

PAPER • OPEN ACCESS

Real-time workshop digital twin scheduling platform for discrete manufacturing

To cite this article: LIU Zhifeng *et al* 2021 *J. Phys.: Conf. Ser.* **1884** 012006

View the [article online](#) for updates and enhancements.

You may also like

- [Research on NSGA-II Flexible Job Shop Scheduling Based on Variable Length Chromosomes](#)
Yuanfeng Hao, Chunlei Ji and Wei Xiao
- [Solving Flexible Job Shop Scheduling Problem in Cloud Manufacturing Environment Based on Improved Genetic Algorithm](#)
Yunlong Li and Guofu Luo
- [Time-space intelligent management and dispatch of electric Beidou based on Beidou and digital twin technology](#)
Zanyou Su, Liming Lin and Yifei Wang



ECS
The
Electrochemical
Society
Advancing solid state &
electrochemical science & technology

DISCOVER
how sustainability
intersects with
electrochemistry & solid
state science research

Real-time workshop digital twin scheduling platform for discrete manufacturing

LIU Zhifeng^{1*}, ZHANG Yueze¹, ZHANG Caixia¹, YAN Jun¹, GUO Shiyao²

¹ Institute of Advanced Manufacturing and Intelligent Technology, Beijing University Of Technology, Beijing, 100124, China;

² Beijing Key Laboratory of Advanced Manufacturing Technology , Beijing University Of Technology ,Beijing, 100124,China

*Corresponding author's e-mail: lzf@bjut.edu.cn

Abstract. Compared with other production methods, multi-variety, small-batch production driven by order become a lot more sensitive to the disturbances of workshop environment, orders, and processing equipment. This makes a great impact on workshop scheduling. Aiming at this problem, this paper designs a real-time workshop digital twin scheduling platform for discrete manufacturing. It improves the flexibility of the intelligent workshop and the response processing speed after dynamic disturbance. The platform can real-time monitor of the physical workshop and track orders, products, equipment and other information. Further, the platform and visualization technology were explored to work together. Then, the true display of changes after production line decision was displayed. It enables managers to carry out production scheduling verification in the virtual workshop, which reduces the repeated changes of physical workshop production scheduling. Finally, the platform was verified in a discrete manufacturing workshop. The scheduling platform based on digital twins helps manager to immersivity develop factory production strategies. The production efficiency was then enhanced. The platform can ensure the effective operation of the manufacturing system.

1. Introduction

At present, a kind of personalized production driven by customer orders with multiple varieties, small batches and fast delivery is widely used in the discrete manufacturing industry^[1-2]. This mode is easy to cause the mismatch between the production mode and the production scheduling plan^[3], and product failures during processing cannot be effectively and accurately located and predicted^[4]. Therefore, a new way to solve this problem is needed.

In the process of workshop scheduling research, the initial focus was on research, rule heuristic algorithm, and simulation scheduling^[5-8]. With the widespread application of the new generation of intelligent technologies such as the Internet of Things and artificial intelligence^[9], Digital Twin (DT) is used as the best technical way to upgrade traditional factories to smart factories and an effective way to improve production intelligence^[10, 11], it has the characteristics of real-time virtual and real interaction and forward-looking optimization to guide production configuration, which can realize the efficient production of products. Tao Fei et al. proposed the concept of digital twin workshop, and conducted detailed research and elaboration on the key enabling technologies required by the system of the digital twin workshop^[12]. Zhang Haijun et al. proposed a digital twin-driven intelligent workshop architecture, which can improve the optimal allocation of dynamic resources in the workshop^[13]. Nikolakis N and others took advantage of the real-time simulation capabilities of the digital twin to optimize the



Content from this work may be used under the terms of the [Creative Commons Attribution 3.0 licence](https://creativecommons.org/licenses/by/3.0/). Any further distribution of this work must maintain attribution to the author(s) and the title of the work, journal citation and DOI.

