

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
MA-ES	Michael Hellwig and Hans-Georg Beyer. A Matrix Adaptation Evolution Strategy for Constrained Real-parameter Optimization (CEC 2018)
IUDE	Anupam Trivedi, Dipti Srinivasan and Nimagna Biswas. An Improved Unified Differential Evolution Algorithm for Constrained Optimization Problems (2018)
LSHADE-IEpsilon	Zhun Fan et. AL. LSHADE with an Improved ε Constraint-handling Method for Solving Constrained Single-objective Optimization Problems (2018)
L-SHADE+BOC	Takeshi Kawachi, Jun-ichi Kushida, Akira Hara, Tetsuyuki Takahama, L-SHADE with an Adaptive Penalty Method of Balancing the Objective Value and the Constraint Violation(GECCO 2019)
HECO-DE	Tao Xu, Jun He and Changjing Shang. Helper and Equivalent Objective Different Evolution for Constrained Optimisation(GECCO 2019)

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	1	1	1	1	1	1	9	1	1	1	7	7	1	2	2	1	1	3	2	3	5	1	3	2	1	1	3	2	65
LSHADE44 + IDE	1	1	6	1	1	1	2	1	1	1	8	5	1	5	1	6	3	4	4	1	8	1	2	1	6	2	4	3	81
LSHADE44	1	1	4	4	1	7	3	1	1	1	3	4	9	3	6	1	2	2	4	5	4	6	4	8	4	4	1	9	103
UDE	1	1	3	3	1	1	8	1	1	1	5	6	1	1	3	1	4	5	4	6	1	7	1	3	1	3	5	4	82
MA-ES	1	1	1	8	1	4	1	1	1	1	4	9	6	9	9	1	9	1	9	8	7	4	9	5	1	7	2	6	126
IUDE	1	1	5	7	8	6	4	1	1	1	9	1	7	4	5	5	7	6	4	9	6	8	5	3	5	8	6	5	138
LSHADE-IEpsilon	1	1	8	5	1	8	5	1	8	1	2	8	1	7	8	8	6	7	3	2	3	5	7	6	8	6	7	8	141
L-SHADE+BOC	1	1	7	6	1	9	6	1	1	1	1	3	1	8	4	7	5	8	4	4	2	3	8	7	7	5	9	7	127
HECO-DE	1	1	9	9	9	5	7	9	9	1	6	1	8	6	7	9	8	9	1	7	9	9	6	9	9	9	8	1	182

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	9	9	1	7	5	9	9	1	1	2	1	6	7	9	9	9	1	7	4	1	8	9	9	9	9	1	154
LSHADE44 + IDE	1	1	8	5	1	9	6	1	1	2	1	3	1	9	6	8	5	8	5	4	5	1	9	8	8	7	8	3	134
LSHADE44	1	1	7	6	1	8	7	1	1	2	1	9	1	8	8	7	6	6	3	2	1	1	7	7	7	5	7	8	129
UDE	1	1	4	7	1	6	4	1	1	2	9	1	1	1	1	5	8	7	5	9	1	1	1	1	5	8	6	3	101
MA-ES	1	1	1	8	1	1	1	1	1	2	1	4	1	3	9	1	7	1	5	8	6	1	3	6	1	6	1	7	89
IUDE	1	1	1	1	1	1	8	1	1	2	1	7	1	1	1	1	1	5	5	6	1	1	1	1	1	1	5	3	61
LSHADE-IEpsilon	1	1	5	4	1	1	3	1	1	2	7	5	1	3	1	1	4	3	4	5	8	1	5	1	1	4	2	9	85
L-SHADE+BOC	1	1	6	1	1	1	2	1	1	2	1	6	1	7	1	6	2	2	5	1	9	1	4	1	6	3	4	6	83
HECO-DE	1	1	1	1	1	1	9	1	1	2	8	8	1	3	1	1	3	4	2	3	7	1	6	1	1	2	3	2	76

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	LSHADE 44 + IDE	LSHAD E44	UDE	MA-ES	IUDE	LSHADE-IEpsilon	L-SHADE +BOC	HECO-DE
Total rank values	219	215	232	183	215	199	226	210	258
Rank	6	4	8	1	4	2	7	3	9

