

Research on Virtual Manufacturing System of High-End Equipment Manufacturing Under Virtual Simulation Technology

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Abstract. This paper constructs a manufacturing architecture based on big data cloud computing. The three manufacturing level systems of equipment, workshop and enterprise based on virtual simulation technology are studied. This paper establishes the equipment flexible adaptive processing model, the multi-agent flexible workshop dynamic scheduling model, the individualized predictive manufacturing model, and the enterprise connection crystal-like model driven by the dynamic network industrial structure. The system realizes closed-loop management and control of automatic issuance, execution, feedback and analysis of key control parameters in the production process of high-end manufacturing. The system can help enterprises improve product quality and work efficiency in an all-round way.

Keywords: virtual simulation; high-end equipment; manufacturing system; real-time simulation

1. Introduction

At present, the market competition of mechanical products is becoming increasingly fierce, and emerging technologies are emerging one after another. Traditional manufacturing equipment and systems can no longer meet the needs of the market and social environment. Therefore, the research on intelligent manufacturing technology has become the main direction of current manufacturing technology research. In the cloud manufacturing environment, various manufacturing resources and manufacturing capabilities are virtualized and serviced and then connected to the cloud manufacturing platform, and then the cloud manufacturing platform performs unified and centralized intelligent management and operation of them. The cloud manufacturing platform provides flexible, economical, safe, reliable and high-quality cloud services for the resource demander's manufacturing life cycle process through the optimized selection and configuration of virtual resources according to demand, so as to achieve low cost and high efficiency of complex products Mass manufacturing [1]. Compared with traditional grid manufacturing, cloud manufacturing focuses more on the flexible configuration of manufacturing resources and on-demand matching of manufacturing capabilities, while the virtualization of manufacturing resources is the premise to achieve flexible configuration of manufacturing resources and on-demand matching of manufacturing capabilities. In the cloud manufacturing environment, a series of issues, such as the diversity of manufacturing resources, the diversity of manufacturing capability descriptions, and the diversity of manufacturing resource organization forms, are the key issues that need to be solved to realize the virtualization of manufacturing resources. Based on the research progress of the research team in virtual procurement platform technology, on the basis of the platform architecture and the integrated modeling technology for technology and management, this paper focuses on equipment function/performance, RMS (reliability, maintenance, and repair) for the entire life cycle. The requirements of design, analysis and verification of the characteristics of safety and security, as well as the requirements of comprehensive management analysis and decision-making of procurement projects, focusing on virtual prototype modeling and simulation, RMS-oriented modeling and simulation and integrated management modeling and simulation technology.

2. Equipment manufacturing networked collaboration mode and functional structure

In order to realize collaborative resource sharing and complementary advantages in the design, manufacturing, management and operation and maintenance of complex heavy equipment products, as shown in Figure 1 (the picture is quoted from Complex networks in advanced manufacturing systems), the construction includes platform integrated management, collaborative design, collaborative manufacturing, product delivery and collaborative operation and maintenance and other functions of complex heavy equipment networked collaborative model.