formulation and debugging of the production plan by the workshop personnel, and used the knowledge management system to capture the variable dynamic knowledge data implicit in the execution of the task, which solved the problem of ignoring the real-time changes of the production system during the work process in traditional digital simulation tools^[14]. In order to improve the situation where traditional simulation tools ignore the changeable production environment of the production system, Delbrügger T et al. built a digital twin model of the production workshop based on digital twin technology to simulate various changes in the production system^[15], Zhuang Cunbo et al. proposed an intelligent production management and control service framework model for the assembly workshop of complex products, and established the production management and control service of the assembly workshop based on twin data^[16]. In addition, other researchers also discussed the application of big data technology in product maintenance^[17], fault detection^[18], fault prediction^[19], risk assessment^[20], production scheduling^[21-22] and other fields.

In order to solve the above problems, this research proposes a new way to solve the problem of discrete manufacturing production scheduling based on digital twin and scheduling technology-real-time workshop digital twin scheduling platform. This technology combines digital twins with scheduling. By studying the application process of the real-time workshop digital twin scheduling platform for managers, the framework model of the real-time workshop digital twin scheduling platform is formulated, and the scheduling configuration model based on the digital twin is constructed. Take the production workshop of an enterprise as an example to establish a device-level digital twin model from the real environment to the digital environment. Finally, a real-time workshop digital twin scheduling platform is formed. The platform displays workshop scheduling data and operating data in real time.

2. Design of a real-time workshop digital twin scheduling platform

This paper constructs the framework model of the real-time workshop digital twin scheduling platform. The framework has user service layer, digital twin model layer, production scheduling plan management, network transmission storage layer, and physical device layer. As shown in Figure 1, the arrows indicate the flow of information between the various layers. The framework includes a visual interaction engine that can perform 3D visualization functions, a scheduling engine for scheduling rules, a set of web-based status detection integrated management applications, and an application program interface that exposes order analysis and processing.

