Modeling and Solving Parallel Machine Scheduling with Contamination Constraints in the Agricultural Industry

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Industry Abstract

In the modern agricultural industry large amounts of compound feed are produced to fulfill the demands of livestock farming. Usually a highly-automated production is used to handle the large-scale requirements in this domain. However, finding efficient production schedules is challenging, as several problem-specific constraints regarding contamination levels need to be fulfilled. Furthermore, job tardiness is a critical minimization objective in this domain as there is the need to distribute the products to many consumers. Currently, human planners often create the production schedules manually or simple greedy algorithms are used. Thus, there is a strong need for novel efficient automated scheduling methods.

In our work[1] we formally introduce a novel challenging real-life machine scheduling problem originating from the agricultural industry. As a set of predetermined jobs has to be scheduled on multiple machines, the problem can be categorized as a parallel machine scheduling problem with setup times (PMSP). A plethora of different techniques have been proposed to solve many PMSP variants and surveys such as (Allahverdi 2015) provide an overview of the literature. However, as practical machine scheduling problems appear in many different variations regarding the specified constraints and the objective function, complex large-scale applications are still being investigated in the recent literature (e.g. (Yepes-Borrero et al. 2021; Bitar, Dauzère-Pérès, and Yugma 2021)).

The real-life problem variant we investigate contains a set of unique contamination level constraints and additionally requires the consideration of optional cleaning jobs. Further, the objective function includes a domain-specific tardiness objective where due dates are associated to groups of jobs.

As exact approaches to the problem we propose several constraint programming models that include novel modeling techniques regarding the contamination constraints. Further, we investigate a local search approach to tackle large-scale real-life problem instances which utilizes problem specific neighborhood operators. We further provide 19 novel real-life problem instances from the agricultural industry that we use to evalute our methods.

Inst.	LB	Gap	CP	LS
I1	403617	0	**403617**	**403617**
I2	295211	25.21	**394696**	**394696**
I3	25702	0	**25702**	**25702**
I4	2305	0	**2305**	**2305**
I5	24086	28.54	**33707**	**33707**
I6	136288	0	**136288**	**136288**
I7	707234	26.29	**959455**	**959455**
I8	20816	0	**20816**	**20816**
I9	97586	0	**97586**	**97586**
I10	80027	24.7	**106274**	**106274**
I11	412877	82.68	2434331	**2383478**
I12	604160	13.3	**696805**	**696805**
I13	1020957	0	**1020957**	**1020957**
I14	407439	0	**407439**	**407439**
I15	1268739	12.75	**1454166**	**1454166**
I16	773924	0	**773924**	776526
I17	528173	9.16	**581404**	**581404**
I18	32662	1.77	**33251**	**33251**
I19	232434	10.47	1082993	**259614**

Table 1: Results achieved with exact and heuristic methods.

An experimental evaluation of the proposed approaches shows that the constraint modeling approach is able to provide 9 optimal results and further produces high-quality solutions for all instances. The local search approach we propose can reach 8 optimal results, similar upper bounds as obtained by the exact methods for the majority of instances, and two overall best upper bounds. Table 1 summarizes the cost results for the 19 real-life instances (I1-I19), where each row includes the best lower bounds (LB), the duality gap (Gap), the best upper bound achieved by exact methods (CP) and the best results achieved by local search (LS).

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References

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[1]The full version of this work appeared in the proceedings of the 28th International Conference on Principles and Practice of Constraint Programming (CP 2022).