ICSI'2022 Special Session

Definitions for the ICSI 2022 Special Session on Single Objective Bounded Optimization Problems

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1 Introduction

Since optimization problems are widely used in real-world applications, it has always been one of the hot topics in research. With the popularity of machine learning and deep learning, how to efficiently and accurately solve optimization problems has become an urgent problem that needs to be addressed. Among them, the single-objective bounded optimization problem is one of the basic types of all optimization problems. Due to the complexity of modern optimization problems, the optimization of some complex functions is relatively difficult. Decades ago, the emergence of stochastic search algorithms such as evolutionary algorithms and swarm intelligence algorithms makes it possible to find the global optimal solutions of some complex functions. In order to test the performance of numerous evolutionary algorithms and swarm intelligence algorithms, we propose a test suite to complete this task.

This special session is devoted to the evolutionary algorithms and swarm intelligence algorithms for solving single-objective bounded optimization. We encourage all researchers to test their algorithms on the ICSI'2022 test suite. This test suite includes 10 black-box test functions which means you do not need to know the exact form of these test functions. This form of benchmark functions is convenient for researchers to design and improve their algorithms, and it is also helpful for improving the generalization of the algorithms.

The participants are required to send the final results in the format specified in the technical report to the organizers. The original code of the algorithm also needs to be attached. The organizers will present an overall analysis and comparison based on these results. We will select the algorithms that perform well and give them a certain amount of bonuses. We are encouraging all researchers to test their algorithms on this test suite and take part in our competition.

We provide python and MATLAB code for our benchmark functions. All the code are available on URL. You could check the README file to learn how to use our ICSI'2022 test suite.

2 Details

2.1 Summary

Type	No.	Functions	$F_i^* = F_i(x^*)$
Unimodal Functions	1	Rotated Shifted High Conditioned Elliptic Function	1000
	2	Rotated and Shifted Bent Cigar Function	1000
Multimodal Functions	3	Rotated and Shifted Rosenbrock's Function	200
	4	Rotated and Shifted Rastrigin's Function	200
	5	Rotated and Shifted Modified Schwefel's Function	300
	6	Rotated and Shifted Alpine Function	300
	7	Shifted HappyCat Function	500
Composition Functions	8	Composition Function 1	0
	9	Composition Function 2	0
	10	Composition Function 3	0

Table 1: Summary of the 10 ICSI'2022 Functions

2.2 Definitions and symbols

Our test suite contains 10 test functions, and all these functions are minimization problems. The unified form of the problem can be expressed as:

$$\min_{\mathbf{x}} f(\mathbf{x}), \mathbf{x} = [x_1, x_2, \ldots, x_D]^{\mathrm{T}} \tag{1}$$

where D is the dimension of $\mathbf{x}$.

Search range: $x_j \in [-100, 100]$ for $j = 1, 2, \ldots, D$.

Shift vector: $\mathbf{o} = [o_{i_1}, o_{i_2}, \ldots, o_{i_D}]^T$. Shift vectors are generated randomly.

Rotation matrix: $\mathbf{R}$. Rotation matrices for each function are generated from standard normally distributed entries by Gram-Schmidt orthonormalization.

2.3 Definitions of the test functions

A. Unimodal functions:

(1) Rotated and Shifted High Conditioned Elliptic Function

$$f_1(\mathbf{z}) = \sum_{i=1}^{D} \left(10^6\right)^{\frac{i-1}{D-1}} \mathbf{z}_i^2, \quad \mathbf{z} = \mathbf{R}(\mathbf{x} - \mathbf{o}) \tag{2}$$

(2) Rotated and Shifted Bent Cigar Function

$$f_2(\mathbf{z}) = z_1^2 + 10^6 \sum_{i=2}^{D} z_i^2, \quad \mathbf{z} = \mathbf{R}(\mathbf{x} - \mathbf{o}) \tag{3}$$

B. Multimodal functions:

(3) Rotated and Shifted Rosenbrock's Function

$$f_3(\mathbf{z}) = \sum_{i=1}^{D-1} \left(100 \left(z_i^2 - z_{i+1}\right)^2 + (z_i - 1)^2\right), \quad \mathbf{z} = \mathbf{R}(\mathbf{x} - \mathbf{o}) \tag{4}$$

(4) Rotated and Shifted Rastrigin's Function

$$f_4(\mathbf{z}) = \sum_{i=1}^{D} \left(z_i^2 - 10\cos\left(2\pi z_i\right) + 10\right), \quad \mathbf{z} = \mathbf{R}(\mathbf{x} - \mathbf{o}) \tag{5}$$

(5) Rotated and Shifted Modified Schwefel's Function

The definition of Schwefel's Function is

$$f(\mathbf{x}) = 418.9829 \times D - \sum_{i=1}^{D} x_i \sin\left(\sqrt{|x_i|}\right), \quad x_i \in [-500, 500] \tag{6}$$

In order to unify the search range, we need to transform the domain of Schwefel's function.

