A Heuristic Algorithm for the Flexible Job Shop Problem with Changeover Times

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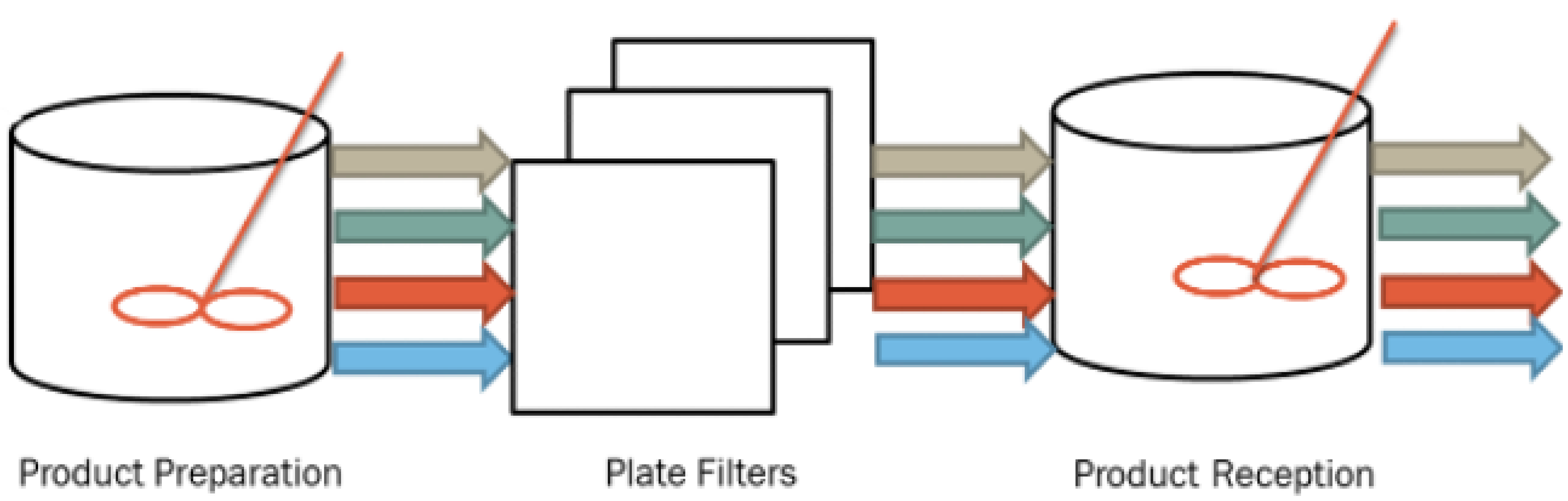
Introduction

For the enzyme production line of a DSM plant, a schedule has to be made following a set of complex constraints. There are machines of different types, that perform different operations and multiple different enzymes with each their own recipe. The scheduling problem in this production line can be seen as a variation on the flexible job shop problem (FJSP), which introduces cleaning times between every two operations performed on a machine.
Heuristic scheduling algorithms have short runtimes but have been shown to still be able to create feasible schedules of good quality for the regular FJSP. This makes them a good option for an applied use case where a correct balance between runtime and solution quality is important.



Objective

Determine the performance of a heuristic algorithm compared to that of the existing MILP solver solution on the DSM case of the FJSP with changeover times.

THE MILP SOLVER

A MILP solver is a Mixed-Integer Linear Programming solver, that uses a mathematical formulation of the problem to find an optimal solution.
The runtime of the MILP solver is too high to be feasibly used in this applied use case.

THE ALGORITHM

The algorithm loops over the set of operations that can currently be scheduled. Using a weighted combination of several heuristics, it then determines the next operation and machine combination and adds it to the schedule. This process repeats until all operations have been scheduled.

THE HEURISTICS

The heuristics used aim to minimize:

- Idle-times of machines
- Completion times of machines
- Wait times before operations
- Processing times of operations
- Changeover times

And to prioritize:

- Operations of recipes with a long total time

Results

Figure 1 and Figure 2 show comparisons between the lowest makespans found by the MILP solver and the heuristic algorithm in two experiments with different runtimes for the MILP solver on sets of increasingly large instances. For the smaller instances, the MILP solver outperformed the heuristic algorithm slightly in both figures. In both figures, we also see that as the complexity increases the performance of the heuristic algorithm improves increasingly compared to the MILP solver. For the larger instances, the heuristic algorithm consistently outperforms the MILP solver, even with only a fraction of the runtime.

