

A Digital Twin Framework for Flexible Job Scheduling Problems in Industry 5.0

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Résumé : *We present a digital twin model for monitoring and simulating NP-hard problems such as flexible job-shop scheduling in order to put human issues at the center of industry challenges. Different criteria and variables can be considered in such a solution, including the working environment, standard, and behavior of the operators, as well as security and safety. In addition, the solution develops different objective functions for optimizing numerous variables, so that decisions can be made promptly and effectively.*

Mots-clés : *Flexible Scheduling Jobshop problem ; Job-Rotation ; Ergonomy ; Industry 5.0*

1 Introduction

Technological advances have always played a significant role in industrial shifts throughout history. Thus, the invention of the vapour machine gave rise to industry 1.0 and mechanical production in the 1760s. It was in the 1870's that electrical energy allowed humans to mass produce, which was industry 2.0. Almost a century later, electronics, computers, and industrial robots automated the industry, marking the start of industry 3.0. An initiative was presented during the 2011 Hanover Fair by the German Ministry of Education and Research to encourage the digitization of factories and the intersection of supply chains. So, it is evident that technology plays a significant role in the change of eras in industrial production. In contrast to previous industries, Industry 5.0 is a direct result of environmental and human factors, not technological advancements. In fact, Industry 5.0 is much more humane, social, and environmentally friendly.

According to the European Commission, 'Industry 5.0 offers a vision of an industry that goes beyond efficiency and productivity as sole objectives, and strengthens the role and contribution of industry to society'. Workers' well-being is at the heart of the production process, while new technologies ensure prosperity beyond jobs and growth. Putting research and innovation at the service of a sustainable, people-centred, and resilient industrial transition complements the existing Industry 4.0 approach. A digital twin is a comprehensive physical and operational representation of a given system, matching a digital replication, regarded as a twin, that enables the mutual exchange of information between the real system and its digital pair [5]. Through such a twin, data from the real system can be monitored and analyzed in real-time, enabling stakeholders to identify problems in physical systems sooner, improve the accuracy of their results, and produce better products in a more effective manner [2].

By considering FJSP as a multi-objective problem in Industry 5.0, we propose a model of a digital twin for a production manufacturing system that includes a decision maker within the data analysis system [1]. Besides operators, machines, and production constraints, a decision maker will also be represented in this twin to interact directly with it.

2 Problem description

A flexible job shop scheduling problem (FJSP) involves scheduling multiple jobs according to an ordered sequence of operations. An operation can be executed by any machine among a subset of machines that are compatible with it. It is known that this problem is NP-hard [3]. Firstly, we consider three classical objectives : makespan (f_1), total machine processing time (f_2), and balanced machine utilization (f_3). Additionally, three other objectives are considered in the context of Industry 5.0 :

Human-centered criteria : intelligent manufacturing systems (ergonomics).

f_4 minimizes the operator effort ; we propose a job rotation technique between workers to balance the effort of using some machines at the expense of others. (We assume that the workers have the same qualification).

Sustainability criteria : Minimizing machine running times and delays [4].

f_5 minimizes the total delay. The minimization of the running time of the machines is ensured by f_2 .

Resilience criteria : It is to anticipate the breakdowns, and unplanned unavailability of workers [6]

f_6 is an objective function in conflict with the previous ones. Indeed, for a system to be resilient, machines and operators should remain on standby in case of breakdowns and absences. Maximizing critical path resources is the goal of this function.

3 Proposed framework

Our work proposes a digital twin model for monitoring production factories. The model is based on an application of the Flexible Job Shop problem to a human-centred and social context. Based on the decision maker's preferences, a guided metaheuristic will be proposed to perform simulations and provide solutions.

4 Conclusion

A digital twin model is presented in this paper that monitors, simulates and proposes compromise solutions to the flexible job shop scheduling problem. A flexible job shop scheduling problem is proposed and implemented according to Industry 5.0 criteria. This type of tool will make sense in Industry 5.0 by including more criteria related to the environment, so operators can reach decisions more quickly.

Références

- [1] Madani Bezoui, Alexandru-Liviu Olteanu, and Marc Sevaux. Integrating preferences within multiobjective flexible job shop scheduling. *European Journal of Operational Research*, 2022.
- [2] Stefan Boschert and Roland Rosen. Digital twin-the simulation aspect in mechatronic futures : Challenges and solutions for mechatronic systems and their designers, 2016.
- [3] Y. Demir and S. K. İşleyen. Evaluation of mathematical models for flexible job-shop scheduling problems. *Applied Mathematical Modelling*, 37(3) :977–988, 2013.
- [4] Md Riyad Hossain, Md Kamruzzaman Rasel, Md Isanur Shaikh, and Utpal Kumar Dey. Optimization of the flexible job shop scheduling problem for economic sustainability. *Global Journal of Research In Engineering*, 2018.
- [5] Vyacheslav Kharchenko, Olga Morozova, Oleg Illiashenko, and Sergii Sokolov. A digital twin for the logistics system of a manufacturing enterprise using industrial iot. *Information & Security*, 47(1) :125–134, 2020.
- [6] Valentin Le Fèvre. *Resilient scheduling algorithms for large-scale platforms*. PhD thesis, Université de Lyon, 2020.