(6) Rotated and Shifted Alpine Function [1]

$$f_6(\mathbf{z}) = \sum_{i=1}^{D} \left|z_i \sin\left(z_i\right) + 0.1 z_i\right|, \quad \mathbf{z} = \mathbf{R}(\mathbf{x} - \mathbf{o}) \tag{7}$$

(7) Rotated and Shifted HappyCat Function [2]

$$f_7(\mathbf{z}) = \left|\sum_{i=1}^{D} z_i^2 - D\right|^{1/4} + \left(0.5 \sum_{i=1}^{D} z_i^2 + \sum_{i=1}^{D} z_i\right) / D + 0.5, \quad \mathbf{z} = \mathbf{R}(\mathbf{x} - \mathbf{o}) \tag{8}$$

C. Composition Functions

(8) Composition Function 1

Basic functions:

i. Rotated and Shifted Ackley's Function

ii. Rotated and Shifted High Conditioned Elliptic Function

iii. Rotated and Shifted Griewank's Function

iv. Rotated and Shifted Rastrigin's Function

Bias: $[0, 1000, 100, 100]$

Scale: $\lambda = [10^4, 10^4, 10^{10}, 3 \times 10^1]$

(9) Composition Function 2

Basic functions:

i. Rotated and Shifted Alple Function

ii. Rotated and Shifted Katsuura's Function

iii. Rotated and Shifted Rosenbrock's Function

iv. Rotated and Shifted Rastrigin's Function

Bias: $[0, 10, 100, 1000]$

Scale: $\lambda = [10^3, 5 \times 10^1, 10^1, 10^3]$

(10) Composition Function 3

Basic functions:

i. Rotated and Shifted HappyCat Function

ii. Rotated and Shifted Griewank' plus Rosenbrock's Function

iii. Rotated and Shifted Schwefel's Function

iv. Rotated and Shifted Weierstrass Function

v. Rotated and Shifted High Conditioned Elliptic Function

Bias: $[0, 100, 100, 100, 100]$ $\lambda = [10^5, 10^5, 10^5, 10^8, 10^{10}]$

2.4 The construction method of composition function

Composition functions are composed of basic functions $g_i(x)$. The way of composition is determined by

$$
\begin{aligned}
f_c(\mathbf{x}) &= \omega \exp(\sigma \ln(v-1)+1) \\
v &= \prod_{i=1}^{n} (g_i(\mathbf{z_i})/\lambda_i + b_i) \\
\mathbf{z_i} &= \mathbf{R_i}(\mathbf{x}-\mathbf{o_i})
\end{aligned} \tag{9}
$$

The shift vector and bias for each basic function are not the same, which means the composition function has more than one local optimum.Here we control the value of each local optimum to ensure that there is only one global optimum. b_i is the bias of each function. It determines the global optimum for composition function. $b_i = 0$ means the optimum of i-th basic function is the global optimum. λ_i is the scaling factor for each function. Since the range of each function value is different, it needs to be scaled to a uniform amplitude to prevent a function with a larger value dominate the composition function. σ and ω is the scaling factor for composition function. They control the global trend of the composition function and the relative aptitude of the function value.

3 Evaluation Criteria

3.1 Settings

- **Number of functions:** 10 functions.
- **Dimensions:** $D = 10, D = 20, D = 50$.
- **Search range:** $[-100, 100]$ for each dimension.
- **Number of runs:** 50.
- **Max Function evaluation times(MaxFET):** For each single run MaxFET=10000 when $D = 10$. MaxFET=30000 when $D = 20$. MaxFET=70000 when $D = 50$.
- **Randomness:** Random initialization within the search space. Random seed is based on time and process identifier. MATLAB users can use

  "rng(mod(9301*mean(clock)+49297,233280));"

  to specify random seed. For python users, you can use

  "int(os.getpid()*time.time())%233280"

  as your random seed. It is worth noting that we will randomly generate a set of seeds when we compare the final results.
- **Global Optimum:** The optimal value of each function is shown in the Table-1. All problems are promised to have global optimums within the given bounds.
- **Termination condition:** Terminate when reaching MaxFES.
- **Precision:**10^{-8}. When the error is less than this value, it can be regarded as 0.

4 Paper submission

People who participate in our competition need to submit a conference paper to ICSI'2022. The paper must include at least the following information.

4.1 Basic Information

The paper should include introduction to the algorithm, related work and detailed description of the algorithm.

4.2 Results form

The experimental part of the paper needs to contain the following content.

