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The Group Cumulative Scheduling Problem

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Rapport sur la Thèse

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This thesis is motivated by scheduling problems occurring in the food industry where the existing scheduling constraints cannot cover limits on the numbers of orders that can be processed simultaneously. This thesis introduces a new constraint, called Group Cumulative (GC) to cover these cases. It also shows that solving this constraint is an NP-complete problem. An algorithm for this new scheduling problem is developed, based on two existing ones, and integrated in an ERP solver. Experimental results compared different state-of-the-art scheduling algorithms on different classes of problems. Finally, the thesis studies how automatic algorithm selection can be used to find the most suitable algorithm based on the characteristics of the problems.

Chapter 1 introduces Constrained Optimization Problems (COP) and more specifically the different classes of scheduling problems. The thesis focuses on the class of parallel machine scheduling problems where any of the given machine can process any jobs, and each job needs to be processed by only one machine. These problems are clearly formulated and formalized. The notion of NP-completeness is also introduced.

Chapter 2 describes the different state-of-the-art methods to solve the different problems in the parallel machine scheduling class. Greedy algorithms quickly construct a “good” solution. Two other incomplete methods are reviewed. Ant Colony Optimization is constructive as it repeatedly constructs new solutions starting from an empty one. Local search is perturbative as it iteratively explores the neighbor of a current solution to move to a next solution. Two complete methods are then considered. Linear programming requires the problem to be modeled as a set of linear constraints with a linear objective function. In constraint programming, a combination of propagation and branching explores the search space while reducing the domains of the variables. What is nice in this chapter is the careful description of the methods and their precise application to different parallel machine scheduling problems.

Chapter 3 introduces a new scheduling problem: the Group Cumulative Scheduling Problem (GCSP). It extends the assignment problem within the parallel scheduling problems by partitioning jobs into groups and stating a limit on the number of active groups. A group is active in a solution as soon as its first task begins and becomes inactive after the completion of its latest task. The GCSP is compared with three related problems: cumulative scheduling problems, Open Stack Problems and hierarchical scheduling problems. The thesis then proves the NP-completeness of GCSP, or more precisely LS-GCSP which is a related decision problem of deciding whether a solution of GCSP is consistent with a given list schedule. The proof of completeness is done through a polynomial reduction to the Pathwidth problem, which is known to be NP-complete. The practical interest of GCSP is handled in Chapter 5. The problem is here clearly stated and analyzed. The complexity proof is a plus; not only does it underline the complexity of GCSP, but it also shows the mastery of complexity theory by the author.

Chapter 4 proposes methods to solve the GCSP. First, a decomposition approach is used within the CP framework to handle the new Group Cumulative constraint. The development of a new global constraint for this constraint is mentioned. Then an approximated algorithm is proposed to obtain a schedule from a list-schedule for the GCSP. It is approximated as this problem is NP-complete. A greedy algorithm is also introduced for the construction of a solution for the GCSP. Finally, a new hybrid CPO-ACO approach is

described, where CPO is CP Optimiser, a commercial optimization tool. This is a new way to combine ACO and CP. Each solution of ACO is a starting point for CPO, and each solution of CPO is used to update the pheromone trails. This chapter analyzes various interesting algorithmic possibilities to solve GCSP. One could, however, regret that the idea of developing a new global constraint for CP has not been considered.

Chapter 5 briefly discusses scheduling applications and the context of the thesis in a company developing an ERP dealing with scheduling problems in the agrifood industry. It clearly justifies the interest and the potential applications of the Group Cumulative constraint when handling several preparation orders for different clients. Ten scheduling problems, all variants of the uniform parallel machine scheduling problems will be used in the experiments. Four of them include the Group Cumulative constraint. This chapter also describes the collected data for the experimentations. All the data were collected in an industrial environment.

Chapter 6 is important in this thesis. It reports a large and structured number of experiments. Ten different parallel scheduling problems are considered, four of them including a Group Cumulative constraint. Six algorithms or models have been implemented: Tabu search, ACO, CP, MIP, ACO-Tabu and CPO-ACO. As Tabu search, ACO and ACO-Tabu have been applied with different parameters, a total of twelve algorithms are compared. The performance measures are precisely stated, and all the results are clearly reported on graphs. An analysis on the individual problems is proposed, followed by a global analysis on the different algorithms.

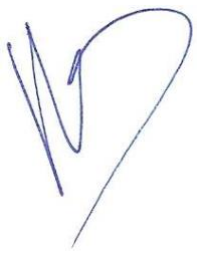
Chapter 7 proposes to automatically select a suitable algorithm on a given instance. This is done through learning. In order to apply classification techniques, a performance measure of the use of an algorithm on an instance has first to be defined. Two performance measures are defined in the thesis. Then each instance must be represented by a vector of values in order to apply existing classification algorithms. Using 10-fold cross validation, it is shown that the automatic selection of an algorithm outperforms a static choice.

Chapter 8 is a short introduction to dynamic scheduling where all the jobs are not known beforehand but are dynamically revealed. Some existing methods are reviewed and an algorithm, based on the CPO-ACO algorithm is proposed. It allows a rescheduling when a new job is revealed. Experimental results are shown.

Chapter 9 concludes the thesis and proposes various perspectives to continue this research.

The thesis is well written and is nice to read. All the concepts are correctly introduced and defined. The state-of-the-art is complete as well as the comparison with related work, and suitable references are given. The thesis has different contributions. First, it introduces and defines a new class of problems, the Group Cumulative Scheduling Problem (GCSP) and the Group Cumulative constraint. Then it proves the NP-completeness of this problem. The combined CPO-ACO algorithm is also novel. The experimental chapter is well developed. The automatic selection of an algorithm as well as the proposed dynamic scheduling algorithm lead to a proof of concept of the proposed techniques. This thesis led to publications in two international conferences, GECCO (Genetic and Evolutionary Computation Conference) and CP (international conference on principles and practice of Constraint Programming), a major and selective conference in this research area. At the time of the thesis publication, the contributions in chapters 6 to 8 have not yet been published but deserves publication in conferences or in a journal.

In conclusion, I support the defense of this thesis.



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