Guidelines for Real-World Single-Objective Constrained Optimisation Competition

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For this competition, we develop a set of 57 real-world single-objective constrained problems [1] with different dimensions to vary from 2 to 158. The developed problems contain a wide variety of constraints. In [1], a brief description and baseline results of these problems are reported. This additional attachment provides the basic guidelines of the experimental setting and presentation of results (for manuscript and competition) for the participants. In addition, performance measures used to evaluate the performance of algorithms are also provided in this attachment.

1. Experimental Setting

Number of Trials/problem: 25 independent trials.
Maximum Function Evaluation:

$$Max_{FEs} = \begin{cases} 1 \times 10^5, & \text{if } D \leq 10 \\ 2 \times 10^5, & \text{if } 10 < D \leq 30 \\ 4 \times 10^5, & \text{if } 30 < D \leq 50 \\ 8 \times 10^5, & \text{if } 50 < D \leq 150 \\ 10^6, & \text{if } 150 < D \end{cases} \tag{1}$$

where Max_{FEs} is maximum allowed function evaluations and D is dimension (number of decision variable) of problem.
Population Size: You are free to have an appropriate population size to suit your algorithm while not exceeding the Max_{FEs}.
Search Range: Search range for each problems are provided in *Source Code*.
Initialization: Uniform random initialization within the search range. Random seed is based on time, Matlab users can use rand ('state', sum(100*clock)).
Parameter Setting: We discourage participants searching for a distinct set of parameters for each problem/dimension/etc. Please provide details on the following whenever applicable.

1. All parameters to be adjusted.
2. Corresponding dynamic ranges.
3. Guidelines on how to adjust the parameters.

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4. Estimated cost of parameter tuning in terms of number of function evaluations.
5. Actual parameter values used.

Algorithm Complexity: Following procedures are suggested to calculate the algorithmic complexity.

1. $T_1 = \frac{\sum_{i=1}^{57} t_{1i}}{57}$, where t_{1i} is the computation time required to evaluate function for 100000 times for problem i.
2. $T_2 = \frac{\sum_{i=1}^{57} t_{2i}}{57}$, where t_{2i} is the computation time required by algorithm for 100000 function evaluations for problem i.
3. The algorithmic complexity is evaluated using T_1, T_2, and $\frac{T_2-T_1}{T_1}$.

PC configuration in terms of CPU, OS, RAM, Environment (MATLAB, PYTHON, etc), and Algorithm's name need to mention before algorithm complexity.
Encoding: If the algorithm requires encoding, then the encoding scheme should be independent of the specific problems and governed by generic factors such as the search ranges.
Objective Function: Objective functions of benchmark problems are treated as blackbox problems. The explicit equation of objective function (provided in [1]) must not be used.
Constraints: Constraints can be treated as white-box. Explicit constraint equations (provided in [1]) can be used except for RC27, RC33, RC40, RC42, RC43, and RC44 problems. In these problems, explicit functions are not defined for the constraints. Authors can manipulate the constraint equations. But, evaluations of a constraint equation or its derivatives must also be counted as one function evaluation.

2. Preparation of Statistics

Record the objective function value $f(x)$ and constraint violation $v(x)$ for the achieved best solution x after $0.1Max_{FEs}$, $0.2Max_{FEs}$, $0.3Max_{FEs}$,..., $0.9Max_{FEs}$ and Max_{FEs} function evaluations for each problems. To calculate the $v(x)$ for solution x, following equation must be used.

$$v(x) = \frac{\sum_{i=1}^{p} G_i(x) + \sum_{j=p+1}^{m} H_j(x)}{m}, \tag{2}$$

where

$$G_i(x) = \begin{cases} g_i(x), & \text{if } g_i(x) > 0 \\ 0, & \text{if } g_i(x) \leq 0. \end{cases}$$

and

$$H_j(x) = \begin{cases} |h_j(x)|, & \text{if } |h_j(x)| - 0.0001 > 0 \\ 0, & \text{if } |h_j(x)| - 0.0001 \leq 0. \end{cases}$$

Also, calculate Feasibility Rate (FR) and a vector c for each problems over 25 trails using following procedures.

