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INDUSTRIAL MULTI-OBJECTIVE OPTIMIZATION OF A LARGE COMPLEX JOB SHOP IN SEMICONDUCTOR MANUFACTURING

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ABSTRACT

This paper surveys the industrialization of an advanced optimization engine that was developed by Planimize and put into production in the cleaning and diffusion work center of the most advanced factory of a semiconductor manufacturing company. Hundreds of lots requiring several thousands operations in the work center must be scheduled on about 150 machines, while taking complex constraints into account, in particular hundreds of time constraints, and optimizing a collection of criteria. The optimization engine provides significantly better results, runs significantly faster, and can handle much larger problem instances than the previous Constraint Programming optimization engine used in the factory.

1 CONTEXT

The recent extension of the most advanced factory (fab) of a semiconductor manufacturing company led to the significant increase of the number of machines and of the number of lots to be scheduled on these machines. Moreover, advanced technologies require more and more time constraints (also called queue time constraints), i.e. a maximum amount of time that a lot can spend between two operations (that do not have to be consecutive) in the routes of products. The fab extension makes it impossible to use the Constraint Programming engine designed for the cleaning and diffusion work center as running times of more than 20 minutes did not lead to acceptable results, in particular regarding the satisfaction of time constraints which is critical to ensure the quality of products and to avoid scrapping products.

The considered cleaning and diffusion work center is characterized by a large (more than 150) number of heterogeneous machines, i.e. with different characteristics. Some of these machines require their internal components to be modeled in detail to determine realistic schedules (see (Tamssaouet, Dauzère-Pérès, Yugma, Knopp, and Pinaton 2018)). Machines are processing lots in batches, the maximum size of which depends both on the operation and the machine. Lots have to perform up to seven consecutive operations in this work center. Several criteria need to be optimized simultaneously, including the satisfaction of time constraints, the batch size, the weighted flow factor (the cycle times of the lots in the work center weighted by their priorities) and the satisfaction of production targets imposed by global scheduling.

Other important constraints and criteria are not discussed in this abstract. Hence, numerous extensions of the flexible shop-shop scheduling problem discussed in the review of (Dauzère-Pérès, Ding, Shen, and Tamssaouet 2023) are combined. The problem is thus a typical example of a complex job-shop scheduling problem. To solve the considered problem, mathematical programming, in particular mixed-integer linear programming, approaches are not relevant as multiple criteria, including non-linear ones, must be optimized and complex non-linear constraints, that cannot always be linearized, must be taken in account. Moreover, very large instances of the problem must be solved, which cannot be handled by standard mathematical programming solvers in some minutes.

2 INDUSTRIAL IMPLEMENTATION

Following some of the ideas introduced in (Dauzère-Pérès and Paulli 1997), (Knopp, Dauzère-Pérès, and Yugma 2017) and (Tamssaouet, Dauzère-Pérès, Knopp, Bitar, and Yugma 2022), an optimization engine was developed that relies on state-of-the-art research in Operations Research and Artificial Intelligence but also advanced software engineering. Only few months were necessary to put the new optimization engine into production. An important first step was to show on real-life instances that the new engine was strongly dominating the former optimization engine used at the time. Significantly better results were obtained on critical key performance indicators and, as importantly, these results were obtained in only several minutes. This latter point proved critical to improve the reactivity of the work center to random events.

Once the scheduling engine was installed and through various back-and-forth iterations with the engineers in the fab, the engine was improved to better take various industrial expectations into account. The engine thus showed its adaptability.

3 CONCLUSIONS AND FUTURE WORK

The combination of state-of-the-art research and advanced software engineering led to the development of a novel optimization engine that now schedules, in few minutes, several thousands operations on about 150 machines, while taking complex constraints into account and simultaneously optimizing multiple criteria. The engine has been successfully running for several months every 8 minutes 24 hours per day 7 days per week in the most complex work center of a large semiconductor manufacturing factory.

Following the successful implementation in the cleaning and diffusion work center, the engine is being extended (and not a new engine developed) to schedule lots in other work centers.

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