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Time dependent and Ergodic behaviour of the Constrained Cost Reliability of Wheel manufacturing

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Abstract: Nature inspired algorithm has become one of the most applicable technique in literature to solve real world optimization is one of the popular and efficient optimization methods. Here inPSO is extended for solvingcost constrained Reliability Optimization of Wheel manufacturing problem.Optimum Reliability of wheel manufacturing and number of redundant components in plant for cost constraint are obtained using PSO. The description, objective function and their constraints for undertaken problem are analyzed.

Keywords: Optimization, Reliability, MATLAB,Particle Swarm Optimization

1. Introduction

To find optima is the technique of making the best possible decision in available options. A number of tools are available from computer science and mathematics which may be employed in most of fields for the purpose of optimization of objective function.Data Mining field is increasingly adopting advanced matrix calculation algorithms and methods, graph theory, and optimization. In these methods, the data is described using a matrix representation and the data mining problems are formulated as optimization problems with matrix variables. The problems of optimization may be divided into two categories called local and global optimization,in the 1st type it is to locate optima in finite region of objective function value space, whereasin second optimization it is to evaluate optimum value in whole region,where in which the function value space exists.In general, a unique-objective optimization problem may be stated as under:

$$min_{x\epsilon s} f(x),$$

$$x = \text{Li} \leq \text{xi} \leq \text{Ui}$$

$$\text{Such that } g_i(\text{x}) \leq 0, \text{j} = 1, 2, \ldots, (1)$$

$$h_m(x) = 0, \text{m} = 1, 2\ldots, \qquad (2)$$

here f(x) is known as objective function

x is arbitrary D-dimensional decision vector.

conditions (1)& (2)indicate number of inequality& equality constraints respectively.

L_i *and* U_i are the lower and upper bounds of i[th]variable i.e., x_i.

There are several manufacturing plants, but the present study analysis reliability of Wheel manufacturing consisting of six machines, whose reliability and costs are provided by the machine manufacturer.

1.1 Types of Optimization Problems

1.1.1 Constraint optimization: In majority of structural optimization issues are expressed as restricted minima problems. The objective function in a special structural design problems is a relatively simple function consisting of design variables such as density, mass, length, weight, cost etc., but the design must fulfil a variety of pre-aimed displacement,stress, production, frequency limitations, etc., such restrictions are frequently complex functions of various design factors that can only be determined by a finite space element analysis of structure.The design space constraints divided in two domains: first is feasible domain, in which all constraints are met, and second is infeasible domain, in which at least one criterion is broken. The minimaareevaluated on boundary between feasible and infeasible regions in most of practical issues, i.e., at a boundary point where $g_j(x) = 0$ for at least one value of j. The inequality limitations can be altered or removed without changing solution if required.

1.1.2 Unconstraint Optimization: Unconstrained optimization is concerned with locating the provided function's global minimum or maximum throughout the entire real line. The global optimum point can then be found by searching for all local extreme values and comparing the value of the function at each of them.To begin, if there are no restrictions active in the design, an unconstrained function minimization technique is used to determine a search moving journey distance and direction for optimizing objective function.

1.2 Particle update equation: Velocity of the particle gives the direction to the particle in which the particle is moving in search of optimal. The particle update equation of PSO is as follows:

$$x^{t+1} = x^t + v^{t+1}$$

The followingtwo main propertieswill update the solution and will be repeated until a pre-defined termination criteria is satisfied.PSO is population-based method in which more than one candidate solutions take part in optimizing the solution. Each solution is guided by its local best and global best of entire search space. Some of the important properties of PSO are as follows:

1. It is based on swarm intelligence. Hence applicable to both science and engineering.
2. It has no overlapping and no mutation calculation like GA.