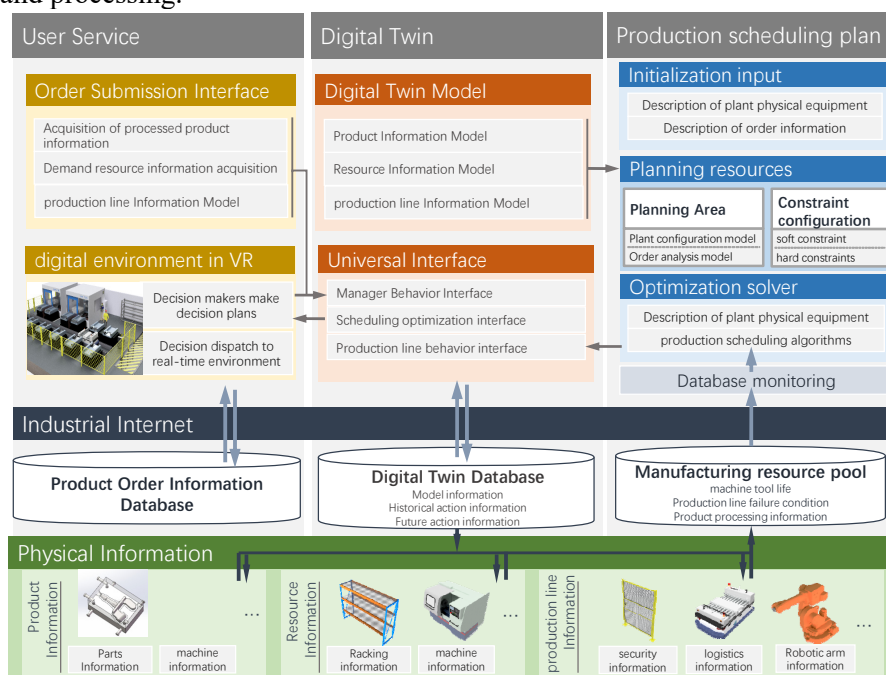


Fig.1 Framework model of real-time workshop digital twin scheduling platform

The user service layer opens the order entry and supply chain entry interfaces for customers. After communicating with manufacturing experts, customers submit content such as product manufacturing methods and supply chain requirements to the digital twin model layer. In the digital twin model layer, there is a digital twin model that contains the definition of equipment functional units on the processing line. The digital twin layer will parse and re-encode the submitted information, and submit the re-encoded information to the production scheduling layer. The production scheduling layer performs scheduling based on the submitted information and the production line change information uploaded by the monitoring database, and returns the scheduling information to the model layer. The model layer transmits the content of the scheduling information to the user layer, and uses virtual reality technology to view the scheduling content. The model layer sends the manager's decision-making plan to the production line for execution. The physical device layer collects the information and data generated during the manufacturing process in the physical world, and transmits it to the monitoring database through the industrial network layer for synchronous monitoring with the digital twin model layer. The data information is transmitted to the production scheduling layer for production scheduling re-planning. Therefore, the industrial network layer consists of a communication interface that transmits manufacturing data and a database that stores data for synchronization. The network transmission storage contains three databases: one database is used to store the monitored production line status information, one database is used to store customer production orders, and one database contains the virtual model of the production line and the production plan schedule.

The framework model unifies the real workshop events, scheduling algorithm, and workshop monitoring through the digital twin model. Solve the problem that each module of the platform is independent of each other and data sharing is difficult. Through the way of data monitoring, real-time transmission of changed data to the virtual workshop and scheduling plan management, to achieve rapid transmission of overall platform data.

3. System implementation and verification

Based on the above research, using tools such as Unreal engine 4 to develop a real-time workshop digital twin scheduling platform. The platform is applied in a manufacturing workshop of a discrete industry to realize the input and collection of processes, products, and orders, combined with the production line status for scheduling, and realize real-time monitoring of site and equipment data in a high-fidelity virtual workshop.

According to the actual production workshop of the enterprise, as shown in Figure 2, the key equipment information is formed through the digital twin high-fidelity model construction method, so that it has a highly restored and highly realistic appearance. As shown in Figure 8, build the internal logic of logistics carts, cranes, pallet exchange lines, robotic arms, machine tools, and logistics pallets, and package them as a workshop digital twin overall model, so that each device model has control motion and data communication Ability to exchange. Through database communication, the real-time data on the production line is transferred to the digital twin model to realize the physical and virtual twin movement.



Fig.2 Digital twin high-fidelity model of a company's actual production workshop

In the scheduling planning process, the product, process, and bill of materials are first taken as input conditions of the production line and brought to the platform. The platform passes the input conditions to the scheduling algorithm in the solving thread, and the scheduling algorithm starts to calculate. When the result set is generated and fed back to the digital twin environment in the platform, the manager can observe the scheduling results in the digital twin environment and determine the final plan. At the same time, any disturbance on the production line will be passed to the data monitoring. In the case of monitoring the disturbance, the digital twin environment will pass the disturbance to the solving thread, and the solving thread will recalculate the scheduling and solve the new scheduling result. The manager re-observes the results and issues new instructions. Figure 3 is the production scheduling interface, in which the Gantt chart, time axis, and time multiplier functions are provided. Click on the device to query the device status at the current time and production resource information.

