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Solving Approaches for High Multiplicity RCPSP with Learning Effect and Compound Activities

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1 Context Description

The High Multiplicity Resource-Constrained Project Scheduling Problem (HM-RCPSP) [1], commonly encountered in numerous industrial manufacturing environments, involves scheduling multiple repetitive projects from different classes that share limited resources. This problem is also encountered as a challenge in the design of a Satellite Assembly Line (SAL), where a number of satellites of different categories are built using shared resources like machines, tools, workers, etc. Each category of satellite can be viewed as a class, and any satellite within this category is considered a project in that class, which must be completed by a specific deadline. The building process of satellites for each category, consists in realizing a set of activities, and there are precedence relationships between them. Moreover, there are some activities that encompass others, reflecting the fact that their starting (or finishing) times depend on those of the activities they encompass. These activities are referred to as *compound activities*.

The *learning effect* is a widely studied phenomenon in scheduling problems. In factories, the overall system becomes more efficient over time, thereby decreasing the production time required for a product. This improvement results from various factors, such as workers learning the manufacturing process, mastering the necessary gestures, becoming proficient with the tools, and better controlling the supply chain, etc. A historical review and comprehensive survey about the learning effect can be found in [2].

This work takes into account the learning effect in SAL design, or more specifically, focuses on a HM-RCPSP with learning effect and compound activities (HM-RCPSP/L-C). The objective is first to minimize the sum of tardiness of all projects, then minimize the total production time [3].

2 Contribution

To account for the learning effect, our approach involves counting the number of times an activity has been fully completed prior to the start of each of its occurrences. The duration function, which depends on the number of repetitions of the same activity, is referred to as a *learning curve* and serves as an input to the problem. Consequently, the duration of each activity becomes a variable within the problem.

We propose a Constraint Programming (CP) model, based on IBM CP Optimizer, for the HM-RCPSP, incorporating additional constraints to account for both compound activities and the learning effect. Furthermore, we prove the existence of dominant/symmetrical solutions for HM-RCPSP/L-C, which can be eliminated using specific constraints (referred as CP^{DB}). Additionally, we conducted tests using other approaches: adapting the metaheuristic Squeaky Wheel

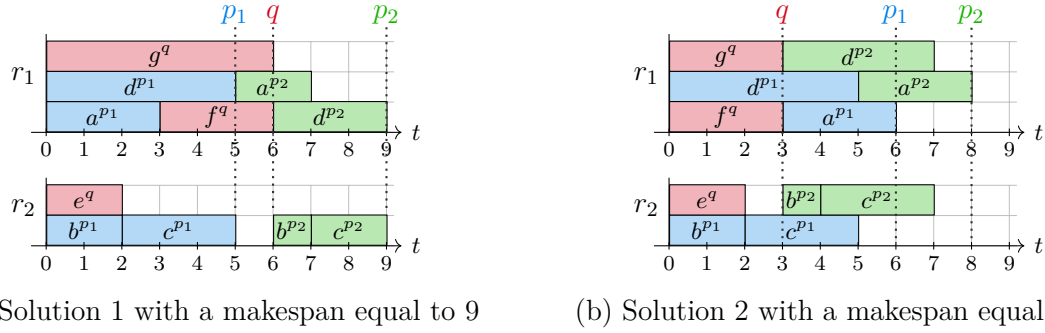


FIG. 1: Two different solutions of a simple HM-RCPSP/L-C with 3 projects $\{p_1, p_2, q\}$, showing the compound activities $\{d, g\}$ and the variations in activity durations due to learning effect

Optimization (SWO), developing an approximation method, and creating a hybrid approach combining SWO and CP for comparison. Experiments are conducted using a real industrial dataset for the SAL, as well as our generated PSPLIB-based dataset, which is available online at [4].

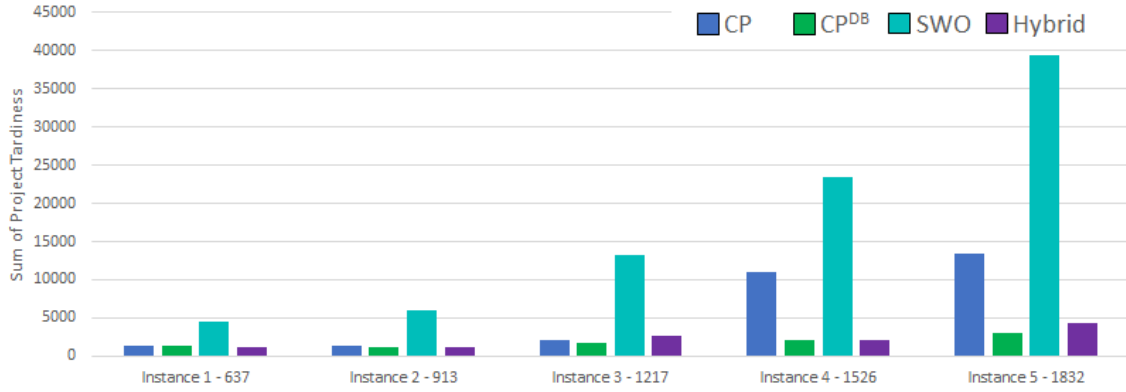


FIG. 2: Performance comparison of different approaches on the SAL dataset (lower is better)

The approaches tested in this work can generate a schedule within a reasonable amount of time for the SAL dataset. Moreover, the performance of the CP-based approaches was boosted by breaking dominances/symmetries on these industrial instances. For future research, considering the uncertainty in learning efficiency could be explored to enhance the robustness of the schedule. Accounting for the learning effect within similar activities instead of identical ones could be considered.

References

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