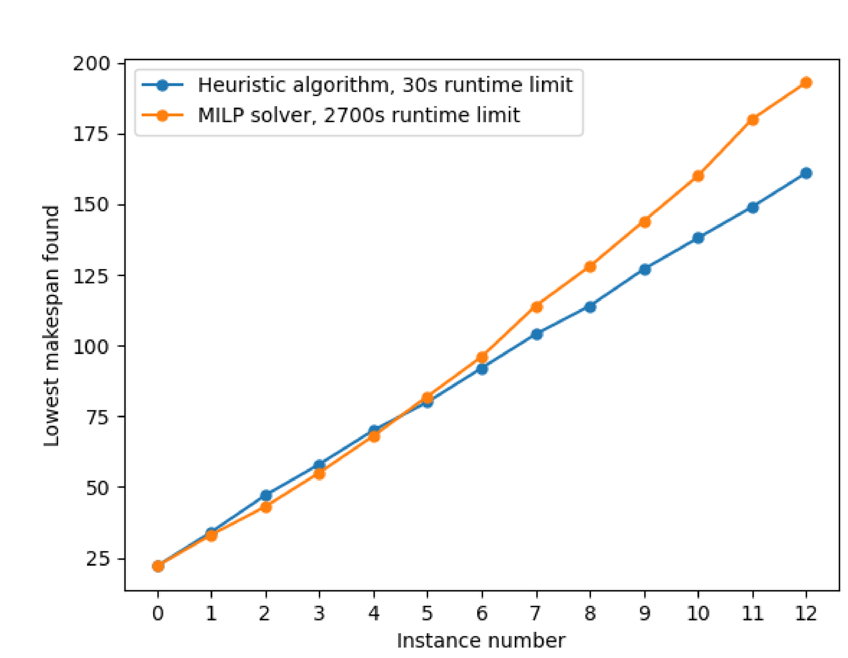


Figure 1: Comparison between the performance of the MILP solver with 2700s runtime and the heuristic algorithm with 30s runtime

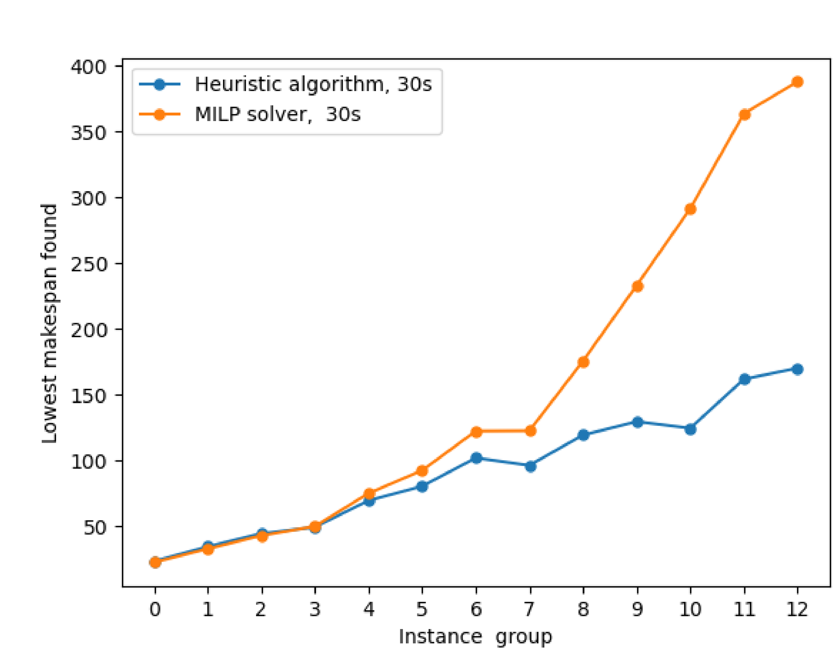


Figure 2: Comparison between the performance of the MILP solver with 30s runtime and the heuristic algorithm with 30s runtime

Conclusion & Future Work

We can conclude that for the DSM case of the FJSP with changeover times, in cases where the available runtime is limited and a good balance between runtime and schedule quality is important, a heuristic algorithm performs better than the existing MILP solver solution.
A suggestion for future work is to compare the MILP solver and heuristic algorithm for different objective functions, or on instances of the FJSP with changeover times for cases other than that of the DSM enzyme production line.

RELATED LITERATURE

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