1.3 Pseudo Code of PSO Algorithm

Initialize the swarm of particles
For every particle
For every dimension
Update velocity of each particle
Update each particle position using updated velocity
Repeat until the termination criteria are met
End

2. Literature review of PSO

PSO is a widely used optimization technique which is continuously modified over the recent time. Many hybrid versions of PSO are also available in the literature; itfinds its applications in many real-life optimization issues as well. A brief literature review of PSO is necessary to understand the mechanism of PSO. Kumar et al. **(2018)** discussed the 3:4: G System. Anchal et al. **(2021)** discussed the SRGM model using differential equation has been proposed, in which two categories of faults: simple and hard with respect to time in which these occur for isolation and removal after their detection has been presented. The model is presented for a validated on real SW data set.Kumar et al. **(2019)** studied thecold standby system with priority for PM. Gupta et al. **(2011)** discussed the heuristic algorithm for n jobs, three machines flow shop preparation problematic where handling times are related with the corresponding probabilities connecting transportation time, break down intermission and job block criteria.sKennedy and Eberhart **(1997)** have presented a discrete binary description of PSO. Many real-life issues have been solved using this description of PSO. Zhang et al. **(2014)**developed a new bare-bones multi-objective PSO (BBMOPSO) to determine Pareto optimal solutions, which was a practical approach to combine bare-bones particles with swarm optimization &sensitivity-based clustering for finding solution of multi-objective RAP.Beji et al.**(2010)** designed a hybrid type algorithm depending on PSO and local search algorithm to solve RAP, in that study, an investigation has been carried out for redundant reliability problems of the series-parallel system, when a mixture of components was allowed. Poonam and Goel **(2018)** have analyzed sensitivity analysis of a biscuit plant. Tsung-Jung **(2021)** developed hybrid artificial-bee colony algorithm and simplified swarm optimization to solveRedundancy Allocation Problem (RAP).Garg et al. **(2009)** analyzed the screw plant utilizing MATLAB Tool. Kumari et al. **(2021)** discussed the profit analysis of an agriculture thresher plant in steady state using RPGT. Jieong et al**.** **(2009)** used hybrid algorithm known as GA/PSO for solving multi-objective optimization issues.Kumar et al. **(2019**) presented behavioural analysis of a washing unit of paper mill using RPGT.Kumar et al. **(2018)** studied behaviour of a bread-making system, consisting of five distinct sub-systems such as Mixer, Oven, Tunnels, Divider & Proofer and evaluated system parameters useful to the management utilizing RPGT under steady-state.Kumar et al. **(2017)** studied the edible oil refinery industry using RPGT.

3. SYSTEM DESCRIPTION OFWHEEL MANUFACTURING

Wheel manufacturing consists of various machines which are connected in series. They are working one by one. If someone machine flops in amid the production, the production procedure will stop.The complete produce is then packed utilizing a packing machine for the last dispatch. The data associated to the cost and reliability of these machines is providing by the industrial system operations team to us.

3.1 ASSUMPTIONS

Path Set: It is set of subsystems in which system operates successfully.

Minimal path set: It is a path set in which if any unit/component is fails/removed from it, remaining subsystem no longer form path i.e., system will fail.

3.2 NOTATIONS

x_i	i^{th} component
$R_i(x_i)$, $Q_i(x_i)$	Reliability, unreliability of component-x_i
$R_s(x)$	System reliability
n_i	number of i^{th}components
$g_j(x_i)$	j^{th} resource consumed by i^{th}components
$n = 6$	number of components
t_i	Component selection factor
l	number of constraints

3.3 PROBLEM FORMULATION: In case of Wheel manufacturing, problem is to maximize reliability with cost constraint as defined in Table 1. Considering cost constraintC= 4680000.