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	9	9	9	4	8	1	9	1	4	7	9	4	8	9	9	9	1	4	4	9	9	9	9	9	8	1	174
LSHADE44 + IDE	1	1	8	6	1	9	6	9	1	9	3	6	6	9	6	7	6	8	5	5	8	5	8	8	7	6	9	7	170
LSHADE44	1	1	7	3	1	8	5	2	1	2	2	4	4	8	7	8	5	6	3	2	7	6	7	7	8	5	7	8	135
UDE	1	1	3	8	7	3	2	8	1	8	8	8	7	5	5	5	7	7	8	8	5	4	5	5	4	7	6	5	151
MA-ES	1	1	1	7	1	2	1	2	1	2	1	9	1	6	9	1	8	2	9	9	9	1	6	6	1	8	1	4	110
IUDE	1	1	4	5	1	6	7	2	1	2	5	1	3	1	4	3	2	5	7	7	6	3	4	3	3	2	5	6	100
LSHADE-IEpsilon	1	1	6	2	1	7	4	2	1	2	9	5	8	3	3	4	4	1	4	3	3	7	2	4	5	4	2	9	107
L-SHADE+BOC	1	1	5	1	1	5	3	2	1	2	6	2	5	7	1	6	3	4	6	1	2	8	1	1	6	1	4	3	89
HECO-DE	1	1	1	3	8	1	9	2	1	2	7	3	1	2	2	1	1	3	2	6	1	2	3	2	1	3	3	2	74

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	9	9	1	5	8	1	1	1	4	7	9	5	8	9	9	8	1	4	1	9	6	9	9	9	7	1	152
LSHADE44 + IDE	1	1	8	3	1	9	7	9	2	9	3	1	1	9	6	7	7	9	4	5	8	6	9	8	7	5	9	7	161
LSHADE44	1	1	7	4	1	8	6	2	2	2	2	6	7	8	7	8	6	5	3	2	7	7	8	6	8	7	8	8	147
UDE	1	1	3	8	1	4	2	8	2	8	8	8	6	4	5	4	8	7	4	8	1	5	1	5	4	8	6	5	135
MA-ES	1	1	1	7	1	3	1	2	2	2	1	9	1	6	9	1	5	1	9	9	9	1	7	7	1	6	1	4	108
IUDE	1	1	4	6	1	7	5	2	2	2	5	2	1	1	3	3	2	6	4	7	1	1	1	2	3	1	5	6	85
LSHADE-IEpsilon	1	1	6	2	1	6	4	2	2	2	9	3	8	2	4	5	4	2	4	3	6	8	4	4	5	2	2	9	111
L-SHADE+BOC	1	1	5	1	1	1	3	2	2	2	6	4	1	7	1	6	3	4	4	1	1	1	3	1	6	3	4	3	78
HECO-DE	1	1	1	4	1	1	9	2	2	2	7	5	1	3	2	1	1	3	2	6	1	4	5	3	1	4	3	2	78

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	LSHADE 44 + IDE	LSHAD E44	UDE	MA-ES	IUDE	LSHADE-IEpsilon	L-SHADE +BOC	HECO-DE
Total rank values	326	331	282	286	218	185	218	167	152
Rank	8	9	6	7	4	3	4	2	1

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	9	9	9	9	8	3	8	9	9	7	5	6	9	4	9	9	9	8	1	4	5	8	9	9	9	9	7	1	201
LSHADE44 + IDE	8	1	8	5	1	8	6	8	7	9	1	4	6	9	6	7	7	7	4	5	7	4	8	8	8	7	8	8	175
LSHADE44	1	1	7	2	1	7	5	1	3	1	2	8	5	8	7	8	6	6	3	2	8	5	6	7	7	6	6	7	136
UDE	1	1	3	8	9	2	2	7	1	8	6	5	8	5	5	4	8	9	7	7	2	7	5	5	4	8	9	5	151
MA-ES	1	1	1	7	1	1	1	2	8	1	3	9	7	7	8	1	5	1	9	9	6	3	7	6	1	4	1	4	115
IUDE	1	1	4	6	1	9	7	4	1	1	7	3	4	1	3	3	2	5	6	8	3	2	4	3	3	1	5	6	104
LSHADE-IEpsilon	1	1	6	4	7	6	4	6	6	6	8	7	2	2	4	5	4	2	5	3	4	9	2	4	6	5	2	9	130
L-SHADE+BOC	1	1	5	1	1	4	3	2	3	1	4	2	3	6	1	6	3	4	8	1	9	1	1	1	5	3	4	2	86
HECO-DE	1	1	1	2	1	5	9	5	3	5	9	1	1	3	2	1	1	3	2	6	1	6	3	2	1	2	3	3	83