1. FR:
$$\text{FR} = \frac{\text{Total feasible trials}}{\text{Total trials}}, \tag{3}$$
where a feasible trial is a trial during which at least one feasible solution is found under Max_{FEs} function evaluations.
2. The vector c is the vector of number of violated constraints at the median solution that have three elements indicate the number of violations (including inequality and equality constraints) by more than 1.0, in the range [0.01, 1.0] and less than 0.01 respectively.

3. Presentation of Results

The simulation results obtained for the different optimization problems should be reported in the specified formats (in the manuscript and for the competition).

3.1. Presentation of results in the conference manuscript

For each problem, the results need to be presented in the following format in the manuscript.

Table 1: Outcomes at FEs = Max_{FEs} for Problems RC01-RC08.

		RC01	RC02	RC03	RC04	RC05	RC06	RC07	RC08
Best	f								
	v								
Median	f								
	v								
Mean	f								
	v								
Worst	f								
	v								
Std	f								
	v								
FR									
c									

$*$The solution sorting method:

1. Sort feasible solutions in front of infeasible solutions;
2. Sort feasible solutions according to their function values $f(x^*)$;
3. Sort infeasible solutions according to their mean value of the violations of all constraints.

3.2. Presentation of results for the competition

To compare and evaluate the algorithms participating in the competition, it is necessary that the authors send (through email) the results in the following format to the organizers.
Create two txt document with the name "AlgorithmName_FunctionNo._F.txt" and "AlgorithmName_FunctionNo._CV.txt" for each problem.
For example, PSO results for problem RC05, the files name should be "PSO_RC05_F.txt" and "PSO_RC05_CV.txt".
Then save the results matrix (the blocking part) as Table II and Table III in the file.

Table 2: Information matrix saved in"PSO_RC05_F.txt"

	Trial 1	Trial 2	::	Trial 25
Objective Function values of best solution at $FEs = 0.1 * Max_{FES}$				
Objective Function values of best solution at $FEs = 0.2 * Max_{FES}$				
Objective Function values of best solution at $FEs = 0.3 * Max_{FES}$				
::				
Objective Function values of best solution at $FEs = 0.9 * Max_{FES}$				
Objective Function values of best solution at $FEs = 1.0 * Max_{FES}$				

Table 3: Information matrix saved in"PSO_RC05_CV.txt"

	Trial 1	Trial 2	::	Trial 25
Constraint Violation of best solution at $FEs = 0.1 * Max_{FES}$				
Constraint Violation of best solution at $FEs = 0.2 * Max_{FES}$				
Constraint Violation of best solution at $FEs = 0.3 * Max_{FES}$				
::				
Constraint Violation of best solution at $FEs = 0.9 * Max_{FES}$				
Constraint Violation of best solution at $FEs = 1.0 * Max_{FES}$				

Thus $57 * 2$ files should be zipped and sent to the organizers. Each file contains a (10×25) matrix.
Notice: All participants are allowed to improve their algorithms further after submitting the initial version of their papers submitted to conference. And they are required to submit their results in the introduced format to the organizers after submitting the **final** version of paper as soon as possible.

4. Performance Measure for algorithms

The performance measure (PM) for each algorithm is defined using following equation.

$$PM_i = 0.5 * \sum_{j=1}^{57} w_j * \widehat{Af}_{i,j}^{best} + 0.3 * \sum_{j=1}^{57} w_j * \widehat{Af}_{i,j}^{mean} + 0.2 * \sum_{j=1}^{57} w_j * \widehat{Af}_{i,j}^{medium}, \tag{4}$$

where, $\widehat{Af}_{i,j}^{best}$, $\widehat{Af}_{i,j}^{mean}$, and $\widehat{Af}_{i,j}^{median}$ are normalized adjusted objective function value of best, mean and medium solution, respectively, of j-th problem for i-th algorithm and w_j is weight value of j-th problem.
The weight value of $j-$th problem is set as follows.

$$w_j = \begin{cases} 0.008, & \text{if } D_j \leq 10 \\ 0.016, & \text{if } 10 < D_j \leq 30 \\ 0.024, & \text{if } 30 < D_j \leq 50 \\ 0.032, & \text{if } 50 < D_j \leq 150 \\ 0.040, & \text{if } 150 < D_j \end{cases} \tag{5}$$

To calculate the normalized adjusted objective function value of the best solution of an algorithm on a benchmark problem, the following procedure is adopted.

