Abstract

Most multi-objective combinatorial optimization (MOCO) problems that comprise multiple conflicting objectives and have multiple feasible solutions, are computationally hard. Therefore, stochastic approaches such as evolutionary algorithms (EAs) are often suitable for obtaining promising solutions for MOCO as well as constraint satisfaction problems (CSPs). However, EAs may not guarantee feasible solutions for MOCO or CSP problems.

In this work, we consider two MOCO problems: (i) bi-objective minimum spanning tree (BOMST) problem, and (ii) bi-objective graph coloring problem (BOGCP), as well as Sudoku, a constraint satisfaction problem (CSP). We consider polynomial time heuristics that are shown to yield good solutions for the MOCO problems. However, solutions obtained from heuristics may not be optimal. Therefore, we analyze hidden structures of problem instances, thereby attempting to characterize/classify problem instances. In the absence of *a priori* knowledge of the solution space, we use *generic* EAs for solving MOCO problems. However, peer researchers have shown that generic EAs may fail to achieve quality solutions for MOCO problems in terms of convergence, coverage and diversity, with reasonable computational effort. Therefore, in an attempt to yield quality solutions across the complete range of Pareto fronts, we propose problem-specific MOEA frameworks based on Pareto converging genetic algorithms (PCGA) for solving BOMST and BOGCP problems. In these hybrid-MOEA designs, we have incorporated problem-specific knowledge obtained by analyzing the considered heuristics into the evolutionary operation.

Performance assessment is one of the key issues in the MOCO problem domain. Depending on the nature of the MOCO problem, problem instances, and the structure of solution methods, an existing metric may fail to assess the performance of the obtained Pareto fronts. In this work, we propose two problem-specific metrics in order to assess the performance of non-dominated solution sets for the BOMST problem and the BOGCP. For the BOMST problem, we named them *diameter-distribution* and *penalty per diameter*, and for the BOGCP, we named them *color-distribution* and *penalty per color*. We have observed that these metrics provide detailed insights into the obtained Pareto fronts.

In an attempt to yield solutions and perform characterizations for the Sudoku problem, we observe that none of the polynomial strategies may solve a difficult puzzle instance. Therefore, the requirement of evolutionary algorithm arises. We unify heuristics and propose a problem-specific EA framework for solving Sudoku puzzles. This hybrid-EA design incorporates the rules of the problem and problem-specific knowledge obtained through the analysis of polynomial time strategies.

In summary, we have used heuristics for extracting problem-specific knowledge. We have incorporated such knowledge into problem-specific evolutionary operations and proposed hybrid-EA frameworks for (i) yielding quality solutions for BOMST and BOGCP problems, and for (ii) solving difficult Sudoku puzzle instances. We have proposed two problem-specific metrics for assessing the performance of solution sets obtained for BOMST and BOGCP problems.

Keywords: Multi-objective combinatorial optimization, constraint satisfaction, evolutionary algorithm, bi-objective optimization, minimum spanning tree, graph coloring, Pareto front, non-dominated solutions, hypervolume, spread, C measure, Sudoku.