Optimizing layout, process planning and scheduling problems in a Reconfigurable Manufacturing Systems

Isabel Barros Garcia[1], Joanna Daaboul[1], Antoine Jouglet[2], Julien Le Duigou[1]

[1] Université de Technologie de Compiègne, Roberval, CS 60319, 60203 Compiègne, France

[2] Université de Technologie de Compiègne, Heudiasyc, UMR CNRS 7253, CS 60319, 60203 Compiègne, France

Keywords : *Reconfigurable Manufacturing Systems, Layout, Process Planning, Scheduling.*

1 Introduction

The interest in customized products and the diversification in production has increased over the years, making the market subject to high demand variations and creating challenges in production management/decisions. To deal with these new scenarios and maintain competitiveness, reconfigurable manufacturing systems (RMS) are being studied extensively. RMS is a type of system designed to make rapid changes in its structure, e.g., changing machines' configuration (software and/or hardware levels) and machines' layout, in order to quickly adjust its production capacity and functionality within a family of parts to respond to sudden market changes [3]. The research on this topic concentrates mainly on developing its main features, part family formation, and configuration optimization [2]. In this work, we concentrate on the last topic, not in its totality (since it is hugely vast), but on optimizing layout design, process planning, and scheduling. The objective is to integrate these three decision problems to obtain optimal total costs. The choice of integrating the problems is due to the connectivity they have between them, sharing decision variables. Three exact methods, a metaheuristic and a method combining metaheuristic with the local search were developed to solve it.

Then, our work focuses on:

- the integration of layout, process planning, and scheduling problems (separately, they have been widely studied, but not jointly);
- the inclusion of layout reconfiguration that directly impacts material handling times and costs (we still have little research on this part compared to process planning and scheduling);
- the possibility of reconfiguration at any time (most works only allow reconfiguration when the part being processed changes);
- deepen the study of exact methods (for the other authors, the exact method is only for the validation of the problem);
- integrate the best approaches using a genetic algorithm and local search method.

2 Problem description

This problem was first presented in [1]. The client orders are called jobs, and each job is composed of a set of operations that must obey a precedence order. The jobs have a due date to respect, a penalty cost is applied per delay time. The factory is composed of a set of machines, where each machine has a set of possible configurations. Each operation can be processed on at least one machine/configuration. It is possible to change the machine configurations and the layout of machines. However, to respect the plant's physical and safety constraints, there is a set of possible layouts. The objective is to minimize total costs, including production, machine reconfiguration, layout reconfiguration, material handling, and tardiness. Operations cannot be preempted. Each machine can process only one operation at a time. An operation can only be processed after the previous one is complete and the material handling time is also complete. During a machine reconfiguration, it becomes unusable. During the layout reconfiguration, no operation can be processed. Finally, all precedence orders must be respected.

3 Solving methods

We developed some exact and evolutionary methods to solve this problem. The exact methods were: integer linear programming, constraint programming, and constraint programming with a defined search strategy (CPS). The IBM ILOG CPLEX Optimizer software was used for the first, and IBM ILOG CP Optimizer for the other two. When analyzing the execution times of several small instances, it was possible to see the great superiority of the CPS over the others.

As the exact methods can have difficulties in finding a good solution for real-size instances in an acceptable time, in a second moment, two evolutionary algorithms were developed for the problem: genetic algorithm and genetic algorithm combined with local search. The genetic algorithm can find satisfactory solutions for industrial-scale problems but can get stuck in a local optimum. Local search (using CPS) was added to treat this when the total cost difference between generations was not significant.

4 Conclusions and perspectives

The integration of the problems allows better results than when treated separately and sequentially, but this requires a high computational time. The evolutionary algorithms are better for large instances, but using good parameters is essential. The decision to integrate local search with the genetic algorithm was due to the promising results found with CPS and the difficulty at a certain point of GA to improve.

The current approaches can be boosted by applying other techniques or optimizing the coding structure. Future perspectives are to boost it, integrate environmental variables in the model, such as gas emissions and waste, and exclude the strong assumptions, such as the required quality of all products and the constant availability of resources.

References

[1] BARROS GARCIA, Isabel et al. *An Approach to Jointly Optimize the Process Plan, Scheduling, and Layout Design in Reconfigurable Manufacturing Systems.* International Workshop on Service Orientation in Holonic and Multi-Agent Manufacturing. Springer, Cham, 2022. p. 403-415.

[2] KHANNA, Kamal; KUMAR, Rakesh. *Reconfigurable manufacturing system: a state-of-the-art review.* Benchmarking: An International Journal, 2019.

[3] YELLES-CHAOUCHE, Abdelkrim R. et al. *Reconfigurable manufacturing systems from an optimisation perspective: a focused review of literature.* International Journal of Production Research, v. 59, n. 21, p. 6400-6418, 2021.