Journal of Computers Vol. 35 No. 1, February 2024, pp. 185-193
doi: 10.53106/199115992024023501014

Design of Data Monitoring System for Intelligent Production Line System Based on Digital Twin

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Received 15 December 2023; Revised 15 January 2024; Accepted 31 January 2024

Abstract. This article establishes a digital twin model for automated production lines. By establishing a more complete digital model, it achieves comprehensive reproduction of the production line, and then extracts and maps data from various production modules in the digital twin to ensure real-time data. In the software development phase, data analysis is conducted on the production and processing process to achieve prediction and management of production. Finally, based on the established digital twin, online simulation virtual debugging can be achieved when flexibly changing production goals, thereby saving production cycles and costs. Therefore, the digital twin platform established in this article has practical significance.

Keywords: digital twin, automatic production line, intelligent decision, systems design

1 Introduction

Currently, the large-scale personalized customization production mode has become a typical intelligent manufacturing production mode in the manufacturing industry, representing Industry 2.0. In 2019, the proportion of discrete manufacturing enterprises carrying out personalized customization was 7.93%. Based on internet platforms and intelligent factories, developing personalized customization systems centered around users, constructing centralized control and intelligent decision-making of internal R&D, production, logistics and other processes, and achieving dynamic balance between supply and demand within and outside the enterprise is an important symbol of the transition from traditional industry to intelligent manufacturing stage. Based on the integration of intelligent production lines into customized user needs, improving the adaptability of the production line and monitoring the product production process through digital twin technology, and conducting virtual operation of the production line during the product development stage to ensure the feasibility of production is an important direction for current development.

Digital twins are virtual objects constructed in digital virtual space that accurately map the form, texture, behavior, and actions of physical entities in real space. Find the optimal solution in a three-dimensional virtual space, and verify and debug the virtual production line process to obtain the best equipment utilization and product quality. The combination of digital twins and intelligent production lines can shorten product development time, accelerate product iteration, reduce product costs, and promote continuous innovation of products and production processes. This article takes the transmission system bearings of new energy vehicles as the processing object.

The current digital twin based intelligent production line monitoring system has the following problems:

1) The degree of automation is low, and currently the traditional bearing processing mode mainly relies on manual labor or the semi-automatic production mode using automatic equipment for key workstations.

2) The production line is single and only produces and processes specific products, while the market's demand for parts with different characteristics is constantly changing, resulting in poor adaptability of the production line.

3) Poor monitoring ability for the production process and poor predictive ability for production.

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Therefore, in response to the current issue, the work done in this article is as follows:

1) Establish a digital twin model for the target part, which is based on fully automated workstations for modeling, maximizing the automation of the entire process.

2) Implement data mapping for models and production lines, and be able to predict and analyze production processes

3) Capable of achieving virtual simulation and virtual debugging of new parts production lines, improving the adaptability of the production line.

Therefore, the chapter composition of this article is as follows: Chapter 2 mainly discusses some research achievements of relevant personnel, Chapter 3 is the establishment process of digital twins, Chapter 4 describes relevant research on data mapping in digital twins, Chapter 5 is the system creation and experimental process, and Chapter 6 is the conclusion.

2 Related Work

Yongxiang Lei studied a digital twin virtual reality simulation system for blast furnace ironmaking based on Unity 3D for data monitoring of the blast furnace smelting process. This system can reproduce the production process more realistically and has reference significance [1]. Georgios Gourlis proposed a semi automated data collection workflow for twin models of buildings and energy consumption data, exploring energy efficiency [2]. Yuxin Zhang achieved the development of an intelligent battery management system by establishing a digital twin that maps to the physical entities of the battery, providing virtual and real interaction feedback, mechanism and data fusion, and achieving reliable operation of lithium-ion battery energy storage systems [3]. Guizhong Tian proposed a digital twin driven visual monitoring method for the assembly and welding production line in order to solve the problem of low level of visual monitoring for group vertical assembly and welding production lines in ships. Finally, the effectiveness and practicality of the method were verified through visual monitoring and display of the assembly and welding production line in a certain shipyard [4]. Pengfei Niu studied the characteristics of digital twin technology in seal production lines and constructed an operation management system based on digital technology to achieve deep integration of physical and virtual production lines [5]. Jie Liu, based on the idea of digital twinning, studied the application of digital twinning in the axis testing platform. From the aspects of object selection, model construction, database design, etc., proposed a method for constructing digital twinning in the axis testing platform, and verified its authenticity through real experiments [6].

3 Construction of Digital Twin Model

The goal of the vehicle intelligent production line structure system studied in this article is to form an intelligent manufacturing process remote monitoring system, with a focus on achieving analysis and management of production line data and diversified remote applications. Therefore, this article proposes a web-based digital twin workshop structure model [7].

