Enabling Technology of Intelligent Manufacturing -- Digital Twin

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Abstract. This paper sorts out the key technologies of the four industrial revolutions. In order to achieve the effective integration of information physical systems, the paper introduces the enabling technology of intelligent manufacturing, Industry 4.0 and Industrial Internet - Digital Twin. This paper describes in detail digital twin modeling technology, simulation optimization technology, application interface technology, data acquisition technology, virtual reality technology needed to achieve the integration of physical world and virtual world. Finally, the effectiveness of digital twin technology is verified through cases. This paper provides a reference for the in-depth application and related research of intelligent manufacturing, automation, and digital twin technology.

Key words: intelligent manufacturing; digital twins; modeling technology

1.Introduction

In today's era, "industry 4.0" has become the wind vane of high-end manufacturing. Unlike the past industrial revolution, which was guided by a single core technology, although the concept of "industry 4.0" includes many new generation manufacturing processes, these processes and technologies are not revolutionary in themselves, but they happen to be in the midst of this manufacturing ecosystem change. Therefore, The global horizon top-level science and technology planning document issued by the United States and the framework plan issued by the European Union both mention that intelligent manufacturing guided by digital technology is the key to achieving a new round of industrial revolution. Among them, "digital twin" technology is known as the top technology that is expected to change the "rules of the game" of aviation manufacturing in the future.

2. Key technology of digital twin

The purpose of digital twin technology is to drive the equipment model with the information model, simulate the virtual production process and products, drive the real equipment with the virtual simulation results, and produce real products. In combination with Tao Fei's documents , this paper further studies the key technologies of digital twinning. As shown in Fig 1

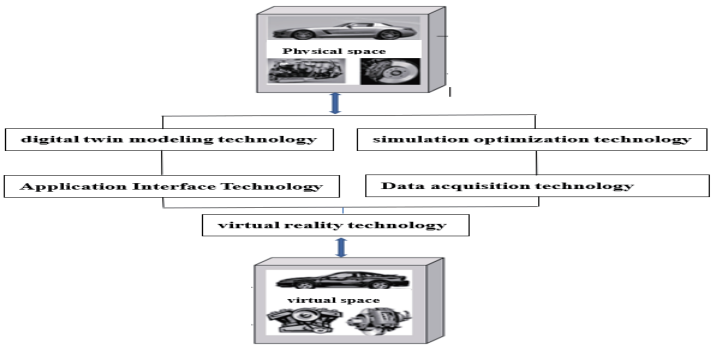

Fig 1 Key technology of digital twin

2.1 Digital twin modeling technology

2.1.1Digital twin product modeling

Product model is a general model used to represent various manufactured objects in the manufacturing process. It represents various target products, raw materials, intermediate products and other objects. These objects have many different side characteristics and are related to their different applications. Such as product bill of materials (BOM), product shape (geometric shape, topological shape and feature shape), etc. In addition to these information, the product model should also contain various information about manufacturing, such as tolerances, shape features, etc.

2.1.2 Digital twin system modeling

2.2 simulation optimization technology

Although computer simulation is an effective method to study the performance of complex systems, the simulation model is only a visual description of the problem. The simulation operation can only provide feasible solutions under certain conditions, and can not guarantee the optimal solution of the problem. Therefore, it is necessary to combine simulation technology with optimization algorithm to form an optimization method based on simulation.

2.2.1 Scheduling optimization

As a key module, production scheduling, that is, scheduling the production process, is the core of the whole advanced production system to realize the development of management technology, operation research technology, optimization technology, automation and computer technology. Reasonable scheduling of production process can effectively improve the utilization rate of resources and production efficiency.

2.2.2Transportation optimization

In 1939, Kantorovich of the Soviet Union and hichek of the United States began to apply linear programming methods to solve problems in production organization management and transportation optimization. In 2000, F Koazn designed a network model to analyze the process of containers in the port and optimize the transportation of multimodal transport terminals in order to reduce the cost of cargo transportation, accelerate the handling, reduce the delay of ships and reduce the cost of shipping.

2.2.3 Storage optimization

As the closest hub connecting traditional industry and modern logistics industry, warehousing management has always been an industry with great development potential. The unreasonable aspects of warehouse management in China are mainly manifested in the low utilization rate of warehouse capacity; Inadequate storage space design and planning leads to waste of resources; The use of automation equipment is not in place; Duplicate inventory settings, etc. These problems can be solved by simulation and optimization of inventory management, workflow, storage layout, etc.

2.3Data acquisition technology

2.3.1Data to be collected

A. process flow data. It mainly takes product materials as the tracking object. Through data acquisition, it can complete the positioning of product materials and intuitively characterize the process characteristics of assembly line production.

B. equipment production process data. It mainly includes the position, rotation angle and other movement position data of robots and other equipment in the production station of the production line, as well as the relevant information to ensure the actual production state.

C. equipment operation status data. It mainly monitors the working status of the production line station, which can intuitively reflect the working status of the production line equipment.

2.3.2RFID data acquisition technology

A. System composition.RFID systems are usually composed of readers, tags and background servers . RFID tags, also known as transponders, have read-write functions and can be programmed many times. Each electronic tag has a globally unique electronic code, which can only be read and cannot be modified; Reader is a read-write or read-only device with sufficient memory and computing capacity, which is responsible for two-way communication between control and tag; The background server is the application layer software of the RFID system and the control center that provides services and management. It is responsible for storing and processing tag information from the reader and distributing read-write instructions and tasks to the reader [4, 5].