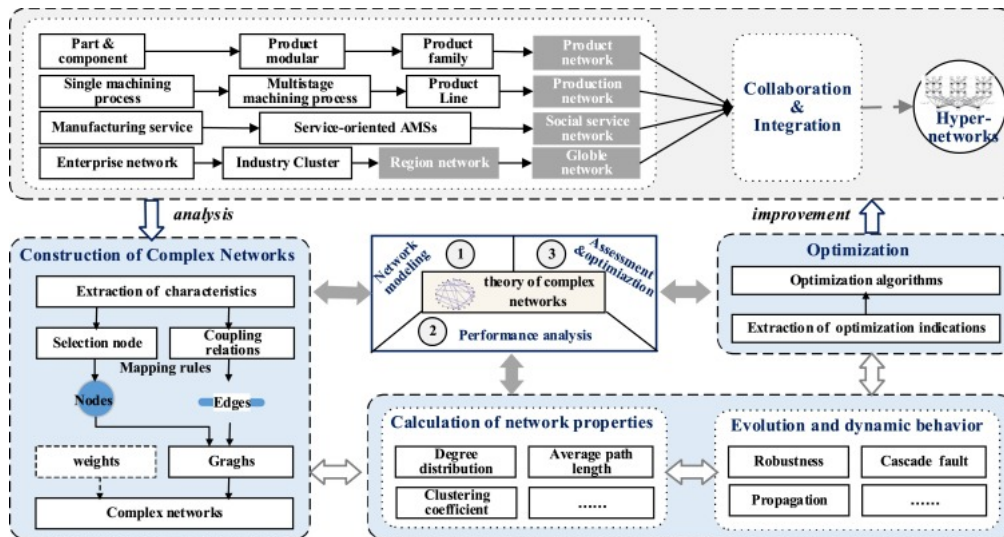


Figure 1. Networked collaboration mode and functional structure of complex heavy equipment manufacturing

3. Collaborative design pattern and functional structure

By standardizing the collaborative design process of complex heavy equipment under the networked collaborative manufacturing mode, and designing five functional modules of user demand management, design task decomposition, design task matching, design task execution management and collaborative design knowledge management, the collaborative design of complex heavy equipment is realized. As shown in Figure 2 (the picture is quoted from Identity Management and Access Control Based on Blockchain under Edge Computing for the Industrial Internet of Things). Among them, user requirement management includes: creation of user requirement description, feasibility analysis and requirement confirmation of user requirement, maintenance of user requirement description based on template (including interactive maintenance between user and design engineer). Design task decomposition includes: knowledge-driven user requirement design task mapping and task time estimation, construction and management of design meta-task set, and confirmation of design task decomposition [2]. Design task matching includes: design task matching based on dynamic information and task decomposition, maintenance of matching rules and matching algorithms, estimation of key time nodes of design tasks, and matching feasibility analysis and confirmation. Design task execution management includes: design task progress tracking and key node early warning, interface management of multi-disciplinary collaborative design (mechanical, electrical, hydraulic, etc.), design scheme review and release, and design change management. Collaborative design knowledge management includes: classification of collaborative design knowledge (design standards, technical specifications, historical design archives), construction of the relationship between design knowledge, design knowledge push and visual expression based on tasks and knowledge graphs.

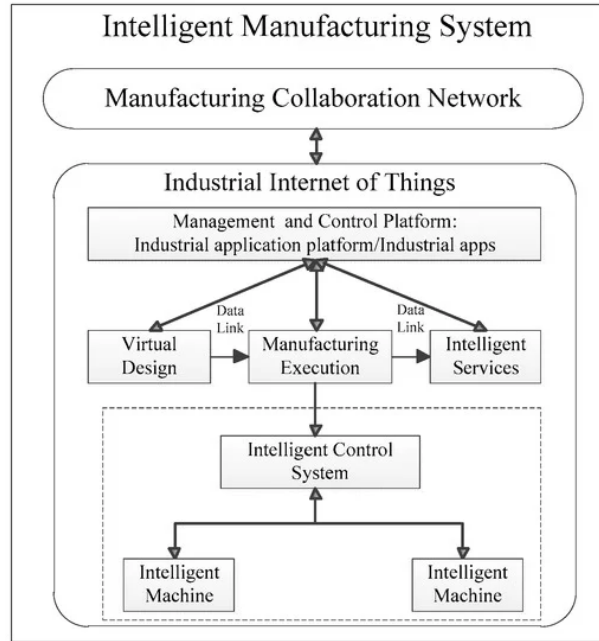


Figure 2. Networked design collaboration of complex heavy equipment

4. IntelliSense and Network Optimization Configuration Technology

Machine tool equipment resources are the core manufacturing resources in the production and operation process. Research on the intelligent perception and network optimization configuration technology that supports the wide area of workshops, heterogeneous machine tool equipment resources and their operation information is the basis for Cloudless to realize cloud-based management of workshop manufacturing processes. Figure 3 shows the realization framework of the intelligent perception and network optimization configuration technology of machine tool equipment resources in the workshop (the picture is quoted from Integration of Design, Manufacturing, and Service Based on Digital Twin to Realize Intelligent Manufacturing).

