Multi-skill Project Scheduling Problem and Total Productive Maintenance

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In this paper, we propose a multi-skill project scheduling problem model for maintenance activities organization. Preventive maintenance activities are usually planned in advance: production is stopped and all maintenance activities should be processed as fast as possible in order to restart production. Moreover, these human resource handled activities require specific skills and are subject to precedence constraints. The main difference with Multi-Skill Project Scheduling Problem is that some activities may be submitted to disjunctive constraints due to material constraints of the production channel that we consider. We describe how we use these constraints to improve usual MSPSP resolution methods.

Keywords: Applications, Multi-Skill Project Scheduling Problem, Maintenance

1 Introduction

This study, based on a real industrial case found in MDGBB\textsuperscript{1} SKF factories, deals with the practical organization of Total Productive Maintenance activities. Total Productive Maintenance (also known as TPM [7]) is a maintenance concept that includes scheduled maintenance downtime of production channels. The idea is to achieve all preventive tasks during one single period. A preventive task is something that has to be done periodically on the machines of the channel. For example, if a filter has to be changed on a machine every 3 months, it may be interesting to change it every 2 months during the scheduled downtime so that there is no specific unscheduled downtime due to this filter. Considering there is a large number of such tasks, the productivity of the channel can be greatly improved if one single downtime period can be scheduled during which all maintenance activities can be done. In this paper, we study how the tasks planned for a given maintenance downtime can be scheduled in order to restart production as soon as possible. Here, we consider that the number of tasks, their duration and the resources they require are given.

We describe how this problem can be modeled as a Multi-Skill Project Scheduling Problem and how exact method can be adapted for solving TPM problem. Finally, we show how the disjunctive constraints that are due to material constraints of the production channel are modeled and how they can be used to improve the efficiency of the exact method.

2 Problem definition

Each maintenance task is an activity $A_i$, $i \in \{1, \ldots, n\}$ with $n$ being the number of activities. These activities may be submitted to precedence constraints, so an activity cannot start before all its predecessors are completed. In order to perform these activities, $M$ staff members $P_m$, $m \in \{1, \ldots, M\}$

\textsuperscript{1}Medium Deep Groove Ball Bearings
are available. To be processed, activities require specific skills that can not be performed by all staff members. For instance, an electronics specialist would not be able to perform a mechanical operation. The maintenance activities require $K$ skills named $S_k, k \in \{1, \ldots, K\}$ and we define $S_{m,k} = 1$ if $P_m$ masters the skill $S_k$ and 0 otherwise. In the SKF case, there exist hierarchical levels of skills: it means that a person with level $x$ for a skill $S_k$ will not be able to perform a task that requires this skill but at a higher level $y > x$. This problem has been shown to be equivalent to the general problem without hierarchical levels [2], by adding a specific skill corresponding to each level. Lastly, we define the skill requirements for each activity: $b_{i,k}, i \in \{1, \ldots, n\}, k \in \{0, \ldots, K\}$ the number of persons who masters the skill $S_k$ required to perform $A_i$. We assume that a staff member is able to perform at most one skill for one activity at a time.

The main difference between the MSPSP and TPM problem is the existence of additional disjunctive constraints. These constraints are introduced for security reasons, due to material configuration of the production channel: for instance, when someone is working on a specific machine, it may be avoided having another technician doing something else on the same machine. So, these are disjunctive constraints that are not related to precedence constraints. A simple way to model these disjunctive constraints is to add a common resource requirement for all disjunctive activities, corresponding for instance to the machine on which these activities are performed. For example, if $A_i, A_j, A_k$ cannot be performed at the same time, we add a skill $S_{dis_{i,j,k}}$ that can only be performed by a virtual person $P_{dis_{i,j,k}}$. This person only has this skill and the activities are the only ones to require this resource. Adding these new requirements is enough to take into consideration the disjunctive constraints, in the MSPSP model.

Here is presented a problem instance: disjunctive/conjunctive graph used to model precedence and disjunctions, skill requirements of activities and their processing times. On this example specific skill ($S_{dis_{1,2}}$), and specific resource ($P_{dis_{1,2}}$) corresponding to disjunction ($A_1 - A_2$) have been added to the initial instance.

**Figure 1: Example of Total productive maintenance problem**
3 Solving the Total Maintenance Problem

To solve this problem, we have used an existing Branch-and-Bound method described in [3] for solving MSPSP. The branching scheme of this method is based on splitting time-windows of activities, inspired from schedule scheme proposed by Carlier and Latapie [5] for solving RCPSP. At each node, a time-window is reduced until all activities have their starting time fixed. The Branch-and-Bound method, or MSPSP, uses two lower bounds. The first one is based on a compatibility graph: it checks which activities can be processed at the same time. The second lower bound is an adaptation of energetic reasoning [1] that checks if the mandatory parts of the activities during an interval can be processed on the available resources, respecting skill constraints. The computation of the mandatory parts is more efficient if the time-windows are smaller so this lower bound can also be improved by taking into consideration disjunctive constraints. Disjunctive constraints are used both to compute lower bounds and to reduced time-bounds of activities, using for instance edge-finding methods [6]. Reducing time windows is important both for reducing size of the search tree and improving efficiency of the lower bound. Moreover, based on the work of Baptiste et al. [1] for the RCPSP, we apply methods, e.g., [4] and [6], for selecting disjunctive constraints, on the top of the search tree.

4 Conclusion

In this paper, we have presented how the different activities involved during a scheduled maintenance period of a production channel can be optimized using a Multi Skill Project Scheduling Problem resolution method. This problem is made up of disjunctive constraints that can be used to reduce the search space of a Branch-and-Bound method. More details along with experimental results will be presented during the conference.

References


