Competition on Constrained Real Parameter Optimization

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The 28 benchmarked constrained optimization problems can be transformed into the following format:

$$\text{Minimize: } f(X), \quad X=(x_1, x_2, ..., x_n) \text{ and } X \in S \tag{1}$$

$$\text{Subject to: } \begin{cases} g_i(X) \le 0, & i = 1, ..., p \\ h_j(X) = 0, & j = p+1, ..., m \end{cases} \tag{2}$$

Equality constraints are transformed into inequalities of the form

$$\left|h_j(X)\right| - \varepsilon \le 0, \text{ for } \quad j = p+1, ..., m \tag{3}$$

Solution X is regarded as feasible if $g_i(X) \le 0, i = 1, ..., p$ and

$\left|h_j(X)\right| - \varepsilon \le 0$, for $j = p+1, ..., m$ (ε=0.0001).

Reference:

Guohua Wu, R. Mallipeddi, P. N. Suganthan, "Problem Definitions and Evaluation Criteria for the CEC 2017 Competition and Special Session on Constrained Single Objective Real-Parameter Optimization", Technical Report, Nanyang Technological University, Singapore, December 2016.

Problem Properties

Problem/Search Range	Type of Objective	Number of Constraints	
		E	*I*
C01 $[-100,100]^D$	Non Separable	0	1 Separable
C02 $[-100,100]^D$	Non Separable, Rotated	0	1 Non Separable, Rotated
C03 $[-100,100]^D$	Non Separable	1 Separable	1 Separable
C04 $[-10,10]^D$	Separable	0	2 Separable
C05 $[-10,10]^D$	Non Separable	0	2 Non Separable, Rotated
C06 $[-20,20]^D$	Separable	6	0 Separable
C07 $[-50,50]^D$	Separable	2 Separable	0
C08 $[-100,100]^D$	Separable	2 Non Separable	0
C09 $[-10,10]^D$	Separable	2 Non Separable	0

Problem Properties

Problem/Search Range	Type of Objective	Number of Constraints	
		E	*I*
C10 $[-100,100]^D$	Separable	2 Non Separable	0
C11 $[-100,100]^D$	Separable	1 Non Separable	1 Non Separable
C12 $[-100,100]^D$	Separable	0	2 Separable
C13 $[-100,100]^D$	Non Separable	0	3 Separable
C14 $[-100,100]^D$	Non Separable	1 Separable	1 Separable
C15 $[-100,100]^D$	Separable	1	1
C16 $[-100,100]^D$	Separable	1 Non Separable	1 Separable
C17 $[-100,100]^D$	Non Separable	1 Non Separable	1 Separable
C18 $[-100,100]^D$	Separable	1	2 Non Separable

Problem Properties

Problem/Search Range	Type of Objective	Number of Constraints	
		E	*I*
C19 $[-50,50]^D$	Separable	0	2 Non Separable
C20 $[-100,100]^D$	Non Separable	0	2
C21 $[-100,100]^D$	Rotated	0	2 Rotated
C22 $[-100,100]^D$	Rotated	0	3 Rotated
C23 $[-100,100]^D$	Rotated	1 Rotated	1 Rotated
C24 $[-100,100]^D$	Rotated	1 Rotated	1 Rotated
C25 $[-100,100]^D$	Rotated	1 Rotated	1 Rotated
C26 $[-100,100]^D$	Rotated	1 Rotated	1 Rotated
C27 $[-100,100]^D$	Rotated	1 Rotated	2 Rotated
C28 $[-50,50]^D$	Rotated	0	2 Rotated

Evaluation Criteria

(1) Rank all algorithms on one problem with multiple runs

- The procedure for ranking algorithms based on mean values:
  - ① Rank the algorithms based on feasibility rate;
  - ② Then rank the algorithms according to the mean violation amounts;
  - ③ At last, rank the algorithms in terms of mean objective function value.
- The procedure for ranking the algorithms based on the median solutions:
  - ① A feasible solution is better than an infeasible solution;
  - ② Rank feasible solutions based on their objective function values;
  - ③ Rank infeasible solutions according to their constraint violation amounts.

