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The Singapore 2010 Youth Olympic Village

Comparison of Results on the 2010 CEC Benchmark Function Set

presented by

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July 2010

Evaluation Criteria

- **Problems**: 10D and 30D versions of 18 scalable minimization problems with constraints
- Minimize $f(X), \quad X = (x_1, x_2, ..., x_D)$ and $X \in S$
- Subject to $g_i(X) \le 0, \quad i = 1, ..., p$
  $h_j(X) = 0, \quad j = p+1, ..., m$
- Equality constraints are transformed into inequalities of the form
  $$|h_j(X)| - \varepsilon \le 0, \text{ for } j = p+1, ..., m$$
- In this special session ε is set to 0.0001
- **Reference**:

R. Mallipeddi, P. N. Suganthan, "Problem Definitions and Evaluation Criteria for the CEC 2010 Competition on Constrained Real-Parameter Optimization", *Technical Report*, Nanyang Technological University, Singapore, 2010

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Evaluation Criteria – Problem Properties

Problem/Search Range	Type of Objective	Number of Constraints		Feasibility Region (ρ)	
		E	*I*	10D	30D
C01 $[0,10]^D$	Non Separable	0	2 Non Separable	0.997689	1.000000
C02 $[-5.12,5.12]^D$	Separable	1 Separable	2 Separable	0.000000	0.000000
C03 $[-1000,1000]^D$	Non Separable	1 Non Separable	0	0.000000	0.000000
C04 $[-50,50]^D$	Separable	4 2 Non Separable, 2 Separable	0	0.000000	0.000000
C05 $[-600,600]^D$	Separable	2 Separable	0	0.000000	0.000000
C06 $[-600,600]^D$	Separable	2 Rotated	0	0.000000	0.000000
C07 $[-140,140]^D$	Non Separable	0	1 Separable	0.505123	0.503725
C08 $[-140,140]^D$	Non Separable	0	1 Rotated	0.379512	0.375278
C09 $[-500500]^D$	Non Separable	1 Separable	0	0.000000	0.000000

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Evaluation Criteria- Problem Properties

Problem/Search Range	Type of Objective	Number of Constraints		Feasibility Region (ρ)	
		E	*I*	10D	30D
C10 $[-500,500]^D$	Non Separable	1 Rotated	0	0.000000	0.000000
C11 $[-100,100]^D$	Rotated	1 Non Separable	0	0.000000	0.000000
C12 $[-1000,1000]^D$	Separable	1 Non Separable	1 Separable	0.000000	0.000000
C13 $[-500,500]^D$	Separable	0	3 2 Separable, 1 Non Separable	0.000000	0.000000
C14 $[-1000,1000]^D$	Non Separable	0	3 Separable	0.003112	0.006123
C15 $[-1000,1000]^D$	Non Separable	0	3 Rotated	0.003210	0.006023
C16 $[-10,10]^D$	Non Separable	2 Separable	2 1 Separable, 1 Non Separable	0.000000	0.000000
C17 $[-10,10]^D$	Non Separable	1 Separable	2 Non Separable	0.000000	0.000000
C18 $[-50,50]^D$	Non Separable	1 Separable	1 Separable	0.000010	0.000000

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Evaluation Criteria

- D is the number of decision variables
- $\rho = |F|/|S|$ is the estimated ratio between the feasible region and the search space
- I is the number of inequality constraints
- E is the number of equality constraints
- Runs/problem: 25
- Max_FES : 200000 for 10D and 600000 for 30D
- Feasible Run: A run during which at least one feasible solution is found within Max FES.
- Feasible Rate = (# of feasible runs) / Total runs.
- The above quantity is computed for each problem separately.

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Evaluation Criteria

- Ranking is given to each algorithm on every problem based on the following criteria

1. Algorithms giving 100% feasibility rate are ranked based on mean value of the 25 runs
2. Algorithms having feasibility rate in the range >0% - <100% are ranked based on feasibility rate.
3. Algorithms with 0% feasibility rate are ranked based on overall violation (normalized).

- Finally we add all the ranks of a particular algorithm over all problems to get the total rank
- Average Rank = Total rank/36

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Algorithms

- jDEsoco Janez Brest, *et al* (An Improved Self-adaptive Differential …)
- DE-VPS M. Fatih Tasgetiren, *eta al* (An Ensemble of Differential …)
- RGA Amit Saha, *et al* (Hybrid Gradient Projection Genetic …)
- E-ABC Efren Mezura Montes, *et al* (Elitist Artificial Bee Colony…)
- εDEg Tetsuyuki Takahama & Setsuko Sakai (Constrained …)
- DCDE Zhihui Li, *et al* (Differential Evolution with Dynamic …)
- Co-CLPSO J. J. Liang, *et al* (Coevolutionary Comprehensive Learning …)
- CDEb6e6rl Josef Tvrdik & Radka Polakova (Competitive Differential …)
- sp-MODE Gilberto Reynoso-Meza *et al* (Multiobjective optimization …)
- MTS Lin-Yu Tseng and Chun Chen (Multiple Trajectory Search …)
- IEMA Hemanth Kumar Singh, et al (Performance of Infeasibility …)
- ECHT R. Mallipeddi & P. N. Suganthan (Differential Evolution …)