B. working principle. The RFID system mainly utilizes the spatial coupling (inductive coupling or backscattering coupling) transmission characteristics of RF signals to realize contactless bidirectional data transmission between the reader and the tag and identify the tag information of the target object. The reader sends out a certain frequency of radio frequency signal through the antenna. After receiving the signal from the tag within the reading range of the reader, it enters the active state and obtains energy from it. It sends its own encoding and other information through the antenna of the tag. Then the reader reads and decodes the signal and sends it to the background server. Finally, the background server processes the valid tags and sends instructions to control the operation of the reader.

C. collection mode. RFID data acquisition mode adopts wireless communication technology, and uses RFID's real-time, rapid, readable, writable, accurate information characteristics and the form of serial number acquisition to carry out workshop logistics, material supply management, production manufacturing and assembly management (such as knife auxiliary tool management, equipment intelligent diagnosis, production line mixed production management).

2.3.3Point cloud data acquisition technology

Point cloud data acquisition technology is famous for its convenient use and operation. Various size detection systems collect the spatial coordinates of the measured workpiece surface points through scanners to restore the geometric shape of the workpiece surface. The set of coordinate points on these surfaces is called point cloud. Through the combination with computer graphics, these point clouds can be imaged quickly in the computer. Levoy and whitted proposed the concept of point cloud data processing based on points in 1985, which has become a research hotspot of computer graphics.

2.4Application Interface Technology

2.4.1IOT gateway

The IOT gateway is the bridge between the equipment and the industrial Internet platform. It connects the equipment at one end and the industrial Internet platform at the other end. The IOT gateway can not only understand the "language of the device" (industrial control protocol), but also translate the "language of the device" into the "language of the Internet of things platform" (Internet of things protocol) and send it to the industrial Internet platform, and vice versa. Therefore, IOT gateway is the key element to realize bidirectional connection between equipment and industrial Internet platform.

2.4.2OPC-UA Technology

OPC (object linking and embedding (OLE) for process control) is the application of Microsoft's object linking and embedding technology in process control, which is called "middleware technology" of control system. It is an interface specification specially designed

to achieve seamless system integration among field devices, automatic control applications and enterprise management application software. OPC UA effectively integrates and extends the existing OPC specifications (DA, a & E, HDA, commands, complex data and object types). It solves the problem that information of the same system cannot be accessed in a unified way in the past. This makes traversing the firewall no longer a barrier for OPC communication, and in order to improve transmission performance, the encoding format of OPC UA messages can be XML text format or binary format, or a variety of transmission protocols (such as TCP) can be used for transmission. OPC UA is a platform independent standard with higher security and reliability. OPC technology, which was originally limited to Windows systems, has been extended and improved to Linux, UNIX and other systems, and has completed cross platform development [6-8].

2.4.3Research on S7-PLC communication based on Modbus / TCP protocol

S7-plcs, as the core of local control, is widely used in automatic control, but S7-PLC currently has no published Ethernet communication standard protocol As a standard protocol of industrial Ethernet communication, Modbus / TCP protocol is widely used in the field of industrial automation and control. Compared with S7-PLC, many large and medium-sized PLCs at home and abroad support Modbus / TCP communication protocol, and users can use it directly without writing Modbus / TCP application layer programs, such as quantum and Premium Series PLCs launched by Schneider company abroad and MB40 and MB80 series iPLC (intelligent programmable controller) launched by NARI Group Company in China. At present, S7-PLC requires users to purchase expensive software packages to realize Modbus / TCP communication, It cannot be directly implemented [10-11], which is not conducive to the application of Modbus / TCP communication on S7-PLC, nor to the application of S7 PLC in the direction of digitalization, informatization, networking and standardization in the field of automation control. Therefore, it is particularly important to design Modbus / TCP application layer programs on the basis that S7-PLC supports TCP / IP protocol to realize the application of Modbus / TCP communication on S7-PLC.

2.4.4Modbus Protocol

Modbus protocol is a general language used in electronic controller. Through this protocol, controllers can communicate with each other and with other devices via the network. It has become a general industrial standard. This protocol defines the message structure that a controller can recognize and use, regardless of the network through which they communicate. It describes the process of a controller requesting access to other devices, how to respond to requests from other devices, and how to detect and record errors. It formulates the common format of message domain pattern and content. When communicating on a MODBUS network, this protocol determines that each controller needs to know their device address, identify messages sent by address, and decide what action to take. If a response is required, the controller will generate feedback information and send it using Modbus protocol. On other networks, messages containing Modbus protocol are converted into frame or packet structures used on this network. This conversion also extends the method of solving node addresses, routing paths and error detection according to specific networks.

3. Conclusion

As an enabling technology and method for practicing advanced concepts such as intelligent manufacturing, industry 4.0, industrial Internet, CPS, smart city, etc., digital twin is currently widely concerned by enterprises, research institutions and scientific researchers. The industrial digital twin is reasoned by this paper as a precursor technology to promote the fifth industrial revolution because of its prospective application prospects such as the implementation of analog intelligent workshops, and the realization of virtual scene control of physical entities and cooperative operation to participate in production activities. The article expounds various basic technologies related to the realization of digital twin, and shows the application of the technology through practical cases.

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