Construction of a Model Based Digital Twin Factory

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Abstract: In the digital factory system, physical factories, virtual factories, and digital twin service systems are three essential components. This article elaborates on the roles of the three in factory construction. The article utilizes model-based system engineering as the main idea to construct a digital twin service system, providing a basis for subsequent research.

Keywords: model-based system engineering, digital twins, model systems, disassembly planning systems, enterprise information systems

Introduction

With the development of technologies such as cloud computing, big data, the Internet of Things, mobile connectivity, and 3D visualization, driven by policy requirements for energy conservation, consumption reduction, and emission reduction, as well as the demand for intensive and efficient management, the construction of digital twin factories has become increasingly popular among factory planning and construction personnel due to its multiple characteristics.(Havard et. al., 2019) propose a co-simulation and communication architecture between digital twin and virtual reality software, then it presents a use case on a human-robot collaborative workplace design and assessment. (Bicocchi et. al., 2019) discuss an interoperability architecture for digital factories. (Liang et. al., 2019)present a comprehensive survey on recently approved International Electrotechnical Commission standard Wireless networks for Industrial Automation–Factory Automation (WIA-FA). The second aim of the project is to extend locally integrated information management systems into an ecosystem that supports the interchange of data and services between factories and their suppliers, i.e., by incorporating and inter-linking both supply and value chains. (Terkaj et. al., 2019) present a set of integrated digital tools to support the design of roll shop plants, i.e. plants dedicated to grinding cylinders for rolling mills. Diversely from machines, humans are naturally smart, flexible and intelligent, so putting the operators in the digital loop can bring more powerful and efficient factories.(Nunes et. al., 2020) aim to apply the concepts of digital factory in an example of aircraft manufacturing system, to analyze the efficiency and workload of the AGVs that transport materials from the warehouse to the assembly stations.

1. Selective disassembly digital twin factory architecture

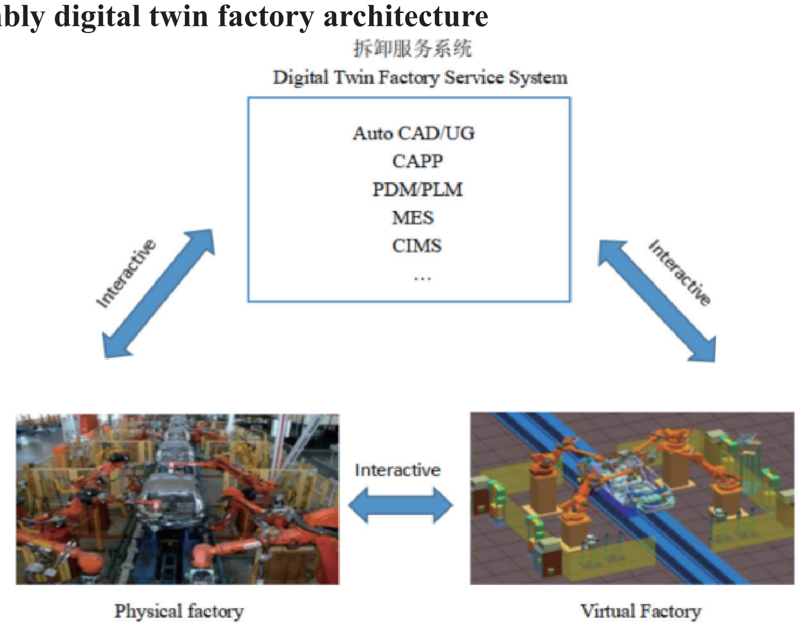

Figure 1 Selective Disassembly Digital Twin Factory

Selective disassembly digital twin factory, including three parts: physical factory, virtual factory, and disassembly service system, and the three parts interact and integrate with each other. As shown in Figure 1, the physical factory is an objective collection of entities, including machines and equipment, automated production lines, testing equipment, ACV carts and other physical equipment; it is mainly responsible for receiving production tasks issued by the digital twin factory service system and executing production activities and completing production tasks in strict accordance with the production instructions predefined by the virtual factory through factory simulation, process simulation and logistics simulation; the virtual The virtual factory is a faithful and completely digital mirror of the physical factory, capable of mapping the manufacturing scenario of the physical factory in real time, and mainly responsible for simulation, evaluation and optimization of production planning/activities, as well as real-time monitoring, prediction and regulation of the production process, etc; the digital twin factory service system is a collection or general name of data-driven functions of various service systems, including Auto CAD/UG, Plantsimulation, CAPP, PDM/PLM, MES, CIMS are mainly responsible for providing system support and services for intelligent shop floor control driven by shop floor twin data, such as control and optimization services for production factors, production planning/activities, production processes, etc. The physical factory, virtual factory, and digital twin factory service system, interact with each other to produce fusion, and the derived data generated after the fusion is continuously optimized and iterated to prompt the operation and interaction of the whole factory system.