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	8	9	1	5	7	9	7	7	5	6	9	4	9	9	9	9	1	4	5	8	6	9	9	9	7	1	174
LSHADE44 + IDE	1	1	9	2	1	8	6	8	9	9	3	3	7	9	6	8	7	8	5	5	8	6	9	8	8	7	9	8	178
LSHADE44	1	1	7	3	1	7	5	1	3	1	1	9	6	8	8	7	6	6	4	2	9	7	8	7	7	6	6	7	144
UDE	1	1	3	8	9	4	2	7	1	8	6	5	8	5	5	4	8	7	9	7	1	5	1	6	4	8	8	5	146
MA-ES	1	1	1	7	1	3	1	2	8	1	2	8	1	6	7	1	4	1	8	9	7	4	7	5	1	4	1	4	106
IUDE	1	1	4	6	1	9	8	4	1	1	7	4	1	2	2	3	1	5	2	8	3	3	1	2	3	1	5	6	95
LSHADE-IEpsilon	1	1	6	1	1	6	4	6	3	6	8	7	5	1	4	5	5	2	6	3	4	9	5	4	6	5	2	9	125
L-SHADE+BOC	1	1	5	5	1	1	3	2	3	1	4	2	1	7	1	6	3	4	7	1	6	2	1	1	5	3	4	3	84
HECO-DE	1	1	1	3	1	2	9	5	3	5	9	1	1	3	3	1	2	3	3	6	2	1	4	3	1	2	3	2	81

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	LSHADE 44 + IDE	LSHAD E44	UDE	MA-ES	IUDE	LSHADE-IEpsilon	L-SHADE +BOC	HECO-DE
Total rank values	375	353	280	297	221	199	255	170	164
Rank	9	8	6	7	4	3	5	2	1

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	8	8	9	9	6	2	9	9	7	8	5	6	8	2	9	9	9	9	1	2	4	6	9	9	9	9	7	1	189
LSHADE44 + IDE	9	9	7	3	4	8	5	6	2	7	1	2	4	9	4	7	7	7	4	5	5	5	6	6	8	7	8	6	161
LSHADE44	1	1	6	2	3	7	6	2	1	1	4	9	5	8	7	8	5	6	3	4	8	4	8	5	7	5	6	8	140
UDE	7	7	3	8	9	3	2	8	9	9	6	3	9	6	6	3	8	8	8	8	3	9	2	7	3	8	9	5	176
MA-ES	1	1	1	6	8	1	1	3	8	4	2	8	2	7	8	1	4	1	9	9	7	1	7	3	1	4	2	4	114
IUDE	1	1	8	7	5	9	7	4	5	5	3	4	7	1	3	4	2	5	6	7	1	7	5	4	5	2	5	7	130
LSHADE-IEpsilon	6	6	5	5	7	5	4	7	6	6	8	5	3	4	5	5	6	2	5	3	2	8	4	8	6	6	3	9	149
L-SHADE+BOC	1	1	4	4	1	6	3	1	4	2	7	1	6	5	1	6	3	4	7	1	9	3	1	1	4	3	4	2	95
HECO-DE	1	1	1	1	1	4	8	5	3	3	9	7	1	3	2	1	1	3	2	6	6	2	3	2	2	1	1	3	83

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	8	8	9	9	6	3	9	9	5	8	5	5	8	1	9	9	9	9	1	2	2	6	6	9	9	9	9	1	183
LSHADE44 + IDE	9	9	8	1	3	8	7	6	2	7	4	3	5	9	5	7	7	6	4	5	6	5	7	7	8	7	6	7	168
LSHADE44	1	1	7	2	4	7	8	2	1	1	2	9	6	8	8	8	5	7	3	4	7	4	9	8	7	4	7	8	148
UDE	7	7	3	8	9	2	3	8	7	9	6	2	9	6	7	3	8	8	8	8	4	9	3	5	3	8	8	5	173
MA-ES	1	1	1	6	8	1	2	3	9	5	1	7	3	7	1	1	4	1	9	9	5	2	8	3	1	5	1	4	109
IUDE	1	1	6	7	5	9	6	4	8	4	3	4	7	2	6	4	2	5	7	7	1	7	5	4	5	2	5	6	133
LSHADE-IEpsilon	6	6	5	4	7	4	5	7	6	6	8	6	4	5	1	5	6	2	6	3	3	8	4	6	6	6	4	9	148
L-SHADE+BOC	1	1	4	5	1	5	4	1	4	2	7	1	2	3	1	6	3	4	5	1	9	3	1	1	4	3	3	2	87
HECO-DE	1	1	1	2	1	6	1	5	3	3	9	8	1	4	1	1	1	3	2	6	8	1	2	2	2	1	2	3	81

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	LSHADE 44 + IDE	LSHAD E44	UDE	MA-ES	IUDE	LSHADE-IEpsilon	L-SHADE +BOC	HECO-DE
Total rank values	372	329	288	349	223	263	297	182	164
Rank	9	7	5	8	3	4	6	2	1

Ranks of the algorithms

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

	CAL-SHADE	LSHADE 44 + IDE	LSHAD E44	UDE	MA-ES	IUDE	LSHADE-IEpsilon	L-SHADE +BOC	HECO-DE
Total rank values	1292	1228	1082	1115	877	846	996	729	738
Rank	9th	8th	6th	7th	4th	3rd	5th	1st	2nd