Research on Intelligent Manufacturing Flexible Production Line System based on Digital Twin Technology

Rui Zhang[a], Guoqin Li, Sanpeng Deng, Xianqi Yuan

Institute of Robotics and Intelligent Equipment, Tianjin University of Technology and Education, Tianjin 300222, China.

[a]871733037@qq.com

Abstract

Intelligent flexible production line of digital twin technology in the modern sensor technology, network technology, automation technology, robot technology, etc. on the basis of advanced technology, through perception, human-computer interaction, intelligent decision-making and implementation technology of intelligent design process, manufacturing process and manufacturing equipment, is information technology, intelligent technology and equipment manufacturing technology the depth of the fusion and integration. The concept of manufacturing automation is updated to be flexible, intelligent and highly integrated. It can be applied not only in the small variety mass production mode, but also in the multi-variety small batch intelligent production mode, which has broad market prospect and huge technical impetus.

Keywords

Intelligent manufacturing flexible production line, Digital twin, Intelligent manufacturing flexible production line virtual debugging platform, Multi-source heterogeneous information.

1. Introduction

In recent years, the major industrial countries in the world have successively put forward the major strategy of transforming and upgrading intelligent manufacturing. Among these strategies, the construction of information physical system is one of these major strategies. With the increasing demand of the new generation of production and manufacturing equipment information development and network expansion, the traditional single point technology has been unable to meet the current demand [1]. With the further implementation of "Made in China 2025", a hot research direction is information physics system. Information physical system is an important support of information integration technology, it integrates automatic sensitivity, fast intelligent signal processing, to accelerate the data transmission and eventually control equipment operation, equipment, environment, information and other basic elements for a series of extraction, constructs a physical space and has a very high similarity, continuous interaction, accurate and efficient information space model for collaborative operation, the purpose is to realize the system of internal resource optimization configuration and runtime on demand timely, dynamic response, high effective iteration optimization [2]. The best technical method to achieve this interaction and fusion is digital twin technology, which has been highly recognized by some large enterprises and scholars at home and abroad [3].

Digital twin is the physical objects in the virtual space of specific intact replica, the physical entity completely corresponds to the virtual model are made by the digital model constructed, as long as the real-time observation and analysis of the virtual model of the corresponding physical entity, understanding, analysis and optimization [4]. The characteristic of digital twin is that it can describe the fusion state between the physical world and the information space. Due to the complexity and changeability of engineering construction, digital twin is suitable for the optimization of practical engineering [5]. Intelligent flexible production line of digital twin technology is based on the robot technology, network technology, modern sensor technology, automation technology and other advanced technology, intelligent design process, manufacturing process and manufacturing

equipment is through the intellisense, human and computer interaction, decision making and implementation of technology, the technology is the depth of the information, intelligent technology and equipment production technology integrated [6]. The concept of manufacturing automation is updated to be flexible, intelligent and highly integrated. Digital twins can be applied not only in small batch production mode, but also in intelligent production mode of small batch and multiple varieties. It has strong technical driving force and broad market prospect [7].

2. Intelligent manufacturing flexible production line based on digital twin technology

The intelligent manufacturing flexible production line based on digital twin technology is mainly composed of physical system and virtual system. The connection between physical system and virtual system is realized by virtual and real interaction, as shown in Figure 1. The actual production system composed of the relevant production equipment of the intelligent manufacturing flexible production line constitutes the physical system and covers the spatial planning information related to robot movement. The virtual system includes production line and product digital twin, which includes product design, manufacturing and product quality analysis and tracking.