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Algorithms' Parameters

Algorithm	Parameters
jDEsoco	*NP,* $p_0, \tau_1, \tau_2, F_l, F_u, \theta, \beta, c_p, \alpha_1, \alpha_2, G_c$
DE-VPS	*NP, CR, F,* $NFT_0, \lambda, \theta, t_c, c_p$
RGA	*N,* p_c, η_c, p_m, η_m
E-ABC	*SN, S, ε, MR, dec, FEs ratio, cycle limit, Step size variation*
εDEg	*N,* F_0*,* CR_0*,* T_c*,* θ*,* P_g*,* R_g*, M*
DCDE	*NP, F, CR, P, L, L_FEs*
Co-CLPSO	*w, c,* V_{max}*, ps, R, L, L_FES, T,* P_c
CDEb6e6rl	*NP,* n_0 *,* δ
sp-MODE	*F, Cr,* $\lvert N_s(k)\rvert, \lvert P(0)\rvert, \alpha_\varepsilon$
MTS	*SSS, Threshold,* M_1, M_2
IEMA	*N, Crossover Probability, Crossover Index, Mutation Probability, Mutation Index, α*
ECHT	*NP, CR, F,* p_f, θ, T_c, c_p

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Algorithms' Comparison (10D)

Alg/Prob	C01	C02	C03	C04	C05	C06	C07	C08	C09
jDEsoco	6	12	8	1	9	4	1	2	3
DE-VPS	10	6	10	8	5	9	9	10	5
RGA	8	8	12	7	10	10	10	4	6
E-ABC	9	7	11	10	7	7	11	11	8
εDEg	1	5	1	4	1	1	1	8	1
DCDE	11	4	1	9	1	1	7	9	4
Co-CLPSO	7	3	5	6	1	1	8	1	7
CDEb6e6rl	4	9	6	1	11	11	1	7	11
sp-MODE	1	11	9	12	12	12	1	6	12
MTS	12	10	7	11	6	6	12	12	9
IEMA	5	1	4	5	8	8	5	5	10
ECHT	1	2	1	1	4	5	6	3	2

Algorithms' Comparison (10D)

Alg/Prob	C10	C11	C12	C13	C14	C15	C16	C17	C18
jDEsoco	4	3	4	3	4	7	8	9	9
DE-VPS	5	7	9	5	5	4	1	6	1
RGA	6	8	10	6	7	6	9	7	7
E-ABC	9	11	4	7	11	10	6	8	8
εDEg	1	1	1	1	1	2	7	4	1
DCDE	3	5	8	11	2	1	5	2	5
Co-CLPSO	7	10	3	8	3	3	2	5	6
CDEb6e6rl	11	6	2	1	10	12	11	11	11
sp-MODE	12	12	12	12	9	8	12	12	12
MTS	8	9	11	10	12	11	10	10	10
IEMA	10	2	4	4	6	5	3	1	1
ECHT	2	4	4	9	8	9	4	3	1

Algorithms' Comparison (30D)

Alg/Prob	C01	C02	C03	C04	C05	C06	C07	C08	C09
jDEsoco	5	8	3	3	8	2	1	6	2
DE-VPS	11	6	7	7	4	7	6	9	8
RGA	7	7	11	6	5	8	11	12	7
E-ABC	8	9	10	9	6	6	12	8	9
εDEg	2	3	2	4	1	1	3	2	3
DCDE	10	2	1	8	9	9	5	3	12
Co-CLPSO	9	1	9	5	2	3	8	7	6
CDEb6e6rl	1	10	5	2	11	10	1	1	1
sp-MODE	3	11	8	12	12	12	10	10	11
MTS	12	12	6	10	7	5	7	11	10
IEMA	4	5	12	11	10	11	4	4	5
ECHT	6	4	4	1	3	4	9	5	4

Algorithms' Comparison (30D)

Alg/Prob	C10	C11	C12	C13	C14	C15	C16	C17	C18
jDEsoco	2	3	1	1	4	6	7	9	9
DE-VPS	6	7	9	9	5	4	6	5	4
RGA	7	6	6	8	9	7	9	8	6
E-ABC	10	9	7	5	7	9	8	7	8
εDEg	3	2	10	4	1	2	1	6	7
DCDE	1	5	2	7	3	1	5	4	3
Co-CLPSO	8	10	3	10	5	3	1	3	5
CDEb6e6rl	12	1	8	3	10	11	10	12	11
sp-MODE	11	12	12	12	12	10	12	10	10
MTS	9	8	4	11	11	12	11	11	12
IEMA	5	11	11	2	2	5	4	1	1
ECHT	4	4	5	6	8	8	1	2	1

Comparison of Algorithms

Algorithm	Ranking			
	10D	30D	Overall	Average
jDEsoco	97	80	177	4.92
DE-VPS	115	120	235	6.53
RGA	141	140	281	7.81
E-ABC	155	147	302	8.39
εDEg	42	57	99	2.75
DCDE	89	90	179	4.97
Co-CLPSO	86	98	184	5.11
CDEb6e6rl	136	120	256	7.11
sp-MODE	177	190	367	10.19
MTS	176	169	345	9.58
IEMA	87	108	195	5.42
ECHT	69	79	148	4.11

Final Rank

Rank	Algorithm
1st	εDEg
2nd	ECHT
3rd	jDEsoco
4th	DCDE
5th	Co-CLPSO
6th	IEMA
7th	DE-VPS
8th	CDEb6e6rl
9th	RGA
10th	E-ABC
11th	MTS
12th	sp-MODE

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