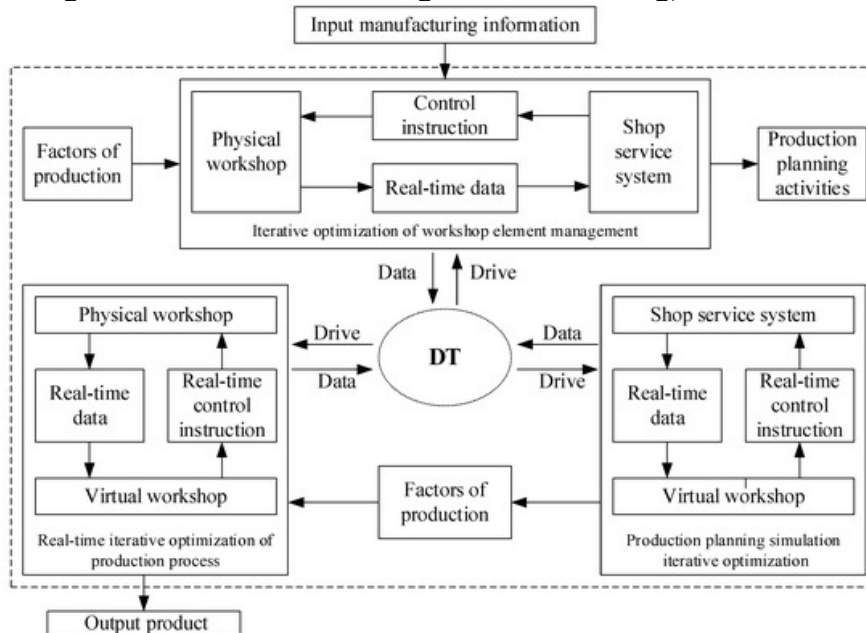


Figure 3. Realization framework of intelligent perception and network optimization configuration technology of machine tool equipment resources in workshop

First, it is necessary to establish the correlation matrix between the collection of information collected by the workshop and the collection of sensors [3]. Assuming that the information collected

by the workshop is of type m , and the available sensor types are type n , the correlation matrix between the amount of information collected by the workshop and the sensor can be expressed as a Boolean matrix $D = [d_{ij}]$,

$$D = \begin{matrix} & \begin{matrix} s_1 & s_2 & s_3 & \cdots & s_m \end{matrix} \\ \begin{matrix} I_1 \\ I_2 \\ \vdots \\ I_n \end{matrix} & \begin{bmatrix} 1 & 0 & 1 & \cdots & 0 \\ 0 & 1 & 1 & \cdots & 0 \\ \vdots & \vdots & \vdots & & \vdots \\ 1 & 1 & 0 & \cdots & 1 \end{bmatrix} \end{matrix} \quad (1)$$

$$i = 1, 2, \dots, n, j = 1, 2, \dots, m$$

In the formula, the row of matrix D represents the sensor type, and the column represents the amount of information collected; element $d_{ij} = 1$ represents the workshop information I_j that can be collected by sensor S_i , and element $d_{ij} = 0$ represents the amount of information I_j that sensor S_i cannot collect.

The correlation matrix simply describes the binary relationship between the workshop information and the sensor, and the information collection reliability of the sensor itself needs to be analyzed. Its definition is shown in formula (2):

$$R_{ij} = (1 + e^{-a(T_{ij}-b)})^{-1} \times (1 + e^{-c(N_i-d)})^{-1} \times \left(1 - \frac{F_i}{L_i}\right) \quad (2)$$

In the formula: R_{ij} is the collection reliability of sensor S_i to workshop information I_j ; T_{ij} is the collection sensitivity of sensor S_i to workshop information I_j ; N_i, F_i and L_i are the noise ratio, failure time and service life of sensor S_i respectively; a, b, c and d are constants. Combining Equation (1) and Equation (2), the actual effective acquisition capability $K_{ij} = d_{ij}R_{ij}$ of the workshop information I_j by the sensor S_i can be obtained, and then the mathematical model of the optimal configuration of the sensor network in the workshop can be obtained:

$$W = \min(\alpha \sum_{i=1}^n c_i g_i + \beta \prod_{i=1}^n e^{g_i K_{ij}}) \quad (3)$$

$$s.t. \quad g_i K_{ij} > \delta_i, g_i \geq 1 \quad (4)$$

$$\alpha + \beta = 1, \alpha, \beta, > 0 \quad (5)$$

Among them: Equation (3) is the objective function, and its physical meaning is that the cost of type n sensor is the smallest under the condition of satisfying a certain acquisition capability, c_i and g_i are the unit price and quantity of the i type sensor respectively; formula (4) is the i type sensor. The acquisition capability constraint δ_i that the sensor needs to meet. α and β are the weight distribution of workshop sensor network cost and acquisition capability [4]. It can be seen that the optimal configuration of the sensor network is a multi-objective combinatorial optimization problem, and many literatures have proposed corresponding algorithms to solve them, such as methods based on greedy strategies, particle swarm optimization, and methods based on logical operations.