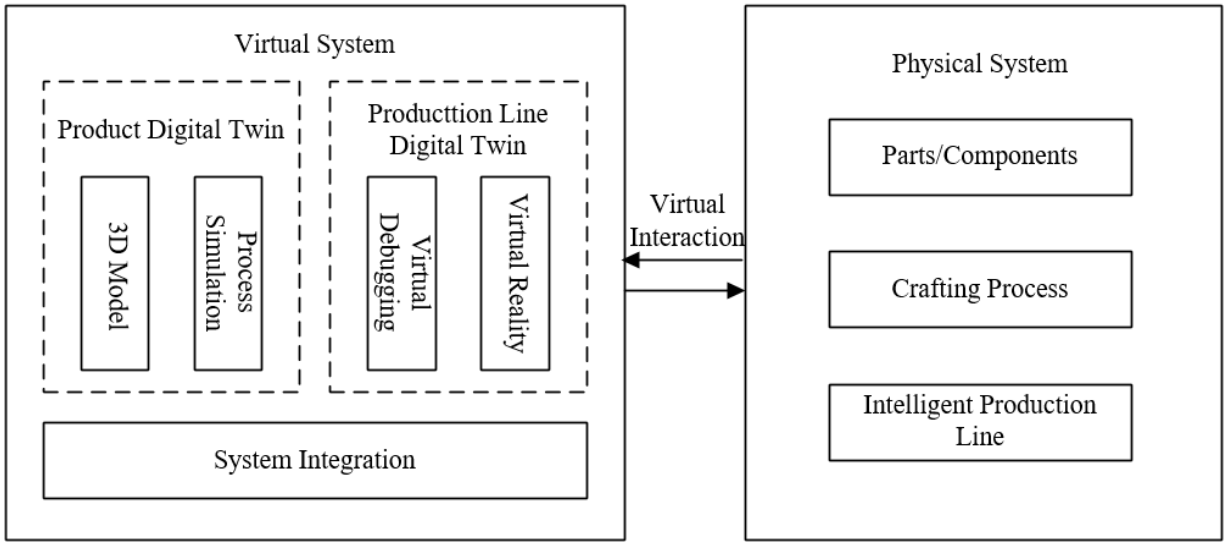

Fig.1 Intelligent manufacturing flexible production line based on digital twin technology

3. Research and development of virtual debugging platform for intelligent manufacturing flexible production line

Digital twin of production line USES digital twin model library to build virtual flexible production line with time dimension, sensor and dynamics simulation. By adjusting material physical attribute parameters and integrating physical production line total elements and whole process data, a virtual simulation environment with ultra-high degree of simulation is established. At the same time, technical means such as programmable controller virtual debugging, virtual reality and data interaction are introduced to build a virtual debugging platform of integrated production line control unit, human-machine interaction interface (HMI), safety light curtain and I/O module, as shown in Figure 2. The hardware system is connected to the virtual debugging platform through the Ethernet network based on TCP/IP protocol, and the information exchange with the factory simulation software is realized through the object connection and embedded technology (OPC) software server used for process control within the platform [8]. Through the platform integrated HMI interface, it can quickly collect the field equipment operation information, and feedback signals drive the digital model of virtual production line to synchronously display the equipment action, so as to realize the

synchronization with the physical production line. At the design stage, through to the robots, numerical control machine and PLC programming, implement calibration and optimization control algorithm, the integrity of the control function will be optimized at the same time point information for the rear output corresponding robot control code, numerical control machine tool equipment, used to control the entity equipment movement, avoid equipment replacement and need reprogramming of trouble; In the debugging stage, the virtual and real mapping is used to evaluate the actual control effect from multiple views, angles and aspects, and improve the control system and physical prototype. In the process improvement stage, complete the process modification, drilling and verification on the virtual production line to ensure the normal production operation of the production line.