2.Physical factory

Traditional physical factories typically have physical equipment such as manufacturing equipment, testing equipment, and experimental equipment. The digital twin factory has the physical equipment of traditional physical factories, while adding software systems. Therefore, the physical factory also needs to have the ability to perceive, access, and integrate heterogeneous and multi-source real-time data, as well as human-machine interaction capabilities. Therefore, physical factories need to have the ability to perceive and integrate heterogeneous multi-source real-time data, as well as the ability to integrate «human-machine environment» elements in the workshop. Therefore, a set of standard data communication and conversion equipment is needed to achieve unified conversion of different communication interfaces and protocols for production factors, as well as unified encapsulation of data. This is also the technical difficulty of the digital dual factory system. The individual production elements of a physical factory can plan their own response mechanisms based on production plan data, process data, and interference data, and collaborate to control and optimize their respective behaviors under global optimal goals. Compared with traditional human centered decision-making workshops, physical workshops that integrate «human-machine object environment» have stronger flexibility, adaptability, robustness, and intelligence.

3.Virtual Factory

Virtual factories are collections of models, which include three levels: elements, behaviors, and rules. At the element level, the virtual workshop mainly consists of the digital/virtual Geometric modeling of workshop production factors such as people, machines, objects, and environment, and the physical model describing physical attributes. For example, SolidWorks establishes a digital twin Geometric modeling for testing the performance of CNC machine tools and a physical model defined by ANSYS's finite element analysis (FEA) software. At the behavioral level, it mainly includes a behavioral model that characterizes the sequential, concurrent, and interconnected characteristics of workshop behavior under the influence of drivers (such as production planning) and disturbances (such as emergency order insertion). Its purpose is to improve the performance of digital twin simulation services. At the rule level, it mainly includes evaluation, optimization, prediction, traceability, and other rule models established based on the various operational and evolutionary laws of the workshop. The purpose is to use modeling to improve service performance.

Before production, the virtual factory iteratively simulates and analyzes the production plan of the digital twin service system based on a model that closely approximates the physical factory entity. It realistically simulates the entire process of production, including factory layout, process flow, logistics simulation, etc., to promptly identify potential problems in the production plan and adjust and optimize it in real-time. In production, virtual factories continuously accumulate real-time data and knowledge of physical factories and continuously regulate and optimize their operational processes while maintaining high fidelity. At the same time, virtual factories can incorporate AR/VR/XR technology, and the realistic 3D visualization effect can create a sense of immersion and interaction for users, which is beneficial for inspiring and improving efficiency; the virtual factory model and related information can be overlaid and interact in real-time with the physical workshop, achieving seamless integration, real-time interaction, and fusion between the virtual workshop and the physical workshop.

4.Disassembly Service System

The digital twin factory service system is a collection or collective term for various data-driven service system functions.Its function is to provide system support and services for intelligent control of the workshop driven by twin data, such as control and optimization services for production factors, production plans/activities, production processes, etc.

The selective disassembly system is a new type of intelligent disassembly system that can perform automated and intelligent disassembly operations based on the pre-established product model. This system can improve disassembly efficiency, reduce disassembly costs, and help achieve resource recovery and environmental protection.

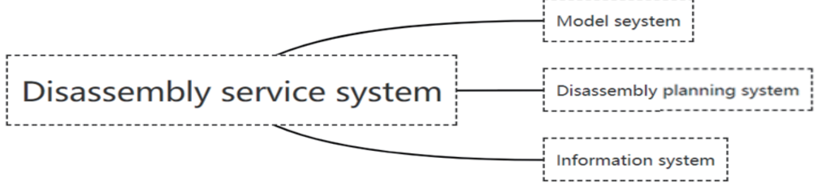

Figure 2 Architecture diagram of selective demolition service system

5. Conclusion

The core of building a model based digital twin factory is to make the production and operation process intelligent through the input of the model. This article uses the digital twin method to project the disassembly process to physical factories, virtual factories, and disassembly service systems, thereby achieving the goal of comprehensive perception, process optimization, and decision-making in the digital twin factory, and better achieving energy conservation, consumption reduction, personnel reduction, efficiency increase, flexible adjustment, and security control in the notebook disassembly process.

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