An industrial multi-skilled resource-constrained multi-project scheduling problem

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1 Introduction

The resource-constrained project scheduling problem (RCPSP) is a well-known problem in project management, which aims to determine a schedule and an assignment of activities on resources over a schedule horizon. It is a particular case of scheduling problems where: **(i)** resource capacities and availabilities are limited, **(ii)** precedence links applied between the activities and, **(iii)** the objective is, generally, to minimize the completion time, defined as the earliest time in which all the activities are completed. This problem is strongly NP-Hard [1]. Several variants and extensions have been introduced over the years (e.g. uncertainty, project selection, multi-mode) [3]. The studied problem contributes to the RCPSP literature by including simultaneously multiple projects, multiple skills, time windows, priorities on activities and a particular resource-based objective. Note that, these characteristics have already been studied independently (e.g. see [4] for multi-skills and [2] for multi-project and time windows) but to the best of our knowledge no paper integrates all these elements as I do to meet some industrial constraints.

2 Problem statement

Consider a resource-constrained project scheduling problem with multiple projects. Each project is composed of multiple activities, grouped in a number of phases. The completions of the activities are subject to: *due dates* and *deadlines*. To avoid the infeasibility generated by the fulfillment of due dates and deadlines, they can be violated but their violation is penalized, more strongly for deadlines than for due dates.

Activities have to be scheduled according to their given assignment to resources and to skills that are required to perform them. Each resource is able to perform a skillset and is associated to an available work capacity for each skill and a global work capacity.

Two performance measures are considered, weighted in the objective function:

- **Minimization of delay of activities**: Due dates have to be fulfilled on pain of being penalized, depending on the priority of the activity. In the same way, deadlines larger than due dates are also penalized in the objective function.
- **Minimization of inactivity of resources**: It consists in minimizing the resource inactivity until a fixed time period. Indeed, unused resources lead to costs, then it is reasoning to encourage the complete use of resource at the beginning of the time horizon, and keeping time left after a fixed time period for potential new projects and activities.

Let us explain in the following the changes due to some industrial concerns. Note that no additional type of constraints is required compared to the RCPSP.

- **Resource constraints** One of the main characteristics of the RCPSP is the limitation of resources availability. In our problem, resources are used for multiple projects in the same time. In consequence, resource constraints link the different projects and prevent from solving several independent RCPSP problems. In addition to global limiting capacity, each resource has a limited capacity for each skill that has to be fulfilled.

- **Precedence constraints** Recall that activities are grouped by phases. All activities of a phase have to be completed before to start the next phase of a project. In addition, several activities of a projects have to be completed before to process activities of another project. Thus, there are precedence constraints at three levels: **(i)** intra-phase, **(ii)** inter-phase and **(iii)** inter-project.

3 Solution approach: Genetic algorithm

Note that the problem under study is NP-Hard and the solution approach has to be able to handle large-scale industrial problems. That is why, to solve the problem, I propose a genetic algorithm, as it has been successfully used to solve a large variety of optimization problems, including variants of the RCPSP. In our case, the choice of the genetic algorithm is particularly well-founded for two reasons: **(i)** the method (the chromosome encoding and its reading) is easily adaptable to handle the different variants required by the industrial application, and **(ii)** its tractability on large-scale data sets linked to real-life applications.

The main idea is to build a population of candidate feasible solutions that are then improved by crossovers and alterations to evolved toward better solutions. Each candidate solution has a set of properties (its chromosomes) which can be altered using different operators. In our case, a chromosome corresponds to the order in which activities are selected (according to several priority rules) to be fixed in the time horizon. It does not represent a solution and a special procedure is needed to derive a solution from it. However, crossover and mutation operators are easily used as they do not impact the feasibility of the solution.

To evaluate the proposed solution approach, numerical experiments are conducted on heterogeneous instances of different sizes including industrial data sets. They show the speed and efficiency of the genetic algorithm, in particular in the special case where there is no skillset. Moreover, it appears that priority rules contribute more when they are combined.

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