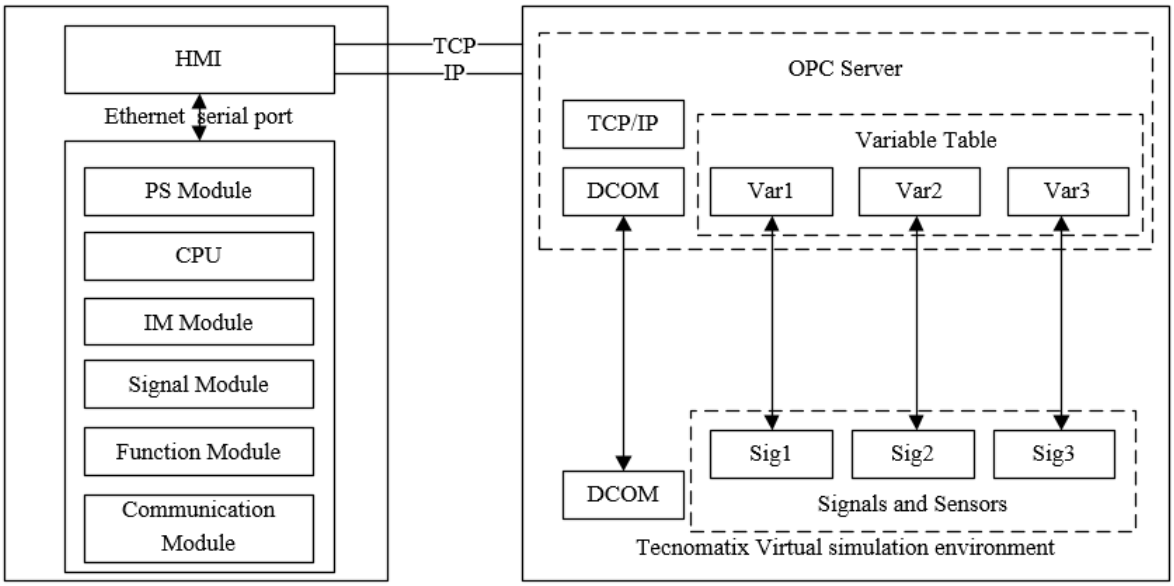

Fig.2 The system architecture of virtual debugging platform

4. Research on digital twin Technology of product design

In digital products, driven by twin data through the whole life cycle of the actual situation, using the existing physical and virtual products in the design of synergy, develop produce novel, unique, has the value of the product concept, into a detailed product design, reduce products constantly inconsistencies between the actual behavior and design expected behavior, improving design quality and efficiency. The framework is divided into five stages: demand analysis, conceptual design, scheme design, detailed design and virtual verification. Each stage is driven by the full life cycle data of physical products, simulation optimization data of virtual products, and fusion data of physical and virtual products [9].

5. Intelligent manufacturing flexible production line analysis system information integration

Intelligent flexible production line based on the technology of digital twin analysis system information integration architecture as shown in figure 3, from the enterprise resource planning management system of production plan, according to the judgment of allocation strategy, if don't need to do a simulation analysis, production plan issued directly to the manufacturing execution system for production, if you need to simulate, the need to process simulation, space interference analysis, logistics accessibility analysis, simulation analysis, personnel, equipment load capacity load analysis, the limit test analysis, production line balance analysis, simulation of machining process simulation operation, The simulation job is sent to the simulation analysis system for production simulation analysis. The simulation analysis system feeds back the results of simulation analysis to the digital

twin, which sends the production plan and simulation strategy to the manufacturing execution system. The manufacturing execution system continuously feeds back the real-time production data to the digital twin. The digital twin improves the simulation analysis model based on the real-time data received, and feeds the execution results of the production plan to the enterprise resource planning management system, so as to complete the entire production process.