1. Select the worst feasible solution ($f_{worst,j}^{F,best}$) from the combined set of best solutions of all algorithms in the competition for j-th problem. If there is no feasible solution in combined set, then $f_{worst,j}^{F,best}$ is set to 0.
2. Then, calculate the adjusted objective function value of best solution for each algorithms using following equation.
$$Af_{i,j}^{best} = \begin{cases} f_{worst,j}^{F,best} + v_{i,j}^{best}, & \text{if } v_{i,j}^{best} > 0 \\ f_{i,j}^{best}, & \text{if } v_{i,j}^{best} \leq 0 \end{cases} \tag{6}$$
3. At last, normalized the adjusted objective function value of best solution for each algorithms using following equation.
$$\widehat{Af}_{i,j}^{best} = \frac{Af_{i,j}^{best} - Af_{min,j}^{best}}{Af_{max,j}^{best} - Af_{min,j}^{best}}, \tag{7}$$
where,
$$Af_{min,j}^{best} = min\{Af_{1,j}^{best}, Af_{2,j}^{best}, ...Af_{i,j}^{best}, ...\}, \tag{8}$$
$$Af_{max,j}^{best} = max\{Af_{1,j}^{best}, Af_{2,j}^{best}, ...Af_{i,j}^{best}, ...\}. \tag{9}$$

A similar procedure is utilized to calculate the adjusted objective function value of the mean and median solution of the algorithms. The best algorithm will provide the lowest PM value. The top three winners will be announced. Special attention will be paid to which algorithm has advantages on which kind of problems, considering dimension and problem characteristics.

5. Details of Real-World Problems

Table 4: Details of the 57 real-world COPs. D is the total number of decision variables of the problem, g is the number of inequality constraints and h is the number of equality constraints, $f(\bar{x}^*)$ is best known feasible objective function value.

