A new multi-objective particle swarm optimization method for solving reliability redundancy allocation problems

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A B S T R A C T
In this paper, a new dynamic self-adaptive multi-objective particle swarm optimization (DSAMOPSO) method is proposed to solve binary-state multi-objective reliability redundancy allocation problems (MORAPs). A combination of penalty function and modification strategies is used to handle the constraints in the MORAPs. A dynamic self-adaptive penalty function strategy is utilized to handle the constraints. A heuristic cost-benefit ratio is also supplied to modify the structure of violated swarms. An adaptive survey is conducted using several test problems to illustrate the performance of the proposed DSAMOPSO method. An efficient version of the epsilon-constraint (AUGMECON) method, a modified non-dominated sorting genetic algorithm (NSGA-II) method, and a customized time-variant multi-objective particle swarm optimization (cTV-MOPSO) method are used to generate non-dominated solutions for the test problems. Several properties of the DSAMOPSO method, such as fast-ranking, evolutionary-based operators, elitism, crowding distance, dynamic parameter tuning, and tournament global best selection, improved the best known solutions of the benchmark cases of the MORAP. Moreover, different accuracy and diversity metrics illustrated the relative preference of the DSAMOPSO method over the competing approaches in the literature.

1. Introduction

The utilization of redundancy is one of the most important attributes in meeting high-level reliability. The problem is to select the feasible design configuration that optimizes the measurement functions such as reliability, cost, weights, and risk [10]. This is called the reliability redundancy allocation problem (RAP) which was first introduced by Misra and Ljubojevic [17]. A series-parallel system is characterized through a predefined number of sub-systems which are connected serially. Multiple component choices and redundancy levels are available to connect in parallel for each sub-system [10]. A given component may have a binary-state or a multi-state in the RAPs [13]. In binary-state RAP, the problem of a proper structure can be handled by increasing the reliability of components or supplying parallel redundant components at some stages [10]. In some other cases, called multi-state systems, the states of a given component may follow more than two different levels, ranging from perfectly working to completely failed [1].

The RAP is assumed to be a NP-hard (non-deterministic polynomial-time hard) problem [3]. The application and the development of the meta-heuristic procedures are assumed to be useful to properly solve NP-hard problem. Different heuristic and meta-heuristic methods such as Evolutionary Computation methods, variable neighborhood search, ant colony optimization, and particle swarm optimization (PSO) were proposed in this area ([4,7,10,14,15,19,21,25]). Gen and Yun [7] surveyed the Genetic Algorithm-based (GA-based) approaches for various reliability optimization problems. Konak et al. [11] presented an overview and tutorial describing GA developed specifically for problems with multiple objectives. Li et al., 2009 [15] proposed a two-stage approach for solving multi-objective system reliability optimization problems. In the first stage, a Multi-Objective Evolutionary Algorithm (MOEA) generated non-dominated solutions. Then, a Self-Organizing Map (SOM) was used to cluster similar solutions.