09E+04 | 2.89E+04 | 2.09E+04 |
| 4             | 7.66E+00 | 1.17E+02 | 1.06E+03 | 2.07E+01 | 5.16E+02 | 5.09E+00 |
| 5             | 3.54E-02 | 8.53E-02 | 1.05E+00 | 4.99E-02 | 2.84E+00 | 6.16E-02 |
| 6             | 4.88E+01 | 4.99E+01 | 2.67E+05 | 2.89E+04 | 9.59E+01 | 4.91E+01 |
| 7             | 2.01E-02 | 4.40E-02 | 3.35E+00 | 2.44E-02 | 8.12E-02 | 4.38E+00 |
| 8             | 1.52E+00 | 2.96E+00 | 9.89E+00 | 3.23E+00 | 3.08E+00 | 2.01E+00 |
| 9             | -9.61E+01 | -9.09E+01 | 2.42E+00 | -8.78E+01 | -9.05E+01 | -1.29E+01 |
| 10            | -4.35E+01 | -3.12E+01 | 4.62E+00 | -3.82E+01 | -1.50E+01 | -2.78E+01 |
| 11            | 3.61E-02 | 9.70E-02 | 1.61E+02 | 7.04E-01 | 2.21E+00 | 1.14E+02 |
| 12            | 2.76E-03 | 2.91E-03 | 3.72E+00 | 2.91E-03 | 3.04E-03 | 2.83E-03 |
| 13            | 4.09E+00 | 7.37E+00 | 1.69E+01 | 4.15E+00 | 1.45E+01 | 1.53E+01 |
| 14            | 1.69E-02 | 1.08E-02 | 8.04E+00 | 2.87E-02 | 1.11E-01 | 2.00E+00 |
| 15            | 4.26E-01 | 4.26E-01 | 3.69E+02 | 4.58E-01 | 4.60E-01 | 1.74E-00 |
| 16            | 5.89E-01 | 1.31E+00 | 1.06E+01 | 9.37E-01 | 1.60E+00 | 7.08E-01 |
| 17            | 6.43E+00 | 6.10E+00 | 1.60E+05 | 5.98E+00 | 3.42E+02 | 3.14E+00 |
| 18            | -7.44E+01 | -3.22E+03 | -5.89E+03 | -4.84E+03 | -8.94E+03 | -1.50E+04 |
| 19            | 9.37E+00 | 3.29E-01 | 1.46E+01 | 2.11E-01 | 7.94E-01 | 8.86E-01 |
| 20            | 3.11E+00 | 9.90E+00 | 6.76E+00 | 8.35E+00 | 2.87E+00 | 4.38E-06 |
| 21            | 4.06E-01 | 9.14E-01 | 3.79E+01 | 1.23E+00 | 1.76E+00 | 9.37E-01 |
| 22            | 3.73E-02 | 1.03E+01 | 4.07E+02 | 4.98E-02 | 3.78E+00 | 7.45E-02 |
| 23            | 4.43E+01 | 8.57E-01 | 1.86E+02 | 5.76E+01 | 1.61E+02 | 1.48E+02 |
| 24            | -1.89E+02 | -1.79E+02 | 8.56E+02 | -1.73E+02 | -1.79E+02 | -1.50E+02 |
| 25            | 5.23E+03 | 5.26E+03 | 1.18E+05 | 5.23E+03 | 7.31E+03 | 5.23E+03 |
| 26            | 2.29E-04 | 2.34E-04 | 9.69E+03 | 2.27E-04 | 2.31E-04 | 2.25E-04 |
| 27            | -8.43E+08 | -2.62E+08 | -4.00E+04 | -3.60E+08 | -2.39E+09 | -2.32E+09 |
| 28            | -5.54E+00 | -5.85E+00 | 9.52E+01 | -5.78E+00 | -5.56E+00 | -5.54E+00 |
| 29            | 2.00E+01 | 2.00E+01 | 2.17E+01 | 2.00E+01 | 2.00E+01 | 2.00E+01 |
| 30            | 1.04E+00 | 1.04E+00 | 1.45E+00 | 1.11E+00 | 1.09E+00 | 1.14E+00 |

### 3 Ranking Results

In order to rank the performance of the algorithms, we conducted a round robin on them. For each function, if algorithm A performs significantly better (examined by a t-test with 95% confidence level) than algorithm B, then A gets one point. The point numbers are presented in Table 7.
Table 7. Point Number

| Dim | HSDB | MFCPSO | MBO | dynFWA | DESP | EFWA |
|-----|------|--------|-----|--------|------|------|
| 2   | 113  | 104    | 23  | 60     | 16   | 42   |
| 10  | 127  | 88     | 9   | 82     | 46   | 41   |
| 30  | 104  | 85     | 8   | 75     | 63   | 66   |
| 50  | 117  | 77     | 12  | 91     | 45   | 73   |
| Sum | 461  | 354    | 52  | 308    | 170  | 222  |

So, the final ranking is:

1. Hybrid DE and BBO with Self Adaptation
2. Multiple Population Co-evolution PSO Algorithm
3. Dynamic Search Fireworks Algorithm
4. Enhanced Fireworks Algorithm
5. Differential Evolution with Sparks
6. Migrating Birds Optimization Algorithm

Congratulations to YuJun Zheng and XiaoBei Wu, whose paper *Evaluating a Hybrid DE and BBO with Self Adaptation on ICSI 2014 Benchmark Problems* wins the ICSI 2014 Competition on Single Objective Optimization. HSDB shows a significant advantage over other algorithms on all the dimensionality.

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