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Effects of Control Parameters of Simple Optimization Technique (SOPT) in Solving Constrained Optimization Problem

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Abstract:
Simple Optimization Technique (SOPT) is an efficient Meta-heuristic population based technique where iterations are done in stages namely exploration and exploitation. Each stage is represented with a defining equation and Control parameters are used for each equation. Almost all Meta-heuristic technique is dependent on control parameters. Control parameters play a vital role in obtaining final result tremendously. In the present work the effect of two control parameters of SOPT is studied by selecting two constrained optimization problems.

Keywords- *Meta-heuristic Technique; Simple Optimization Technique (SOPT); Optimization.*

I. INTRODUCTION

One of the important steps in design of any physical system is optimization of the system. Resources available in nature may be in abundance but still it is finite therefore it is always wise to use some optimization technique to minimize the use of resources without effecting the functionality of the system. An optimization model is the mathematical model which is either to be maximized or minimized by satisfying necessary set of conditions. Many real world decision problems can be formulated by optimization framework and they are generally nonlinear in nature. An Optimization problem can be linear or nonlinear. A linear optimization problem must have linear objective function and linear constraints and for nonlinear optimization problem the objective function and constraints would be nonlinear. General representation of a nonlinear programming problem can be given as:

Minimize $f(x_1, x_2, x_3, \ldots.. x_n)$

Subjected to:

$g_j(x) \geq 0 \qquad j = 1,2,3,\ldots.J$

$h_k(x) = 0 \qquad k = 1,2,3,\ldots.K$

$x_i^{\min} \leq x \leq x_i^{\max} \qquad i = 1,2,3,\ldots.N$

Here objective is kept as minimization type. Any problem having an objective to be maximized can be converted to above form by multiplying the function by -1[3].

Main components of an optimization models are:

A. Decision variables: When the best values of variables are identified for any non-linear problem then it is expected that the problem is solved. These are called decision variables because here the problem has to decide what value each variable should take.

B. Objective function: It represents the amount of contribution made by each variable to optimize the function i.e. either maximize or minimize. Sometimes variables do not contribute to the objective function and in this case the variable has zero coefficients.

C. Constraints: These are the set of conditions for the decision variables which are needed to be satisfied. They can be linear or nonlinear constraints with equality or inequality.

D. Non negative constraints: In optimization framework, variables are represented by decision variables. The purpose of solving an optimization model is to achieve the optimal values of these decision variables. These variables are positive integers and sometimes lower bound and upper bound properties are also defined for these variables.

II. META-HEURISTIC TECHNIQUE

Traditional techniques for solving linear and non linear optimization problem are efficient and best technique since it promises a best solution. But for the problems having high complexity or with large number of constraints these technique may fail to get optimized solutions, to solve such type of problems nature inspired population based algorithms called meta-heuristic algorithms are becoming the first preference of researchers. These algorithms are efficiently used to solve the problems otherwise very difficult to solve including problems discrete in nature. These techniques do not guarantee a best solution is obtained but it has been seen that they get best solutions very often.

There are so many meta-heuristic algorithms namely Artificial Bee Colony (ABC) [4], Genetic Algorithm (GA), Particle Swarm Optimization (PSO) [5] etc. The results obtained by such algorithms are mostly dependent on the proper selection of the control parameters. Variation in any of these parameters may cause poor result of the problem. Therefore selection of these parameters is very important to solve a problem. Helwig and Wanka [1] analysed the behaviour of the parameters of Particle swarm optimization (PSO) where it was found that some particles moved out of the search space. In this paper it was suggested that if a particle moves out of the boundary it should be brought back to the nearest boundary of the search space. Van den berg and Engelbrecht [2] experimentely determined the best values of parameter of PSO for getting good results.

