Complex Job-Shop Scheduling
for Semiconductor Manufacturing:
A Batch-Oblivious Heuristic

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1 Introduction and Problem Description

Scheduling decisions in the diffusion and cleaning area can be crucial for the overall performance of a semiconductor manufacturing facility. This area includes complex production constraints and long processing durations. Consequently, we want to optimize scheduling decisions in this area while taking all relevant real-world constraints into account. An important property of machines in this work area is their batching capability: Multiple operations can be performed at the same time. We present an algorithm that includes p-batching within a job-shop environment.

We are given a set of jobs to be scheduled. For each job, a fixed sequence of operations must be performed. This sequence is called the route of the job. Operations can only be performed on qualified machines and their processing durations depend on the selected machine. A capacity limit constrains the number of jobs that can be processed per batch. For each operation we are given a recipe that determines operations that are processable in a common batch. Additionally, we are given for each job a ready date and a due date. Those constraints describe a complex job-shop scheduling problem with p-batching. We aim to minimize regular objectives such as total weighted tardiness.

For the described problem, we present a batch-oblivious disjunctive graph representation that allows to take adaptive batching decisions during a traversal of the graph. Underutilized batches are dynamically “filled up” by resequencing and reassigning eligible operations. We make use of this approach in a heuristic algorithm based on a GRASP meta-heuristic (see [1]).

2 Related Work

The considered problem generalizes classical job-shop scheduling which is already NP-hard. A literature review on scheduling problems with batching in semiconductor manufacturing is given in [3]. Only few results on the inclusion of batching machines in job-shop scheduling problems can be found in literature. [5] introduce a disjunctive graph representation that makes use of dedicated batching nodes. They use this representation in a shifting bottleneck heuristic and improve results of dispatching based solutions. Similar approaches are proposed by [2] and [4]. A Simulated Annealing based approach using a comparable disjunctive graph representation is presented in [6]. We propose a different and novel way to represent batching decisions: Instead of adding auxiliary nodes, batching decisions are encoded into edge weights.
3 Solution Approach

The core of our approach is a batch-oblivious disjunctive graph representation that avoids the complexity of additional batching nodes. Instead, we take adaptive batching decisions during a traversal of the graph. Underutilized batches are “filled up” by resequencing and reassigning eligible operations. We embed this idea in a heuristic algorithm based on the GRASP heuristic of [1]. There, many different initial solutions are created using an insertion heuristic. We successively inserts jobs and perturb their ordering to achieve a randomization. Solutions are then improved using a Simulated Annealing heuristic based on the adaptive neighborhood sketched above. Since each solution is calculated independently, a straightforward parallelization of the approach is possible.

4 Conclusion

We presented a heuristic approach based on a batch-oblivious representation and adaptive batching decisions. This avoids additional complexity and facilitates the integration of further constraints. The adaptive behavior of the dynamic recalculation of batches yields good results in our numerical experiments. Since the problem is very general, it can be applied to various known scheduling problems and existing benchmark instances. Our goal is to include further real-world constraints to obtain a scheduling system that is fully applicable in the daily planning of a semiconductor manufacturing facility. Further research could aim at improving our method by enhancing adaptive batching strategies or by performing lazy graph evaluations to speed up move computations.

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References