Prob	Name	D	g	h	$f(\bar{x}^*)$
Industrial Chemical Processes					
RC01	Heat Exchanger Network Design (case 1)	9	0	8	1.8931162966E+02
RC02	Heat Exchanger Network Design (case 2)	11	0	9	7.0490369540E+03
RC03	Optimal Operation of Alkylation Unit	7	14	0	-4.5291197395E+03
RC04	Reactor Network Design (RND)	6	1	4	-3.8826043623E-01
RC05	Haverly's Pooling Problem	9	2	4	-4.0000560000E+02
RC06	Blending-Pooling-Separation problem	38	0	32	1.8638304088E+00
RC07	Propane, Isobutane, n-Butane Nonsharp Separation	48	0	38	1.5670451000E+00
Process Synthesis and Design Problems					
RC08	Process synthesis problem	2	2	0	2.0000000000E+00
RC09	Process synthesis and design problem	3	1	1	2.5576545740E+00
RC10	Process flow sheeting problem	3	3	0	1.0765430833E+00
RC11	Two-reactor Problem	7	4	4	9.9238463653E+01
RC12	Process synthesis problem	7	9	0	2.9248305537E+00
RC13	Process design Problem	5	3	0	2.6887000000E+04
RC14	Multi-product batch plant	10	10	0	5.3638942722E+04
Mechanical Engineering Problems					
RC15	Weight Minimization of a Speed Reducer	7	11	0	2.9944244658E+03
RC16	Optimal Design of Industrial refrigeration System	14	15	0	3.2213000814E-02
RC17	Tension/compression spring design (case 1)	3	3	0	1.2665232788E-02
RC18	Pressure vessel design	4	4	0	5.8853327736E+03
RC19	Welded beam design	4	5	0	1.6702177263E+00
RC20	Three-bar truss design problem	2	3	0	2.6389584338E+02
RC21	Multiple disk clutch brake design problem	5	7	0	2.3524245790E-01
RC22	Planetary gear train design optimization problem	9	10	1	5.2576870748E-01
RC23	Step-cone pulley problem	5	8	3	1.6069868725E+01
RC24	Robot gripper problem	7	7	0	2.5287918415E+00
RC25	Hydro-static thrust bearing design problem	4	7	0	1.6161197651E+03
RC26	Four-stage gear box problem	22	86	0	3.5359231973E+01
RC27	10-bar truss design	10	3	0	5.2445076066E+02
RC28	Rolling element bearing	10	9	0	1.4614135715E+04
RC29	Gas Transmission Compressor Design (GTCD)	4	1	0	2.9648954173E+06
RC30	Tension/compression spring design (case 2)	3	8	0	2.6138840583E+00
RC31	Gear train design Problem	4	1	1	0.0000000000E+00
RC32	Himmelblau's Function	5	6	0	-3.0665538672E+04
RC33	Topology Optimization	30	30	0	2.6393464970E+00
Power System Problems					
RC34	Optimal Sizing of Single Phase Distributed Generation with reactive power support for Phase Balancing at Main Transformer/Grid	118	0	108	0.0000000000E+00
RC35	Optimal Sizing of Distributed Generation for Active Power Loss Minimization	153	0	148	7.9963854000E-02
RC36	Optimal Sizing of Distributed Generation (DG) and Capacitors for Reactive Power Loss Minimization	158	0	148	4.7733529000E-02
RC37	Optimal Power flow (Minimization of Active Power Loss)	126	0	116	1.8593563000E-02
RC38	Optimal Power flow (Minimization of Fuel Cost)	126	0	116	2.7139366000E+00
RC39	Optimal Power flow (Minimization of Active Power Loss and Fuel Cost)	126	0	116	2.7515909000E+00
RC40	Microgrid Power flow (Islanded case)	76	0	76	0.0000000000E+00
RC41	Microgrid Power flow (Grid-connected case)	74	0	74	0.0000000000E+00
RC42	Optimal Setting of Droop Controller for Minimization of Active Power Loss in Islanded Microgrids	86	0	76	7.7027102000E-02
RC43	Optimal Setting of Droop Controller for Minimization of Reactive Power Loss in Islanded Microgrids	86	0	76	7.9835970000E-02
RC44	Wind Farm Layout Problem	30	91	0	-6.2731715000E+03
Power Electronic Problems					
RC45	SOPWM for 3-level Invereters	25	24	1	3.0739360000E-02
RC46	SOPWM for 5-level Inverters	25	24	1	2.0240335000E-02
RC47	SOPWM for 7-level Inverters	25	24	1	1.2783068000E-02
RC48	SOPWM for 9-level Inverters	30	29	1	1.6787535766E-02
RC49	SOPWM for 11-level Inverters	30	29	1	9.3118741800E-03
RC50	SOPWM for 13-level Inverters	30	29	1	1.5051470000E-02
Livestock Feed Ration Optimization					
RC51	Beef Cattle(case 1)	59	14	1	4.5508511497E+03
RC52	Beef Cattle (case 2)	59	14	1	3.3489821493E+03
RC53	Beef Cattle (case 3)	59	14	1	4.9976069290E+03
RC54	Beef Cattle (case 4)	59	14	1	4.2405482538E+03
RC55	Dairy Cattle (case 1)	64	0	6	6.6964145128E+03
RC56	Dairy Cattle (case 2)	64	0	6	1.4746580000E+04
RC57	Dairy Cattle (case 3)	64	0	6	3.2132917019E+03

References

[1] Abhishek Kumar, Guohua Wu, Mostafa Z. Ali, Rammohan Mallipeddi, Ponnuthurai Nagaratnam Suganthan, and Swagatam Das, "A Test-suite of Non-Convex Constrained Optimization Problems from the Real-World and Some Baseline Results" *submitted to*: Swarm and Evolutionary

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