Chapter 5
Hybridizations of GRASP with Path-Relinking

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Abstract. A greedy randomized adaptive search procedure (GRASP) is a meta-heuristic for combinatorial optimization. GRASP heuristics are multistart procedures which apply local search to a set of starting solutions generated with a randomized greedy algorithm or semi-greedy method. The best local optimum found over the iterations is returned as the heuristic solution. Path-relinking is a search intensification procedure that explores paths in the neighborhood solution space connecting two good-quality solutions. A local search procedure is applied to the best solution found in the path and the local optimum found is returned as the solution of path-relinking. The hybridization of path-relinking and GRASP adds memory mechanisms to GRASP. This chapter describes basic concepts of GRASP, path-relinking, and the hybridization of GRASP with path-relinking.

5.1 Introduction

A combinatorial optimization problem can be defined by a finite ground set \( E = \{1, \ldots, n\} \), a set of feasible solutions \( F \subseteq 2^E \), and an objective function \( f : 2^E \mapsto \mathbb{R} \). In this chapter, we consider optimization problems in their minimization form, where an optimal solution \( S^* \in F \) is sought such that \( f(S^*) \leq f(S) \), for all \( S \in F \). The ground set \( E \), the set of feasible solutions \( F \), and the objective function \( f \) are defined for each specific problem. Many combinatorial optimization problems are computationally intractable, i.e. they fall into the category of NP-hard problems [32].
Much progress has been made in the direction of exact methods for combinatorial optimization, such as branch and bound, branch and cut, and dynamic programming [72, 76]. These methods, however, suffer from the curse of dimensionality, i.e., they tend to break down as the size of the instance being solved increases. Likewise, approximation algorithms [74, 75], which provide a guaranteed suboptimal solution to hard combinatorial optimization problems, have also experienced significant progress. Although interesting in theory, approximation algorithms are often outperformed in practice by more straightforward heuristics with no particular performance guarantees.

Metaheuristics [33, 36] are general high-level procedures that coordinate simple heuristics and rules to find good (often optimal) approximate solutions to combinatorial optimization problems. They include genetic algorithms, simulated annealing, tabu search, scatter search, ant colonies, variable neighborhood search, GRASP, and path-relinking. There are many ways to classify metaheuristics. These include, trajectory-based versus population-based, nature-inspired versus non-nature inspired, memoryless versus memory-based, etc. Genetic algorithms, for example, are nature-inspired, population-based, with memory. Tabu search are trajectory-based with memory. GRASP is trajectory-based.

Hybrid metaheuristics combine one or more algorithmic ideas from different metaheuristics and sometimes even from outside the traditional field of metaheuristics. The main motivation to hybridize metaheuristics is to make up for the shortcomings of one metaheuristic with special characteristics of the other. In this chapter, we consider the hybridization of two metaheuristics: GRASP and path-relinking.

GRASP, or greedy randomized adaptive search procedures [25, 26, 30, 31, 59], is a metaheuristic for combinatorial optimization. GRASP heuristics are multistart procedures which apply local search to a set of starting solutions generated with a randomized greedy algorithm or semi-greedy method. The best local optimum found over the iterations is returned as the heuristic solution. Since GRASP iterations are independent of one another, GRASP heuristics do not make use of solutions produced throughout the search, i.e. they do not have any memory mechanism.

One way to add memory to GRASP is its hybridization with path-relinking. Path-relinking [35, 60, 63] is a search intensification procedure that explores paths in the neighborhood solution space connecting two good-quality solutions. A local search procedure is applied to the best solution found in the path and the local optimum found is returned as the solution of path-relinking.

This chapter describes basic concept of GRASP, path-relinking, and the hybridization of GRASP with path-relinking. In Section 5.2 we describe the main building blocks of GRASP. In Section 5.3 we consider path-relinking and, in Section 5.4, address issues related to the hybridization of GRASP with path-relinking and evolutionary path-relinking. A hybridization of GRASP with path-relinking and Lagrangean relaxation is discussed in Section 5.5. In Section 5.6 we consider parallel implementation of GRASP with path-relinking heuristics. Finally, concluding remarks are made in Section 5.7.