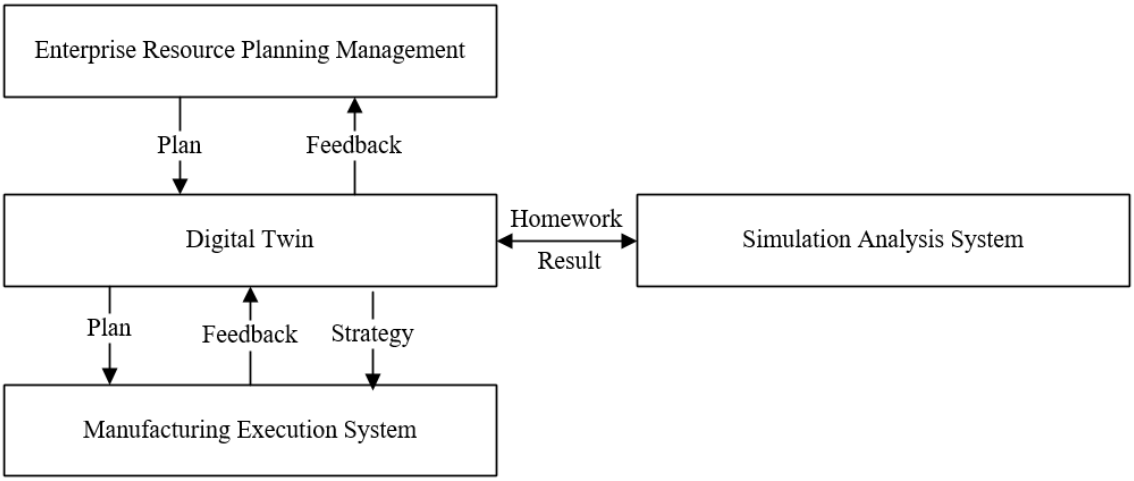

Fig.3 Simulation analysis system information integration architecture

Product quality analysis and traceability based on digital twins refers to the analysis and prediction of product processing quality through simulation calculation in the virtual workshop based on the collection of errors, positioning accuracy, deformation and other information borne by each manufacturing process in the physical workshop [10]. The real-time processing state of the physical production line is synchronized to the virtual production line by constructing the database of physical attribute models such as virtual geometric model, processing procedure and process model, product heat conduction model and deformation, etc., and the real-time quality analysis results are obtained after the virtual production line simulation. At the same time, before the processing, the virtual production line to set the processing technology simulation, optimize the processing technology; In the machining process, the virtual production line real-time simulation is used to further optimize the process. The processing quality database automatically updates the processing quality problems encountered, optimizes the processing technology independently, generates the processing operation instructions independently, and sends the corresponding operation instructions to the processing execution mechanism.

Twin data acquisition is completed through the real-time interaction method of multi-source heterogeneous information, and two-way real mapping and information interaction control of physical and virtual production lines are realized [11]. By analyzing a large number of timely and multidimensional data based on the digital twin model, it breaks through the local optimal limitation of the traditional training set relying on public data, and comprehensively perceives the state of the physical prototype and the processed object, so as to meet the need of the real feedback of the real-time state and historical state of the physical entity in the real-time autonomous decision control. At the same time, in the fault feature extraction and fusion based on twin data, fault process modeling and propagation mechanism research, the equipment health status is evaluated, and the equipment failure and residual life are predicted, so as to transform the post-repair to the pre-repair.

6. Conclusion

Digital twin, as a technology that makes full use of model, data, intelligence and integration of multiple disciplines, faces the whole life cycle process of products, plays the role of bridge and link between the physical world and the information world, provides more real-time, efficient and

intelligent services, provides an effective way for the integration of product design and manufacturing, and can provide fully personalized products and accurate manufacturing information. Digital twin technology is applied to intelligent manufacturing flexible production line to improve the existing independent production mode of simulation and control, establish real-time interaction mechanism between flexible production line and equipment, environment, process and other information, and improve the production efficiency of intelligent manufacturing industry.

References

[1] Hao Li, Fei Tao . Integrated development framework and key technologies for complex product design and manufacturing based on digital twins [J]. Computer integrated manufacturing system, 2019, 25 (06):1320-1336.

[2] Botkina D, Hedlind M,Olsson B, Henser J, Lundholm T. Digital twin of a cutting tool. Procedia CIRP 2018; 72:215-218.

[3] Fei Tao, Xin Ma, Tian Hu. Digital twin standard system [J]. Computer integrated manufacturing system, 2019,25 (10):2405-2418.

[4] Legner C, Eymann T, Hess T, Matt C, Böhmann T, Drews P,et al. Digitalization: opportunity and challenge for the business and information systems engineering community. Bus InfSystEng 2017; 59(4):301-308.

[5] Parviainen P, Tihinen M, Teppola S. Tackling the digitalization challenge: how to benefit from digitalization in practice. Int J InfSyst Project Manage 2017; 5(1):63-77.

[6] Kai Ding, Xudong Zhang, et al. Multi-dimensional multi-scale intelligent manufacturing space based on digital twins and its modeling method [J]. Computer integrated manufacturing system, 2019, 25 (06):1491-1504.

[7] Feiyan Guo, Zou Fang, et al. Status quo and key realization technology of digital twin-driven assembly process design [J]. Chinese journal of mechanical engineering, 2019, 55 (17):110-132.

[8] Jin Liu, Yulan Zhao, Xinsheng Zhang. Construction of intelligent Factory based on Digital Twins [J]. Modern Manufacturing Engineering, 2019(09): 68-75.

[9] Liuqun Fan, DING Kai, LIU Guangjie. Digital Twin technology in intelligent Manufacturing [J]. Manufacturing Technology and Machine Tools, 2019(07):61-66.

[10] Tao F, Qi Q.Make more digital twins. Nature 2019; 573:490-491.

[11] Yihui Cui, Bintao Yang, Yi Fang, et al. Application of digital twin technology in intelligent production line of aeroengine [J]. Aeroengine, 2019,45 (05):93-96.