Exact Methods for a Paint Shop Scheduling Problem from the Automotive Supply Industry

Felix Winter and Nysret Musliu

Christian Doppler Laboratory for Artificial Intelligence and Optimization for
Planning and Scheduling*
DBAI, TU Wien
`{winter,musliu}@dbai.tuwien.ac.at`

Every day, the paint shops of the automotive supply industry will paint a large number of items that are requested by car manufacturing companies. To ensure a cost efficient production, modern factories will utilize a high level of automation that includes multiple painting robots and conveyor belt systems. Because of the sophisticated production process it becomes a hard task to find good painting schedules, and human planners are usually not able to find optimized production sequences. Therefore, there is a strong need to develop automated techniques for paint shop scheduling.

In the literature related problems have been studied and several publications consider the minimization of color changes for paint shop scheduling (e.g. [8], [7], [6], [2]). However, the problem we investigate in this paper includes additional important practical features like the optimized allocation of materials onto carrying devices and the consideration of many sequence and resource constraints. We have previously introduced this real life paint shop scheduling problem that appears in the automotive industry in [9](todo). Its aim is to find a production sequence that fulfills a large set of given demands and to minimize the number of color changes as well as the number of carrying devices that are used to carry materials through the paint shop. To solve the problem, we previously proposed a greedy algorithm as well as a local search based approach and we provided a set of practical benchmark instances in [9]. However, up to now no exact solution approaches have been proposed and optimal solutions are not known yet for all instances.

In this work we investigate two modeling approaches for the paint shop scheduling problem using the MiniZinc constraint modeling language [5]. One of them using a direct modeling approach and the other one using deterministic finite automatons (DFAs). Furthermore, we evaluate and compare our proposed modeling techniques by performing a series of benchmark experiments using state of the art constraint programming and mixed integer programming solvers on known practical paint shop scheduling benchmark instances from [9]. Although currently the exact methods we describe cannot be used to solve very large practical instances, the proposed approaches can provide optimal solutions

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for 7 benchmark instances that have been previously unknown. Final results in our experiments are shown in Table 1.

Additionally, we analyze the complexity of the decision variant of the paint shop scheduling problem and show that it is NP-complete(todo).

	Chuffed	Gurobi	Cplex	LS [9]
I1	**775***	**775***	**775***	844
I2	**842***	**842***	**842***	868
I3	**961***	**961***	**961***	990
I4	**918***	NA	1160	975
I5	**530***	17880	17880	593
I6	**842***	**842***	**842***	887
I7	**1046**	NA	NA	1084
I8	**1237***	NA	NA	1834
I9	**1006**	NA	NA	1735
I10	**973**	NA	NA	1134
I11	NA	NA	NA	**5476**
I12	NA	NA	NA	**5723**
I13	NA	NA	NA	**116235**
I14	NA	NA	NA	**118628**
I15	NA	NA	NA	**172679**
I16	NA	NA	NA	**262252**
I17	NA	NA	NA	**421777**
I18	NA	NA	NA	**581021**
I19	NA	NA	NA	**555829**
I20	NA	NA	NA	**927822**
I21	NA	NA	NA	**917955**
I22	NA	NA	NA	**1128716**
I23	NA	NA	NA	**1884125**
I24	NA	NA	NA	**2086450**

Table 1: The best results achieved with our models for instances 1–24 using Chuffed [1], Gurobi [4] and Cplex [3] compared with the best known upper bounds from [9](LS). Experiments have been performed on an Intel Xeon E5345 2.33 GHz CPU with 48 GB RAM under a one hour time limit. The best result within each line is formatted in bold face. A * denotes proven optimal solutions.

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