5. Information acquisition method of intelligent manufacturing equipment

1) Acquisition of material information. Use barcode, two-dimensional code and RFID and other material information acquisition technologies to obtain the relevant location information of raw materials, semi-finished products, finished products and tools, as well as the status information of the materials themselves. RFID technology transmits wireless signals to readers through read-only or

read-write RFID electronic tags, realizing data transmission and reducing the interference of complex working conditions. The use of II-RFID realizes the traceability of materials.

2) Image information acquisition. The image detection and imaging system is used to obtain the image information of the measured object and preprocess the obtained image information. After analysis, accurate positioning, grasping, and transmission are realized according to the results. Image acquisition methods include high-speed motion sequence image acquisition, position penalty imaging, microscopic imaging, eye-hand image acquisition, omnidirectional image acquisition, stereo vision imaging, scanning imaging, etc.

3) Physical information acquisition. Obtain the physical information data existing in the machining process such as the force of the main shaft of the machining equipment, the cutting force and vibration of the tool, and evaluate the state of the machining equipment through these data. The information is mainly obtained directly by sensors, and the sensors used include pressure sensors, vibration sensors, and fiber grating sensors.

4) Program information acquisition. Obtain the program information of semi-automatic and automatic processing equipment, and obtain the running progress information of the current processing equipment by reading the running program segment information, so as to know the running status of the equipment. Obtaining device information requires a corresponding program interface to read the running program. For example, FANUC Series Oi CNC system itself provides some macro commands to extract system operation data. Siemens 840D CNC system can realize operation data collection through software secondary development, and can also realize CNC system data collection through custom communication protocol.

6. System key technology

OpenCV's is used to manage the scene model database, establish a distributed virtual manufacturing environment, and realize the transmission of network processing data and virtual manufacturing of multi-machine cooperative work. OpenCV's is a real-time scene management software developed by Quantum3D, which has good modularity, programming flexibility and portability [5]. In the Microsoft Visual C++ programming environment, through the OpenCV's SDK, users can easily drive, control and manage the scene model, and at the same time combine MFC (Microsoft foundation Class Library) and Sockets API communication functions to achieve network communication (Figure 4 is quoted from Demonstration and evaluation of a digital twin-based virtual factory).

