A CP model with aggregation for real-life project scheduling

Tanguy Terrien[1], Cyrille Briand[1], Philippe Truillet[2]

[1] Université Toulouse 3 - Paul Sabatier, LAAS-CNRS
tterrien,cbriand@laas.fr

[2] Université Toulouse 3 - Paul Sabatier, IRIT
philippe.truillet@irit.fr

Keywords : *scheduling, decision-aid, aggregation, constraint programming.*

1 Introduction

With the constant evolution of the industry, supervisors have to deal with increasingly complex planning systems. In this context, providing decision-support tools (DST) can alleviate the cognitive load that decision-takers suffer from. Following the results of an ongoing multidisciplinary research project [1], as most DSTs suffer from excessive techno-centered designs, they often fail to efficiently reduce the stress inflicted on supervisors. The lack of flexibility of many of these tools is highlighted. The study also underlines that there is an explicit need for human-centered DSTs that support individuals along the decision process, each person having her/his own methodology. It appears in [1] that, when confronted with a complex project scheduling problem, decision-makers often adopt a dynamic planning approach where decisions are progressively elaborated on a rolling time horizon where short-term decisions are made precise, while long-term ones are more vague. To this end, a classic aggregation/disaggregation methodology is used where, as the decision horizon for implementing some parts of the project becomes more and more imminent, tactical decisions are progressively reinforced to become more and more operational. The ability to disaggregate certain parts of the decision model provides precise values for project implementation over close and short time periods. Aggregation provides a tactical view of mandatory task workload and resource requirements over more distant time periods. A planning DST should therefore take into account the concomitant presence of aggregated and disaggregated decisions, and provide a rigorous mechanism for disaggregating decisions so as to maintain decision consistency.

Through the last decades, constraint programming has emerged as one of the most efficient paradigms for dealing with planning and scheduling problems [2]. This work aims to study the ability of the well-known IBM® ILOG CPLEX Optimization Studio software (CPO) to deal with the previous DST requirements. Indeed, the notion of interval variables (with a beginning time, end time, duration, and energy consumption) provided by CPO sounds promising to deal with aggregation and disaggregation needs. Moreover, the powerful ability to propagate constraints is also a strong asset regarding decision aid that can be provided to decision-makers. As detailed in [3], three aggregation dimensions can be considered, i.e., work, time, and resources. Only time and resource aggregations are studied in this work since CPO already natively manage task disaggregation using arrays of interval variables and Span constraint. The figure (FIG. 1) depicts an example of the use-case under study. It shows explicitly how resource and time disaggregation can be represented in production system planning.

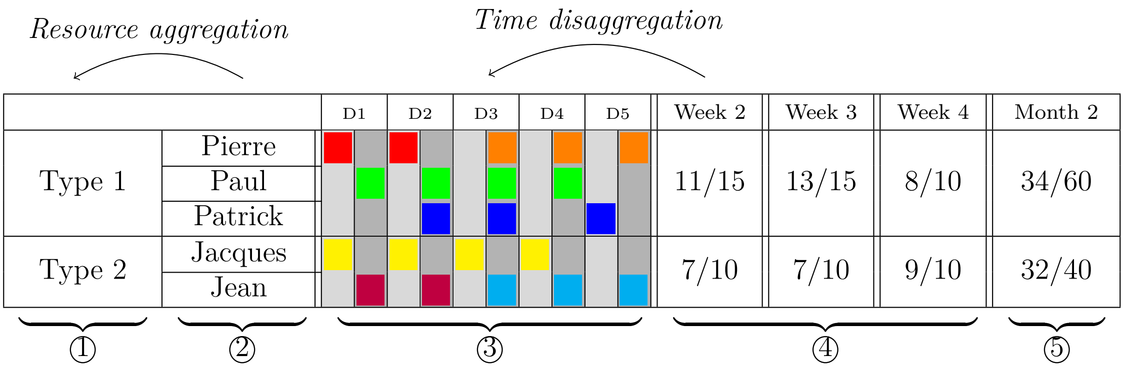

FIG. 1: Example of planning with time and resource aggregation/disaggregation *Note: every day contains 2 work shifts (light grey for AM, dark grey for PM). ① Pools: A pool is a set of resources providing a service (e.g., a specific machine) or a skillset (e.g., a team of operators), ② Operators: an operator is an elementary disjunctive resource, ③ Current week: task-period-operator links are done, ④ Weeks 2 to 4: resources are allocated for the week according to the workload, ⑤ Next month: total resource capacity is defined for the whole month. In weeks and months cells, the first number is the total amount of workload over the corresponding period. The second number is the total amount of resources allocated to the period, here the number of shifts worked by operators (Paul is off during week 4)).*

2 Proposed principles

In our case study, we are given tasks to schedule, numbered from 1 to J. Each task $j \in \{1, ..., J\}$ includes a ready-time r_j, a deadline d_j and a duration p_j needed for its completion. Resources are numbered from 1 to K (operators in our case). We assume that every task is primary, i.e. it can not be decomposed. All tasks are preemptive, meaning that an operator can have rest days, interrupting its work on a task. However, each operator has to end its own ongoing task before starting another one. Every task can be achieved by a subset of operators (required skillset). We propose a new idea that relies on decomposing constraints according to the aggregation level. Following variables are considered (all variables are modeled with CPO intervals).

Variables $\boldsymbol{task_j}$ can be seen as task-period assignments. If restricted to a specific week, they provide aggregated information and if restricted to a specific shift, they provide disaggregated information. Variables $\boldsymbol{W_{jk}}$ are optional and represent intervals where an operator k works on a task j (which can be empty). Variables $\boldsymbol{w^S_{jki}}$ are optional and define task-shift-operator assignments, corresponding to the fully disaggregated information. Of course, constraints ensuring coherence between these variables are mandatory. Long-term considerations differ from short-term constraints. In the short term, constraints restrict variables w^S_{jki} to achieve a precise schedule. However, in the long term, exact task-period-operator allocations are not necessary. Therefore, constraints on variables W_{jk} and $task_j$ are adequate, making the best use of cumulative constraints (available in CPO) for an aggregated perspective.

The accuracy and properties of the above model will be discussed during the conference. We will also present a first tentative DST prototype to favor the interaction between decision-makers and CPO and provide the desired usability, acceptability, and efficiency.

References

[1] M. Mailliez, H. Chevroton, C. Briand, P. Truillet, C. Lemercier, *Chapter 4 - Stepping stone to smarter supervision: a human-centered multidisciplinary framework*, in *Designing Smart Manufacturing Systems*, Academic Press, p.89-118, 2022.

[2] P. Laborie, J. Rogerie, P. Shaw, P. Vilím, *IBM ILOG CP optimizer for scheduling - 20+ years of scheduling*, Constraints An Int. J., 2018.

[3] H. Chevroton, C. Briand, P. Truillet, M. Mailliez, C. Lemercier, *Human-centered interactions for project scheduling decision-aid in space industry*, 18th International Workshop on Project Management and Scheduling (PMS April 2022), Belgium.