Sensitivity analysis of multi-objective optmization metaheuristic in solving the Multi-Product process planning

Abdelkader Mechaacha[1,2], Nadjib Brahimi[2], Fayçal Belkaid[1]

[1] Manufacturing Engineering Laboratory of Tlemcen, University of Tlemcen, Tlemcen, Algeria
abdelkadermechaacha@gmail.com, faycal.belkaid@univ-tlemcen.dz
[2] Rennes School of Business, Rennes, France
nadjib.brahimi@rennes-sb.com

Keywords : *Reconfigurable manufacturing systems, Process planning, metaheuristic, MOEA/D*

1 Introduction

Process planning encompasses decisions on how and for how long to process the operations of a product, serving as input for various other planning problems. In contrast, a Reconfigurable Manufacturing System (RMS) is specifically designed for timely and cost-effective reconfiguration to cope with market changes, with three essential characteristics: scalability, convertibility, and customization. Consequently, the performance of an RMS is highly tied to the effectiveness of the process planning activity.

While conventional papers focus on single-product process planning, emphasizing scalability characteristic, they often overlook its complementary aspect of convertibility in RMS. Conversely, recent works on multi-unit process planning, such as [1, 2], do not consider products of different types, leading to a similar deficiency. Recognizing the critical role of convertibility in RMS, it becomes imperative to extend the scope to multiple products. Multi-product process planning raises questions about the interactions between process plans or the products within the manufacturing system and their impact on its performance.

In this paper, we address a multi-product process planning (MPPP) problem within RMS, using the MOEA/D metaheuristic. We conduct parameter tuning for the metaheuristic to enhance its effectiveness in solving the problem.

2 Problem formulation

MPPP problem can be described as follows: A set of products must be manufactured on a shop floor featuring a predefined layout of Reconfigurable Machine Tools (RMTs). Each RMT has multiple configurations, each offering a distinct set of available Tool Approach Directions (TADs), and can use specific set of tools. Every product on the shop floor undergoes a series of operations, where each operation involves a set of tasks requiring specific tools and TADs.

TAB. 1: A Solution representation

Product	P1	P1	P1	P1	P2	P2	P2
Operation	OP3	OP2	OP4	OP1	OP2	OP1	OP3
Machine	M2	M1	M2	M1	M2	M1	M1
Configuration	C3	C2	C2	C1	C2	C1	C2
Tool	T1	T1	T5	T3	T2	T1	T3

The obtained solution can be presented in a table 1. We can interpret it from left to right column by column. The first line indicates that product P1 is processed before product P2. The second column indicates that we process first operation OP3 on machine M2 under configuration C3 with tool T1; then we proceed with operation OP2 (of the same product P1) on M1 with configuration C2 and tool T1, etc.

Typically, the NSGA-II metaheuristic is widely employed in the literature to address this problem. However, we chose to explore a metaheuristic that has gained recent attention especially in the scheduling problems: the Multi-Objective Evolutionary Algorithm with Decomposition (MOEA/D).

This metaheuristic involves breaking down the problem into N subproblems, with N representing the population size. Each subproblem is characterized by a set of weights assigned to the objectives. During the evaluation of individuals, we utilize the Tchebycheff approach, selecting the individual with the lowest maximum value of weighted objectives.

3 Methodology

We have identified four parameters on which to perform sensitivity analysis. Each parameter is given three different values: High, Medium, and Low. Initially, nine tests were identified using the Taguchi method, and we repeated 10 times each on the instance data of [3]. Figures 1 to 4 represent the obtained results where the Hypervolume (HV) indicator is used to evaluate the performance of different levels of parameters. The best values of the parameters are as follows: 0.5 for the crossover probability, 0.05 for the mutation ratio, 20 for the population size, and 20 for the T parameter which represents the number of neighboring solution in the group where we select parents for crossover.

We are currently evaluating the performance of MOEA/D compared to other multi-objective metaheuristics, such as NSGA-II, and we aim to further compare the metaheuristics' performance against an exact solution method.

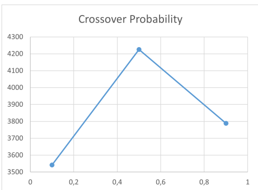

FIG. 1: HV vs. Crossover probability

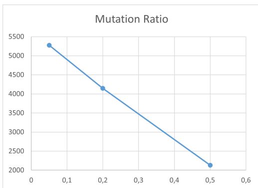

FIG. 2: HV vs. Mutation ratio

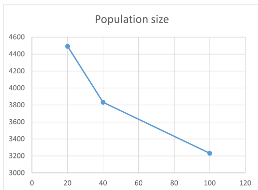

FIG. 3: HV vs. Population size

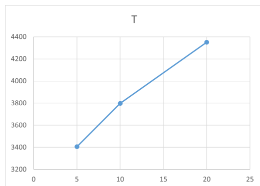

FIG. 4: HV vs. T

References

[1] Amirhossein Kazemisaboor, Abdollah Aghaie, and Hamed Salmanzadeh. A simulation-based optimisation framework for process plan generation in reconfigurable manufacturing systems (rmss) in an uncertain environment. *International Journal of Production Research*, 60(7):2067–2085, 2022.

[2] Faycal A Touzout and Lyes Benyoucef. Multi-objective multi-unit process plan generation in a reconfigurable manufacturing environment: a comparative study of three hybrid metaheuristics. *International Journal of Production Research*, 57(24):7520–7535, 2019.

[3] Ayman MA Youssef and Hoda A ElMaraghy. Assessment of manufacturing systems reconfiguration smoothness. *The International Journal of Advanced Manufacturing Technology*, 30:174–193, 2006.