Genetic Algorithm for Solving the Resource Constrained Project Scheduling Problem

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ABSTRACT

The present paper develops a multi–dimensional genetic algorithm for the Resource k constrained project scheduling problem. This algorithm performs a series of perturbations in an attempt to improve the current solution, applying some problem dependant genetic operators. The procedure used is efficient and easy to implement. The approach was tested on sets of standard problems freely available on the Internet (PSPLIB) and the results were compared to those found in the literature. It was found that the algorithm used is able to generate competitive results compared to the best methods known so far and computes, for the first time, four optimal solutions for four benchmark instance.

Keywords: Genetic Algorithm (GA), Genetic Operators, PSPLIB, Resource Constrained Project Scheduling Problem (RCPSP)

1. INTRODUCTION

Formally, the RCPSP is described as follows. A project consists of a set V = {1…….n} of n activities. Activities 1 and n are dummy activities to model the start and end of the project. The activities are interrelated by two kinds of constraints:

- Precedence constraints force each activity j to be scheduled after all predecessor activities Pred_j are completed.
- Activities require resources with limited capacities. Concerning the second constraint, while being processed, activity j requires r_jk units of resource type k ∈ K during every time instant of its non-preemptable duration d_j. Resource type has a limited capacity of R_k at any point in time.

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For the project scheduling problem considered in this paper, without loss of generality, parameters \( d_j \), \( r_{jk} \) and \( R_k \) are assumed to be integer, non-negative, deterministic and known at the initial time of scheduling. For the project’s start and end activities, it is assumed that

\[
d_1 = d_n = 0 \quad \text{and} \quad r_{1k} = r_{nk} = 0.
\]

An instance of the RCPSP is solved by finding starting (or ending) times of each activity satisfying both precedence and resource constraints, such that the total duration of the project (i.e., the makespan, noted as \( C_{max} \)), is minimized. The related literature is very extensive, including exact methods, heuristic and meta-heuristic solution approaches. It has been shown by Blazewicz et al. (1983) that the RCPSP, as a generalization of the classical job shop scheduling problem, belongs to the class of NP-hard optimization problems, therefore justifying the use of heuristics when solving large scaled problems. In general, restricting all feasible solutions to find the best solution seems to be impossible even for a problem of medium size. Therefore, we can address the resolution of the RCPSP by means of approximate methods, especially heuristics and meta-heuristics methods. As with many other meta-heuristics used to solve these problems, the success of genetic algorithms (GAs) is, to a large extent, due to its ability to recover the search process from getting stuck in a local optimum. GAs has shown a remarkable efficiency on many problems (scheduling, packing and vehicle routing) and often surpasses the best solutions previously found by other approaches. Various solutions approaches were proposed for the RCPSP.

2. LITERATURE REVIEW

The RCPSP is known to be an NP-hard optimization problem (Blazewicz et al., 1983). This features makes the problem hard to solve optimally where addressing large scaled instances. Some surveys for the RCPSP are provided by Icmeli et al (1993), Herroelen et al. (1998), Brucker et al. (1999), Klein (1999), Hartmann and Kolisch (2000), Kolisch and Padman (2001) and Montoya-Torres 2009). Several exact methods to solve the RCPSP are proposed in the literature. Currently, the most competitive exact algorithms seem to be the ones of Demeulemeester and Herroelen (1997), Brucker et al. (1998), Klein and Scholl (1998a,b), Mingozzi et al. (1998), and Sprecher (2000). Stork and Uetz (2005) present several complexity results related to generation and counting of all circuits of an independence system, and study their relevance in the solution of RCPSP. Several authors propose procedures for computing lower bounds on the makespan. Brucker and Knust (2003) presented a destructive lower bound for the multimode Resource-Constrained Project Scheduling Problem with minimal and maximal time-lags. Brucker and Knust (2003) developed a destructive lower bound for the RCPSP, where the lower bound calculations are based on two methods to prove infeasibility of threshold values for the makespan.

The first approach uses constraint propagation techniques, while the second is based on a linear programming formulation. Demassey et al. (2005) proposed a cooperation method between constraint programming and integer programming. Most of the addressed heuristics used for solving RCPSP belong either to the class of priority rule based methods or to the class of meta-heuristic based approaches (Kolisch and Hartmann, 1999). The first class of methods starts with none of the jobs being scheduled. Subsequently, a single schedule is constructed by selecting a subset of jobs in each step and assigning starting times to these jobs until all jobs have been considered. This process is controlled by the scheduling scheme as well as priority rules with the latter being used for ranking the jobs. Several approaches of this class have been proposed in the literature (Davis and Patterson, 1975; Cooper, 1976; Boctor, 1990; Kolisch, 1996a,b; Tormos and Lova, 2001). The second class of methods is based on the design of meta-heuristics which improve upon an initial solution.
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