- **Testing Platform:** Python 3.6/MATLAB R2020B.
- **Computer Configuration Information:** i7-8750H CPU @ 2.20GHz and 32.0 GB RAM, using win 10 OS.
- **Recording Table:**

No.	Best	Worst	Median	Mean	Std
F01	0.00E + 00	0.00E + 00	0.00E + 00	0.00E + 00	0.00E + 00
F02	0.00E + 00	0.00E + 00	0.00E + 00	0.00E + 00	0.00E + 00
F03	0.00E + 00	0.00E + 00	0.00E + 00	0.00E + 00	0.00E + 00
F04	0.00E + 00	0.00E + 00	0.00E + 00	0.00E + 00	0.00E + 00
F05	0.00E + 00	0.00E + 00	0.00E + 00	0.00E + 00	0.00E + 00
F06	0.00E + 00	0.00E + 00	0.00E + 00	0.00E + 00	0.00E + 00
F07	0.00E + 00	0.00E + 00	0.00E + 00	0.00E + 00	0.00E + 00
F08	0.00E + 00	0.00E + 00	0.00E + 00	0.00E + 00	0.00E + 00
F09	0.00E + 00	0.00E + 00	0.00E + 00	0.00E + 00	0.00E + 00
F10	0.00E + 00	0.00E + 00	0.00E + 00	0.00E + 00	0.00E + 00

Table 2: Results for 10D problems

No.	Best	Worst	Median	Mean	Std
F01	0.00E + 00	0.00E + 00	0.00E + 00	0.00E + 00	0.00E + 00
F02	0.00E + 00	0.00E + 00	0.00E + 00	0.00E + 00	0.00E + 00
F03	0.00E + 00	0.00E + 00	0.00E + 00	0.00E + 00	0.00E + 00
F04	0.00E + 00	0.00E + 00	0.00E + 00	0.00E + 00	0.00E + 00
F05	0.00E + 00	0.00E + 00	0.00E + 00	0.00E + 00	0.00E + 00
F06	0.00E + 00	0.00E + 00	0.00E + 00	0.00E + 00	0.00E + 00
F07	0.00E + 00	0.00E + 00	0.00E + 00	0.00E + 00	0.00E + 00
F08	0.00E + 00	0.00E + 00	0.00E + 00	0.00E + 00	0.00E + 00
F09	0.00E + 00	0.00E + 00	0.00E + 00	0.00E + 00	0.00E + 00
F10	0.00E + 00	0.00E + 00	0.00E + 00	0.00E + 00	0.00E + 00

Table 3: Results for 20D problems

No.	Best	Worst	Median	Mean	Std
F01	0.00E + 00	0.00E + 00	0.00E + 00	0.00E + 00	0.00E + 00
F02	0.00E + 00	0.00E + 00	0.00E + 00	0.00E + 00	0.00E + 00
F03	0.00E + 00	0.00E + 00	0.00E + 00	0.00E + 00	0.00E + 00
F04	0.00E + 00	0.00E + 00	0.00E + 00	0.00E + 00	0.00E + 00
F05	0.00E + 00	0.00E + 00	0.00E + 00	0.00E + 00	0.00E + 00
F06	0.00E + 00	0.00E + 00	0.00E + 00	0.00E + 00	0.00E + 00
F07	0.00E + 00	0.00E + 00	0.00E + 00	0.00E + 00	0.00E + 00
F08	0.00E + 00	0.00E + 00	0.00E + 00	0.00E + 00	0.00E + 00
F09	0.00E + 00	0.00E + 00	0.00E + 00	0.00E + 00	0.00E + 00
F10	0.00E + 00	0.00E + 00	0.00E + 00	0.00E + 00	0.00E + 00

Table 4: Results for 50D problems

- **Parameters:**

  People who participate in our competition need to provide:

  1. Symbols of all parameters and their meanings.
  2. Actual parameter values used in the experiment.

4.3 Source code:

People who participate in our competition need to provide the source code with the predefined parameters, and ensure that the code could run correctly to get the results. The source code does not need to be included in the paper, but it needs to be submitted to the conference in the form of compressed package.

References

[1] A. R. Al-Roomi, "Unconstrained Single-Objective Benchmark Functions Repository," Halifax, Nova Scotia, Canada, 2015. [Online]. Available: https://www.al-roomi.org/benchmarks/unconstrained

[2] J. J. Liang, B. Y. Qu, and P. N. Suganthan, "Problem definitions and evaluation criteria for the cec 2014 special session and competition on single objective real-parameter numerical optimization," *Computational Intelligence Laboratory, Zhengzhou University, Zhengzhou China and Technical Report, Nanyang Technological University, Singapore*, vol. 635, p. 490, 2013.