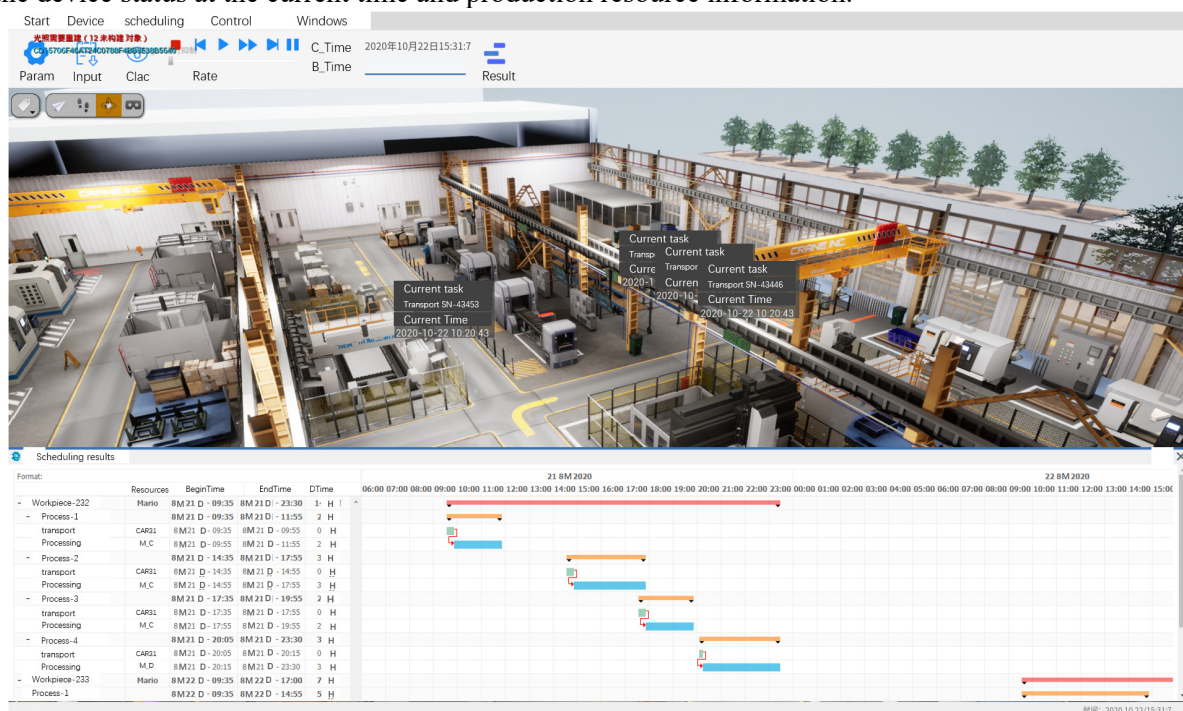


Fig.3 Production scheduling interface

4. Conclusion

This research combines the actual production scheduling requirements encountered in the discrete manufacturing workshop to construct a digital twin high-fidelity model. The platform realizes the synchronization of the on-site data of the discrete manufacturing workshop with the twin model, and proposes a real-time scheduling configuration model of the digital twin. On this basis, a real-time workshop digital twin scheduling platform for discrete manufacturing was developed. This platform realizes the intelligent scheduling of the workshop. Through the twin model, users can understand the changes of future workshop equipment in the current scheduling. The platform is not only limited to the field of scheduling, but the realized function also monitors the disturbance situation on the manufacturing workshop site. In the follow-up work, we will go deep into the equipment processing link to realize the digital twin of the whole life cycle of the manufacturing process.

Acknowledgments

Thanks to the National Science and Technology Major Project (No.2019ZX04024001), Beijing Science and Technology Plan (Z201100006720008), National Natural Science Foundation of China (No.51975019), and Beijing Municipal Education Commission Science and Technology Plan General Project (KM201810005013) for funding this project.