Evaluation Criteria

(2) Rank all algorithms on multiple problems

For each problem, algorithm ranks are determined in terms of the mean values and median solutions at the maximum allowed number of evaluations, respectively. The total rank value of each algorithm is calculated as below.

$$\text{Rank value} = \sum_{i=1}^{28} rank_i(\text{using mean value}) + \sum_{i=1}^{28} rank_i(\text{using median solution})$$

Algorithms

CAL-SHADE	Ales Zamuda. Adaptive Constraint Handling and Success History Differential Evolution for CEC 2017 Constrained Real-Parameter Optimization, CEC 2017
LSHADE44 + IDE	Josef Tvrdik and Radka Polakova. A Simple Framework for Constrained Problems with Application of L-SHADE44 and IDE, CEC 2017
LSHADE44	Radka Polakova. L-SHADE with Competing Strategies Applied to Constrained Optimization, CEC 2017
UDE	Anupam Trivedi, Krishnendu Sanyal, Pranjal Verma and Dipti Srinivasan. A Unified Differential Evolution Algorithm for Constrained Optimization Problems, CEC 2017

Ranks of the algorithms

Table 1 Ranks based on mean values on the 28 functions of 10 dimensions

Problems	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	
CAL-SHADE	3	3	4	4	3	2	4	4	3	3	3	3	3	1	4	4	4	4	1	1	1	3	2	4	4	4	4	1	84
LSHADE44 + IDE	4	4	3	1	1	4	2	2	2	2	2	2	1	4	1	2	2	1	3	3	3	2	3	2	3	2	1	3	65
LSHADE44	1	1	2	2	2	3	3	1	1	1	1	4	2	3	3	3	1	2	2	2	4	1	4	3	2	1	2	4	61
UDE	2	2	1	3	4	1	1	3	4	4	4	1	4	2	2	1	3	3	4	4	2	4	1	1	1	3	3	2	70

Ranks of the algorithms

Table 2 Ranks based on median solution on the 28 functions of 10 dimensions

Problems	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	
CAL-SHADE	1	1	4	4	1	2	2	4	4	1	2	2	1	2	3	4	4	4	1	3	3	1	3	4	4	4	4	1	**74**
LSHADE44 + IDE	1	1	3	1	1	4	3	1	1	2	1	3	1	4	2	3	1	3	3	2	4	1	4	3	3	2	3	2	**63**
LSHADE44	1	1	2	2	1	3	4	1	1	2	2	4	1	3	4	2	2	1	2	1	1	1	2	2	2	1	2	4	**55**
UDE	1	1	1	3	1	1	1	1	3	2	4	1	1	1	1	1	3	2	4	4	1	1	1	1	1	3	1	3	**49**

Ranks of the algorithms

Table 3 Ranks of the four methods on problems of 10 dimensions based on mean value and median solution

	CAL-SHADE	LSHADE44 + IDE	LSHADE44	UDE
Total rank values	158	128	116	119
Rank	**4**	**3**	**1**	**2**

Ranks of the algorithms

Table 4 Ranks based on mean values on the 28 functions of 30 dimensions

Problems	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	
CAL-SHADE	1	1	4	4	4	2	4	1	4	1	3	3	4	1	4	4	4	4	1	2	1	4	4	4	4	4	3	1	**81**
LSHADE44 + IDE	1	1	3	2	1	4	3	4	1	4	2	2	2	4	2	2	2	3	3	3	4	2	3	3	2	2	4	3	**72**
LSHADE44	1	1	2	1	1	3	2	2	1	2	1	1	1	3	3	3	1	1	2	1	3	3	2	2	3	1	2	4	**53**
UDE	1	1	1	3	3	1	1	3	3	3	4	4	3	2	1	1	3	2	4	4	2	1	1	1	1	3	1	2	**60**

Ranks of the algorithms

Table 5 Ranks based on median solution on the 28 functions of 30 dimensions

Problems	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	
CAL-SHADE	1	1	4	4	1	2	4	1	1	1	3	3	4	2	4	4	4	3	1	2	1	4	2	4	4	4	2	1	**72**
LSHADE44 + IDE	1	1	3	1	1	4	3	4	2	4	2	1	1	4	2	2	2	4	3	3	4	2	4	3	2	1	4	3	**71**
LSHADE44	1	1	2	2	1	3	2	2	2	2	1	2	3	3	3	3	1	1	2	1	3	3	3	2	3	2	3	4	**61**
UDE	1	1	1	3	1	1	1	3	4	3	4	4	2	1	1	1	3	2	4	4	1	1	1	1	1	3	1	2	**56**