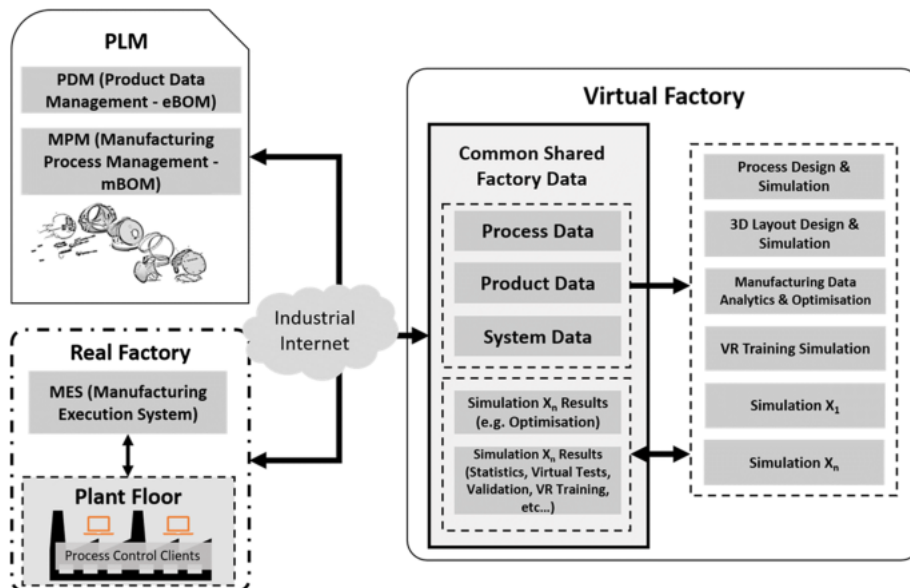


Figure 5. Graphical modeling and control of virtual manufacturing environment

Based on the ProfiBus-DP industrial field bus of the flexible manufacturing system, the data of the logistics equipment and processing equipment in the system are collected in real time, and the data of the virtual experiment (virtual system control computer) is transmitted through the Ethernet network and Profi-Bus-DP according to the TCP/IP protocol. Carry out data exchange to realize the mapping of virtual manufacturing process and actual manufacturing process.

7. Experimental verification

Based on the above research results, the original configurable MES is fully designed and developed by using SOA architecture and Aglets technology to form a Cloudless prototype system [6]. The system was integrated with the pre-developed machine tool equipment cloud manufacturing service platform, and deployed in the first machine plus test workshop of Chongqing University to complete the preliminary application verification of Cloudless (referenced in Figure 5). The following is an example of the cloud service for the optimization of production process parameters of auto parts bracket reinforcement iron components on a four-axis linkage vertical machining center (model TV5) to introduce the experimental verification process.

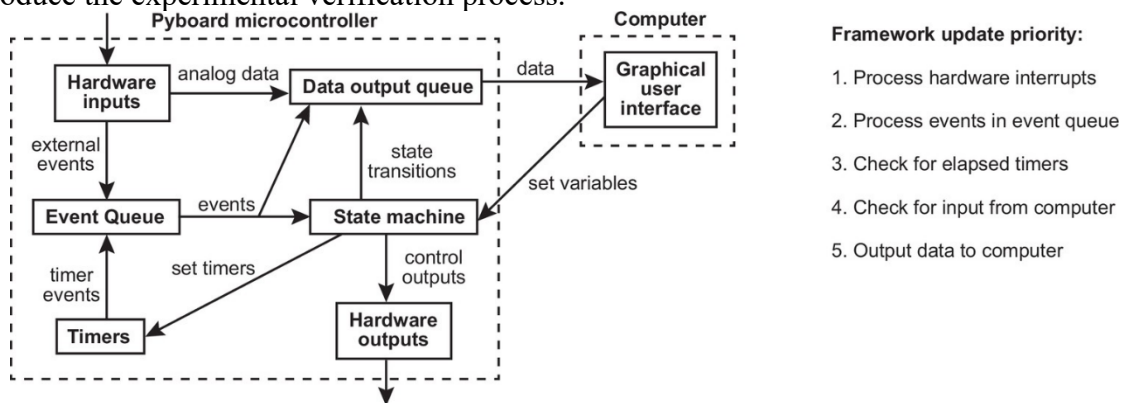


Figure 6. Experiment process diagram

On the basis of analyzing the attribute information of the four-axis linkage vertical machining center that needs to be collected, the tester configures corresponding sensing equipment on the four-axis linkage vertical machining center to collect real-time processing information of the four-axis linkage vertical machining center. Then use WSMO Studio, Java and Aglets and other tools to describe the device ontology and encapsulate the mobile agent, and register and publish it in Cloudless to form a virtual resource of TV5 machining center. It preliminarily verified the support effectiveness of Cloudless for workshop service management, and also provided corresponding technical support for the optimized operation of various workshop production process cloud services. However, at present, the system still has deficiencies in supporting the dynamic arrangement and configuration of enterprise business, integration with ontology tools, networked management and control of machine tool equipment resources, and applications based on mobile Internet. The universality of human-computer interaction needs to be improved. It is also the focus of the next stage of the research group.

8. Conclusion

The product design and manufacturing process needs to be modularized and subdivided, and the service model needs to be virtualized and software-based, and configured to each computing node of the manufacturing network through cloud computing and virtual simulation technology architecture to ensure customer participation throughout the product life cycle; Build the hexahedral cloud architecture of the internal organizational structure of the enterprise to improve the market response speed of the enterprise and the collaboration density of various departments within the enterprise.

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