III. SIMPLE OPTIMIZATION TECHNIQUE (SOPT) [6]

SOPT is a newly introduced simple and efficient meta-heuristic population based algorithm. A random set of solution is generated and these solutions are modified in two stages called exploration stage and exploitation stage. In both the stages the best solution among the population is determined and it is used to generate new solutions based on the equations (1) and (2). If the newly generated solution is better than the worst solution of the population, then worst solution is replaced with new solution. Procedure repeats till the termination criterion is not reached which in this case is the maximum number of iterations. Defining equations for exploration and exploitation stages are

$$X_{i,new} = X_{i,best} + C_1 \times R_i \quad (1)$$

$$X_{i,new} = X_{i,best} + C_2 \times R_i \quad (2)$$

$X_{i,new}$ is the i^{th} parameter of the new candidate solution for any iteration and $X_{i,best}$ is the i^{th} parameter of the best solution in the same iteration.C_1 and C_2 are the positive constants used to control the algorithm R_i is a normally distributed random number with mean zero and standard deviation σ_i. The value of the constant C_1 and C_2 taken in the original paper of the SOPT are 2 and 1.

There are other techniques like Teaching Learning Based Algorithm (TLBO) [7] which is stated to have no control parameters. Absence of parameters causes no control over the movement of solutions in different iterations whereas large number of control parameters makes it difficult to select a correct set of these parameters.

IV. NUMERICAL PROBLEMS

To study the effect of control parameters of SOPT algorithm, two constrained optimization problems are selected which are previously solved using PSO[8]. These problems are defined as:

1. Minimize $f(x) = (x_1^2 + x_2 - 11)^2 + (x_1 + x_2^2 - 7)^2$
   Subjected to:
   $$g_1(x) = 4.84 - (x_1 - 0.05)^2 - (x_2 - 2.5)^2 \geq 0$$
   $$g_2(x) = x_1^2 + (x_2 - 2.5)^2 - 4.84 \geq 0$$
   $$x_1, x_2 \geq 0$$
2. Maximize $f(x) = -2x_1^2 + 2x_1x_2 - 2x_2^2 + 4x_1 + 6x_2$
   Subjected to:
   $$g_1(x) = 2x_1^2 - x_2 \leq 0$$
   $$g_2(x) = x_1 + 5x_2 \leq 5$$
   $$x_1, x_2 \geq 0$$

Problem 2 is maximization type problem which is converted to minimization type by multiplying the objective function by -1. Since both problems are constrained problems therefore some constrained handling technique need to be applied there are various constraint handling techniques available in literature [9]. To solve these problem Deb's rules are used for handling constraints.

V. RESULT AND DISCUSSIONS

Simple Optimization Algorithm (SOPT) is implemented in MATLAB to solve above mentioned problems keeping terminating criteria as maximum number of iterations which is 500. In this experiment value of C2 is changed from 0.2 to 2 in the interval of 0.2 by keeping C1 as constant. The experiment is continued with different values of C1 ranging from

1 to 3 in the interval of 0.2. For each value of C_1 standard deviation, mean value and best value from the results are calculated. It is aimed to keep the standard deviation and mean value to be as minimum as possible therefor one should select the value of C1 for which these values are minimum. Considering problem 1, the deviation obtained is minimum at C_1=3 but at this point the best solution deviates too much from the actual solution and therefore the second best solution at C_1=1.6 is considered for our study but it has slightly more deviation. For problem 2, the deviation is minimum at C_1=2.8 and best solution is obtained here. But comparing with the second best solution which is at C_1=1.8 it can be said that the best solution is obtained near about 1.6 and 1.8. The effects of the parameters for the tested problems are tabulated below:

Table 1. Effects of parameter for Problem 1

C_1	C_2*	Standard deviation (σ)	Mean value	Best value
1	0.4	369.0104	197.6316	13.60218
1.2	0.4	615.7114	307.636	13.90166
1.4	0.8	464.7136	313.2168	14.66538
1.6	**0.2**	**266.4094**	**112.3113**	**13.68926**
1.8	1	897.4611	442.135	13.87496
2	0.2	859.6063	541.973	13.59103
2.2	1	375.4866	208.0383	14.33952
2.4	0.6	704.2725	327.4854	13.78468
2.6	1.4	431.1021	189.2986	14.08294
2.8	0.4	284.6838	126.6126	13.79066
3	0.4	241.1037	125.3693	14.89408

Table 2. Effects of parameter for Problem 2

C_1	C_2*	Standard deviation (σ)	Mean value	Best value
1	0.6	0.831319	-5.1359	-6.60902
1.2	0.2	1.161768	-5.18954	-6.60893
1.4	0.4	1.148865	-5.40732	-6.60359
1.6	0.2	0.992084	-5.23088	-6.41514
1.8	0.8	1.039443	-5.44791	-6.61191
2	0.8	0.841459	-5.53984	-6.58775
2.2	1.2	0.957316	-4.87417	-6.25254
2.4	0.8	0.854248	-5.4513	-6.43741
2.6	1.6	0.675433	-5.81767	-6.59878
2.8	**0.4**	**0.576416**	**-6.08552**	**-6.61288**
3	1	0.6577	-5.65468	-6.52043

* value of C_2 for which best value is obtained.

