Time-constrained project scheduling with adjacent resources

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1 Extended Abstract

We develop a decomposition method for project scheduling problems with adjacent resources. Adjacent resources are resources for which the units assigned to a job are required to be in some sense adjacent. Possible examples of adjacent resources are dry docks, shop floor spaces, and assembly areas. We focus on the Time-Constrained Project Scheduling Problem (TCPSP), [4], with one 1-dimensional adjacent resource. However, the presented concepts and methods can be easily extended to more general models, e.g. multiple 1-dimensional adjacent resources or 2-dimensional adjacent resources.

The Time-Constrained Project Scheduling Problem (TCPSP) with an adjacent resource is defined as follows. We are given a set of jobs, a set of renewable resources and one 1-dimensional adjacent resource. Each job is characterized by a release date, processing time, deadline and its resource requirements, and has to be scheduled without preemption. The processing of jobs is further restricted by precedence relations. The adjacent resource is a special type of resource that is characterized by two properties. First, the resource units of adjacent resource are somehow topologically ordered (in this case ordered on a line) and the resource units assigned to a job have to be neighbored/adjacent and reassignment is not allowed. Second, motivated by the occurrence of adjacent resources in real life problems, we consider the more general case that the adjacent resource is not required only by a single job but by groups of jobs (called job
groups or simply groups). As soon as a job of such a job group starts, the assigned adjacent resource units are occupied, and they are not released before all jobs of that group are completed. In the considered model, it is only possible to hire additional capacity for the renewable resources, and not for the adjacent resource. The objective is to find a feasible assignment of the job groups to the adjacent resources and a feasible job schedule that minimizes the cost of hiring additional capacity.

The consideration of adjacent resources in the above mentioned form is motivated by a cooperation with a Dutch consultancy company. They encountered at several of their clients adjacent resource requirements. Since the project scheduling models in the literature do not cover these requirements, the company either assigns the adjacent resources in advance based on simple rules or they relax the adjacency requirements and repair the achieved solutions afterwards. However, since both approaches do not lead to satisfactory solutions, the company strives to incorporate adjacent resources in their planning software for project scheduling. One practical application is from the ship building industry that we use to illustrate the adjacency requirements. In this problem the docks form 1-dimensional adjacent resources, and all jobs related to building a single ship form a job group. Clearly, the part of the dock assigned to one ship has to satisfy the adjacency requirement. As soon as the construction of a ship starts, the assigned part of the dock is occupied until the construction is finished and the ship is removed from the dock. Removal or repositioning of a partially assembled ship is in practice too cumbersome and time consuming and therefore not an option. The other resources required to build the ships (like machines, equipment and personnel) can be modeled as renewable resources. The capacity of the dock is fixed but the capacity of renewable resources can be increased, e.g. by hiring additional personnel.

Adjacent resources have some relation with other special resource types considered in the literature. Spatial resources, as introduced in [2], are also resources which are not only required by a single job but by a group of jobs. However, no adjacency of the assigned resource units is required. Make-to-order assembly problems under assembly area constraints, see e.g. [6, 7], form a special case of project scheduling problems with spatial resources where each job group requires exactly one unit of the spatial resource. In this case the adjacency requirement is automatically fulfilled. Without the adjacency requirement on the resources, the spatial resource can also be modeled with the concept of cumulative resources, see e.g. [1, 9, 10]. Cumulative resources are, for example, used to incorporate storage facilities into project scheduling problems. When a job group starts the cumulative resource is depleted by a given amount, and replenished as soon as a job group completes. In this paper we show why an adjacent resource cannot be modeled as a cumulative resource.

The literature that does consider an adjacency requirement on resources, only considers the special case in which exclusively adjacent resources are considered and groups consist of a single job. In this case the scheduling problem can be seen as a 2-dimensional packing problem. Examples of this can be found in literature on berth allocation at container terminals, reconfigurable embedded platforms, and check-in desks at airports. In [5] such packing problems are modeled by introducing a mode for each possible placement of a job on the adjacent resource. Consequently, one has to solve a multi-mode project scheduling problem with possibly an exponential number of modes.

Relaxing the group and adjacency requirements, the considered problem reduces to the TCPSP as considered in [4]. The study of such types of time-constrained project scheduling problems started with [8] and [9], for an overview see [10].
Summarizing, the concepts of job groups and adjacency requirement on resources have been treated in the literature, but never in a combined manner. To the best of our knowledge this work is the first to consider this combination.

In this paper we first formally state the time-constrained project scheduling problem with one 1-dimensional adjacent resource and discuss in why existing modeling and solution techniques for related problems are not applicable when we are dealing with an adjacent resource. Next we describe a decomposition method, the main contribution of this paper. This approach, first assigns the groups to the adjacent resource and then schedules the jobs. The group assignment problem is solved via an ILP model. Each solution of the group assignment problem implies additional precedence relations between the jobs. Once these precedence relations are added, the scheduling of the jobs can be done with a method for the TCPSP, e.g. the method of [4]. To improve the quality, we introduce objective functions for the group assignment problem in order to steer the assignment to a promising one. Computational tests are presented to indicate the potentials of the presented approach.

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References

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