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A Genetic Algorithm Approach for Reliability of Bridge Network in Fuzzy System

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Abstract. This paper presents a Genetic Algorithm (GA) approach for solving constrained reliability optimization problem of the five unit bridge network. Considering uncertainty for cost, the reliability optimization problem has been solved by GA technique to maximize system reliability. GA is an efficient method for solving this type of optimization problems. This paper successfully applies the GA technique to obtain the optimal solution of the complex system reliability model under cost constraint in fuzzy environment in which the system cost and component costs might be imprecise. Triangular fuzzy number is used to represent the fuzzy cost coefficients. Static penalty method has been used to handle the cost constraint of the problem. To solve the reliability optimization model, we have developed the GA using MATLAB with tournament selection process, elitism mechanism, arithmetic crossover and uniform mutation operations. Finally, computational results are presented for the reliability of bridge network in crisp and fuzzy environment.

Keywords: Genetic algorithm, Reliability optimization, Penalty method, Bridge network, Fuzzy number

1. Introduction

Genetic Algorithm (GA) is a robust evolutionary optimization search technique that mimics the process of natural evolution to solve optimization problems. Genetic algorithms are based on the combination of principles of genetics and biological evolution. It is one of the heuristic optimization techniques, which include evolutionary strategies [1]. A genetic algorithm is a stochastic global optimization search method that uses natural selection in biological evolution as its model of problem solving as introduced by Holland [2] and further described by Goldberg [3]. John Holland [2][4] is the pioneer of genetic algorithm. GAs were invented and developed by him, his students and colleagues.

Several types of genetic algorithms have been developed to solve single or multiple objective optimization problems with any combination of linear/nonlinear objectives or constraints. Deng et al. [8] proposed the shredding genetic algorithm (SGA) that follows the mechanism adopted in modern breeding technology where healthy animals are cultivated by interfering with the natural selection process and filtering out pubs with undesirable characteristics using the principle of elitism. By simulating this filtration process, SGA can focus the search around the most important genes. Wang and Ghosn [9] proposed an extension algorithm of the SGA by combining the benefits of the shredding and learning operators to the linkage process proposed by Harik and Goldberg [10]. Cheng [11] proposed an artificial neural network based GA. Parallel GA technology [12] can be used to accelerate the speed of GAs. Bi-objective genetic algorithm [13] can be used for makespan and reliability optimized scheduling for workflow applications. Wang et al. [14] proposed the look-ahead genetic algorithm to intelligently optimize both the makespan and the reliability for a workflow application. Deb et al. [15] proposed the Non-dominated Sorting Genetic Algorithm (NSGA-II) which is a fast and very efficient multi-objective evolutionary algorithm. Chang et al. [17] proposed a two-phase sub population genetic algorithm to solve the parallel machine-scheduling problems. Chen et al. [25] proposed hybrid evolutionary algorithms with integration of GA and extremal optimization to solve the hot strip mill scheduling problem. Elsayed et al. [34] developed a multi-operator

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genetic algorithm and a self-adaptive multi-operator genetic algorithm for solving constrained optimization problems. Gonçalves and Resende [5] proposed a multi-population biased random-key genetic algorithm for the single container loading problem. Meng and Weng [7] proposed a GA to assessing work zone casualty risk.

GAs can be used to solve different type of optimization problems such as fuzzy, combinatorial and multi objective optimization problems. In last two decades, different optimization approaches have been proposed to solve reliability optimization problems. These include dynamic programming method, integer programming method, branch and bound method, Lagrange multiplier method, stochastic programming method, etc. ([20]-[24]). Today GA is widely used in reliability engineering to optimize reliability of a system under certain constraints. Painton and Campbell [26] proposed a GA to find maximum reliability to satisfy specific cost constraints. Coit and Smith [28] described a GA to solve the reliability optimization problem for a series-parallel system meeting the cost and weight constraints. Bhunia et al. [29] proposed a GA to solve reliability optimization problem of a series system with interval valued component reliability. Sahoo et al. [16] developed a GA to solve reliability redundancy optimization problem of series-parallel/parallel-series/complex system with interval valued reliability of each component. Cheng and Li [30] proposed a method for structural reliability analysis by integrating the uniform design method [31] with artificial neural network based GA. Hsieh et al. [32] utilized GAs to solve various types of reliability design problems, such as reliability optimization of series system, series-parallel system and complex systems. Yeh et al. [33] proposed a GA to solve the k-node set reliability optimization problem with capacity constraint of a distributed system. Gen and Cheng [6] described the applications of GAs to reliability optimization problems. Moghaddam et al. [35] proposed a GA for a redundancy allocation problem to the series-parallel system when the redundancy strategy can be chosen for individual subsystems. Kumar et al. [27] performed the reliability analysis of waste clean-up manipulator using real coded GA and fuzzy methodology. Kishor et al. [38] proposed a multi-objective GA for complex system reliability optimization problem under fuzzy environment, while minimizing the cost of the system.

In this paper, we have developed GA to solve the reliability optimization problem of a bridge network in crisp and fuzzy environment. Here, we have presented optimal solution of system reliability of bridge network with system cost as constraint in fuzzy and crisp environment. We have used real-value encoding to represent the solution as a chromosome. The initial population of size 40 has been generated randomly. Tournament selection process has been used to select the parent chromosomes from the population. Elitism process, arithmetic crossover operation and uniform mutation operation are applied to generate the offsprings that have higher fitness value than their parent. When a termination condition is satisfied, the GA will give the optimal solution of the problem. Finally, numerical exposure of the proposed GA technique is presented and some conclusion and recommendation are made.

2. Model Formulation

2.1. Notations

A bridge network reliability model is developed using GA technique under the following notations.

Notation	Definition
r_i	Reliability for i^{th} component of the reliability model
c_i	Cost coefficient for i^{th} component of the reliability model
$\widetilde{c}_i$	Fuzzy cost coefficient for i^{th} component of the reliability model
a_i	Shape parameter for i^{th} component of the reliability model
C	Available system cost of the reliability model
$\widetilde{C}$	Fuzzy system cost of the reliability model
c_i^l	Lower end point of the fuzzy cost interval for i^{th} component
c_i^u	Upper end point of the fuzzy cost interval for i^{th} component
C^l	Lower end point of the fuzzy system cost interval