Now it can be clearly understood how parameters can affect the solution of any optimization model. So it is required to have a justified selection process of these parameters so that optimal solution can be obtained with less time. It is observed from the table that best values are obtained for the values of C_2 far less than the corresponding values of the C_1 therefore strategy is made to keep value of C_2 to keep half of C_1 thus one need to select only one control variable judiciously. Now the problems are solved taking C_1=1.6 and C_2 is automatically taken as 0.8, figure 1 and 3 shows the surface plots of these two problems and figure 2 and 4 shows the convergence curve. From the convergence curve it is seen that at about 1000 iterations best values found in literature so far are obtained.

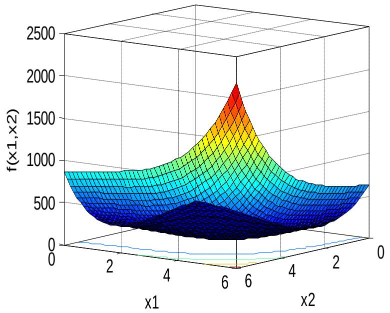

Figure 1. Surface plot for function 1

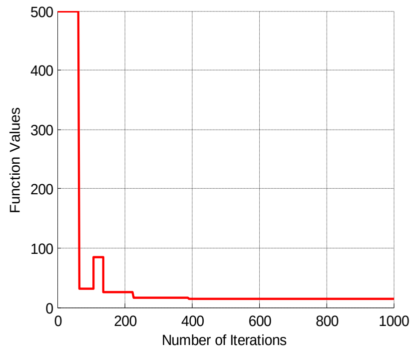

Figure 2. Convergence curve for function 2

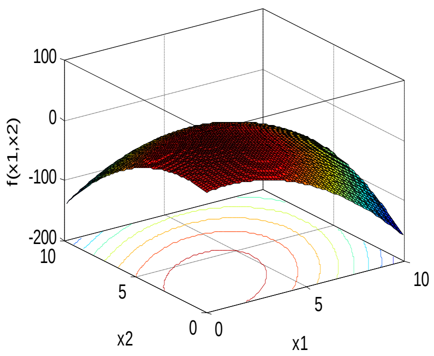

Figure 3. Surface plot for function 2

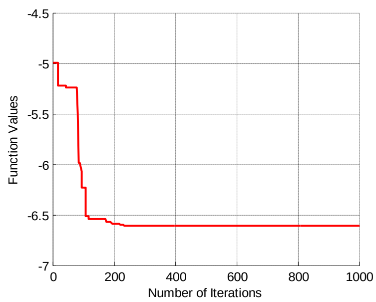

Figure 4. Convergence curve for function 2

VI. CONCLUSION

In this study the effect of control parameters of SOPT on the actual solution is analysed for two different test problems. SOPT is having two parameters C_1 and C_2. Experiments are conducted for various combinations of C_1 and C_2 . In problem 1 it is found that the best value is obtained when the value of parameter C1 is 1.6, but the standard deviation is minimum at C_1= 3 since the function value obtained here is not satisfactory. So we have moved for looking solution at C_1=1.6. Similarly for problem 2, the best solution is obtained at 2.8 at this point the value of the standard deviation and mean is also minimum. Looking at second best solution which is obtained at C_1= 1.8 and C_2=0.2 the deviation is slightly more compared to first best solution obtained which indicates that near the value of C_1= 1.6 to 1.8 one can get better solutions. Therefore it is suggested that any new problem can be started to solve using the value of C_1 as 1.6.

The best so far solutions of these test problems are done using the value of C_1=1.6 and C_2 as half of the C_1 in less than 1000 iterations.

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