Ranks of the algorithms

Table 6 Ranks of the four methods on problems of 30 dimensions based on mean value and median solution

	CAL-SHADE	LSHADE44 + IDE	LSHADE44	UDE
Total rank values	153	143	114	116
Rank	**4**	**3**	**1**	**2**

Ranks of the algorithms

Table 7 Ranks based on mean values on the 28 functions of 50 dimensions

Problems	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	
CAL-SHADE	4	4	4	4	3	2	4	4	4	2	3	3	4	1	4	4	4	3	1	2	2	4	4	4	4	4	2	1	**89**
LSHADE44 + IDE	3	1	3	2	1	4	3	3	3	4	1	1	2	4	2	2	2	2	3	3	3	1	3	3	3	2	3	4	**71**
LSHADE44	1	1	2	1	1	3	2	1	2	1	2	4	1	3	3	3	1	1	2	1	4	2	2	2	2	1	1	3	**53**
UDE	1	1	1	3	4	1	1	2	1	3	4	2	3	2	1	1	3	4	4	4	1	3	1	1	1	3	4	2	**62**

Ranks of the algorithms

Table 8 Ranks based on median solution on the 28 functions of 50 dimensions

Problems	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	
CAL-SHADE	1	1	3	4	1	2	4	4	3	2	3	3	4	1	4	4	4	4	1	2	2	4	2	4	4	4	2	1	**78**
LSHADE44 + IDE	1	1	4	1	1	4	3	3	4	4	2	1	2	4	2	3	2	3	3	3	3	2	4	3	3	2	4	4	**76**
LSHADE44	1	1	2	2	1	3	2	1	2	1	1	4	1	3	3	2	1	1	2	1	4	3	3	2	2	1	1	3	**54**
UDE	1	1	1	3	4	1	1	2	1	3	4	2	3	2	1	1	3	2	4	4	1	1	1	1	1	3	3	2	**57**

Ranks of the algorithms

Table 9 Ranks of the four methods on problems of 50 dimensions based on mean value and median solution

	CAL-SHADE	LSHADE44 + IDE	LSHADE44	UDE
Total rank values	167	147	107	119
Rank	**4**	**3**	**1**	**2**

Ranks of the algorithms

Table 10 Ranks based on mean values on the 28 functions of 100 dimensions

Problems	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	
CAL-SHADE	3	3	4	4	3	1	4	4	3	3	3	3	3	1	4	4	4	4	1	1	2	3	4	4	4	4	2	1	**84**
LSHADE44 + IDE	4	4	3	2	2	4	2	2	2	2	1	1	1	4	1	2	2	2	3	3	3	2	2	2	3	2	3	3	**67**
LSHADE44	1	1	2	1	1	3	3	1	1	1	2	4	2	3	3	3	1	1	2	2	4	1	3	1	2	1	1	4	**55**
UDE	2	2	1	3	4	2	1	3	4	4	4	2	4	2	2	1	3	3	4	4	1	4	1	3	1	3	4	2	**74**

Ranks of the algorithms

Table 11 Ranks based on median solution on the 28 functions of 100 dimensions

Problems	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	
CAL-SHADE	3	3	4	4	3	2	4	4	3	3	3	3	3	1	4	4	4	4	1	1	1	3	2	4	4	4	4	1	**84**
LSHADE44 + IDE	4	4	3	1	1	4	2	2	2	2	2	2	1	4	1	2	2	1	3	3	3	2	3	2	3	2	1	3	**65**
LSHADE44	1	1	2	2	2	3	3	1	1	1	1	4	2	3	3	3	1	2	2	2	4	1	4	3	2	1	2	4	**61**
UDE	2	2	1	3	4	1	1	3	4	4	4	1	4	2	2	1	3	3	4	4	2	4	1	1	1	3	3	2	**70**

Ranks of the algorithms

Table 12 Ranks of the four methods on problems of 100 dimensions based on mean value and median solution

	CAL-SHADE	LSHADE44 + IDE	LSHADE44	UDE
Total rank values	168	132	116	144
Rank	**4**	**2**	**1**	**3**

Ranks of the algorithms

Table 13 Ranks of the four methods on problems of all considered dimensions

	CAL-SHADE	LSHADE44 + IDE	LSHADE44	UDE
Total rank values	646	550	453	498
Rank	4th	3rd	1st	2nd