Problem is to maximize
$R_s(x) = U(R_1(x_1), \ldots\ldots\ldots, R_n(x_n)) = \prod_{i=0}^{6} R_i(x_i)$

$$R_i(x_i) = \prod_{i=0}^{6}[1 - [Q_i(x_i)]^{n_i}]$$

$$\sum_{i=1}^{6} g(x_i) * n_i \leq 4680000$$

Table1. Components Cost and Reliability

Components Symbol	**x_i**	**x_2**	**x_3**	**x_4**	**x_5**	**x_6**
(Reliability of the Components) * 10^{-2}	95	99	96	98	94	93
Cost (Rs) in Thousands	400	1300	420	1000	99	180

Table 2. Results Obtained by PSO for Reliability Optimization Problem

Run No.	**Reliability↓**	**Number ofComponents**					
		n1	n2	n3	n4	n5	n6
1	INFEASIBLE						
2	INFEASIBLE						
3	INFEASIBLE						
4	0.996262217	3	2	3	2	4	1
5	0.99626438	3	2	3	2	4	1
6	0.996262386	3	2	3	2	4	1
7	INFEASIBLE						
8	INFEASIBLE						
9	0.99626294	3	2	3	2	4	1
10	0.996264537	3	2	3	2	4	1

4. Analysis

The above-described as Table 2, reliability optimization issue is solved using proposed PSO and penalty function techniques. The heuristic algorithm is performed ten times. Since the reliability optimization problem is a discrete constrained optimization problem which is difficult and complex.The problem is performed on MATLAB 2017a on a 64-bit windows 10 laptop with RAM 8GB. Maximum number of iterations is 200 and number of runs are 10 here. In total five out of ten runs infeasible solution is obtained. After 200 iterations, the solution obtained in rest of five runs is same. Thus, the PSO with penalty function is considered as a reliable and efficient optimization method for solution of reliability optimization issues. The reliability wheel manufacturing under optimization problem is 0.99626438 and number of units of the components are x*= [3 2 3 2 4 1].

PSO has been used to solve this problem as it has been proved an instrumental natural inspired optimization algorithm for most of the newly developed algorithms. In view of nature inspired optimization techniques, we can say that no one algorithm can solve all the problems. Hence, we are applying one of the most tested and trusted algorithms in the literature for solving reliability problem. Particle Swarm optimization has proved to solve many such optimization problems.

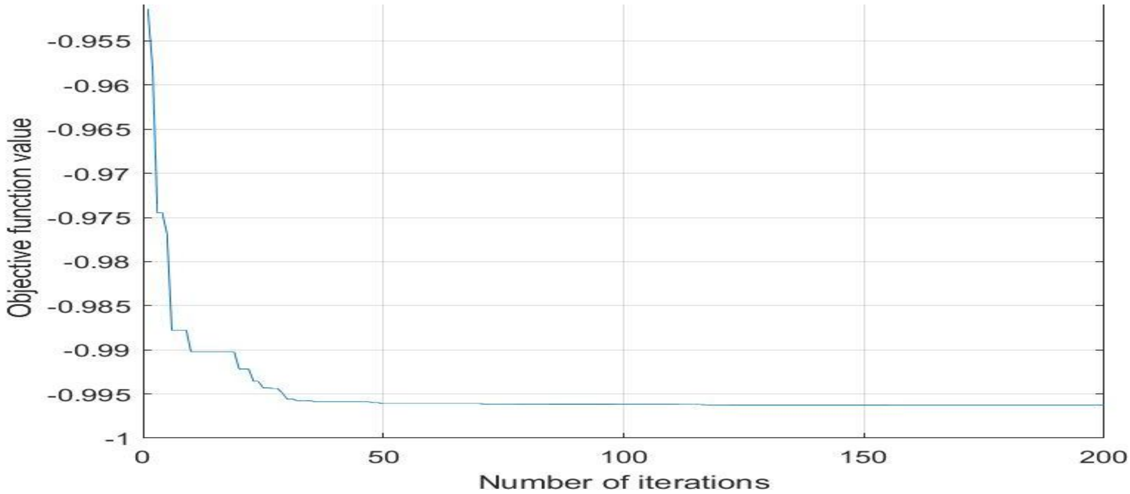

Figure 1. Reliability Optimization Convergence graph

5. Conclusion

Convergence Analysis: In Figure 1, the convergence of the algorithm with number of iterations is given. It can be observed that the maximization optimization problem is converted into a minimization problem. As the number of iterations increases, objective function value decreases.

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