References

- [1] Che W G. Research On Improvement of Lean Production System Under Multi-item Small-lot Settings[D].Tianjin University, 2006.
- [2] Liang F J, Ding R X. Theoretical Research on Reconfigurable Manufacturing System [J]. Journal of Mechanical Engineering, 2003(06):36-43.
- [3] Gui L, Zhang C J, Li X Y. Review of Research On Shop Scheduling Problem with Flexible Process Sequence[J].Industrial Engineering Journal, 2020,23(02):116-123.
- [4] Wei D H, Wang S F, Liu L Y. Visual Monitoring System for Small and Medium-sized Automatic Production Lines [J].China Mechanical Engineering, 2020,31(11):1351-1359.
- [5] Rabadi G, Mollaghasemi M, Anagnostopoulos G C. A branch-and-bound algorithm for the early/tardy machine scheduling problem with a common due-date and sequence-dependent setup time [J]. Computers & Operations Research, 2004, 31(10): 1727-1751.
- [6] Tang L, Xuan H. Lagrangian relaxation algorithms for real-time hybrid flow shop scheduling with finite intermediate buffers [J]. Journal of the Operational Research Society, 2006, 57(3): 316-324.
- [7] Li J, Xu A J, Zang X S. Simulation-based solution for a dynamic multi-crane-scheduling problem in a steelmaking shop[J]. International Journal of Production Research, 2019.
- [8] Liu M Z, Zhang X, Liu C H, Zhang X M, Ge M G. Optimization Method of Remanufacturing Reprocessing Shop Scheduling under Uncertain Conditions [J]. Journal of Mechanical Engineering, 2014,50(10):206-212.
- [9] Mehrabi M G, Ulsoy A G, Koren Y. Reconfigurable manufacturing systems: Key to future manufacturing[J]. Journal of Intelligent Manufacturing. 2000, 11(4): 403-419.
- [10] Tao F, Zhang M, Cheng J F, Qi Q L. Digital twin workshop: a new paradigm for future workshop [J].Computer Integrated Manufacturing Systems, 2017,23(01):1-9.
- [11] Kyu Tae Park, Young Wook Nam, Hyeon Seung Lee, Sung Ju Im, Sang Do Noh, Ji Yeon Son & Hyun Kim. Design and implementation of a digital twin application for a connected micro smart factory[J], International Journal of Computer Integrated Manufacturing. 2019, 32:6, 596-614, DOI: 10.1080/0951192X.2019.1599439
- [12] Tao F, Zhang M. Digital Twin Shop-Floor: A New Shop-Floor Paradigm Towards Smart Manufacturing[J]. IEEE Access, 2017, 5: 20418-20427.
- [13] Zhang H, Zhang G, Yan Q. Dynamic resource allocation optimization for digital twin-driven smart shopfloor[C]. ICNSC 2018-15th IEEE Int. Conf. Networking, Sens. Control, 2018. doi:10.1109/ICNSC.2018.8361283.

- [14] Nikolakis N, Alexopoulos K, Xanthakis E, Chryssolouris G. The digital twin implementation for linking the virtual representation of human-based production tasks to their physical counterpart in the factory-floor[J]. *Int J Comput Integr Manuf*, 2019, 32: 1-12.
- [15] Delbrügger T, Rossmann J. Representing adaptation options in experimentable digital twins of production systems[J]. *Int J Comput Integr Manuf*, 2019, 32: 352-365.
- [16] Zhuang C B, Liu J H, Xiong H. Digital twin-based smart production management and control framework for the complex product assembly shop-floor[J]. *Int J Adv Manuf Technol*, 2018, 96(1-4): 1149-1163.
- [17] Bahga A, Madiseti V K. Analyzing massive machine maintenance data in a computing cloud[J]. *IEEE Trans Parallel Distrib Syst*, 2012, 23(10): 1831-1843.
- [18] Lee H. Framework and development of fault detection classification using IoT device and cloud environment[J]. *J Manuf Syst*, 2017, 43: 257-270.
- [19] Munirathinam S, Ramadoss B. Big data predictive analytics for proactive semiconductor equipment maintenance[C]. *Proceedings of 2014 IEEE International Conference on Big Data*, 2014:893-902,.
- [20] Cha S C, Yeh K H, Kuo H. A Data-Driven Security Risk Assessment Scheme for Personal Data Protection[J]. *IEEE Access*, 2018, 6: 50510-50517.
- [21] Liu Z, Yan J, Cheng Q, et al. The mixed production mode considering continuous and intermittent processing for an energy-efficient hybrid flow shop scheduling[J]. *Journal of Cleaner Production*, 2020, 246:119071.
- [22] Zhifeng Liu, Wei Chen, Caixia Zhang, Congbin Yang, Qiang Cheng. Intelligent scheduling of a feature-process-machine tool supernetwork based on digital twin workshop[J]. *Journal of Manufacturing Systems*, 2020.