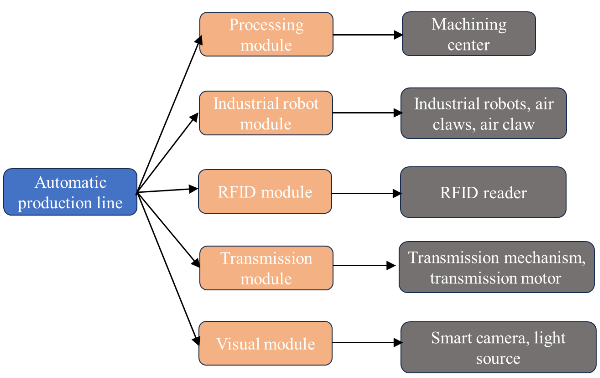

Fig. 1. Production line composition structure

The composition of the intelligent production line system is as follows: mechanical processing intelligent production line mechanical system RFID recognition module, industrial robot module, processing module, visual module, transmission module, and industrial robot module. The composition structure of the production line is shown in Fig. 1.

3.1 Printing Area

The RFID module is controlled by the main PLC. When the AGV is in place to dock with RFID, the target sensor sends the in place information to the main control PLC [8]. The main control PLC controls the AGV top magnet to retract, and the AGV loading and unloading mechanism starts working to complete the unloading of the tray. At the same time, the RFID conveyor belt began to work, docking with the AGV unloading tray and blank parts. When the tray is in place, a signal is sent to the PLC, which controls the conveyor belt to stop working and the block is pushed out. Read the processing process information of the workpiece, and the reader sends the information to the main control PLC. The main control PLC sends a picking command to the industrial robot, and the robot starts the process of preparing to grab the blank as shown in Fig. 2.

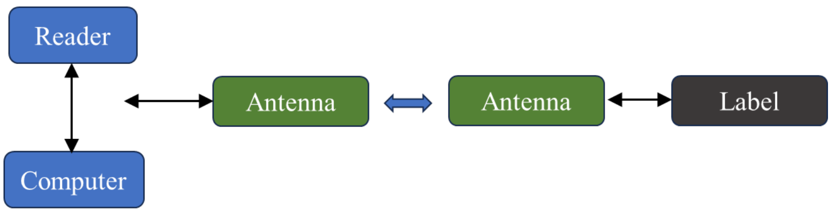

Fig. 2. Robotic pneumatic gripping process

3.2 Layout, Typeface, Font Sizes, and Numbering

The industrial robot module in the mechanical processing production line is mainly composed of six degree of freedom industrial robots, end effectors, system controllers, and auxiliary equipment, taking into account various factors such as site and production rhythm. The robot is assembled on the sliding platform of the ground rail, and the end effector is installed on the flange of the sixth joint of the robot, which has the ability to grasp the workpiece and adsorb the tray. The ABB-120 type robot is selected for this production line, as shown in Fig. 3, which is suitable for applications targeting machine tool loading and unloading. Industrial robots are mainly composed of robot bodies, controllers, teaching aids, and input/output modules. The motion algorithms of the robot are all integrated in the control cabinet, achieving powerful data operations and control of various motion logic. The electrical control system of the system adopts PLC control, and the control system is shown in Fig. 4.

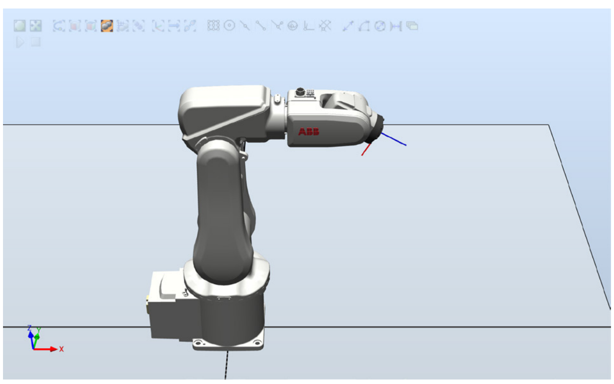

Fig. 3. Industrial robot model

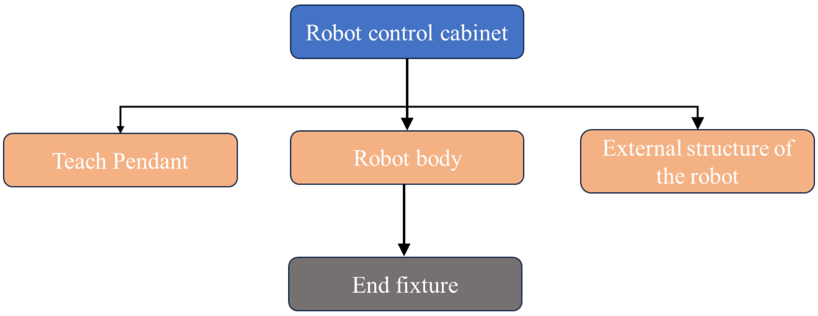

Fig. 4. Robot electrical control system

3.3 Processing Module Control System

The machining program of a CNC machine tool is written in advance according to the instruction code and program format specified by the CNC machine tool, and input into the CNC device of the CNC machine tool. After the RFID device reads the process information of the blank, it sends the information to the main control PLC terminal. The PLC sends instructions to the machine tool of the processing unit, and the machine tool retrieves the corresponding processing program to automatically process the processed part. The modeling of the machining center is shown in Fig. 5. The process flow is shown in Fig. 6.

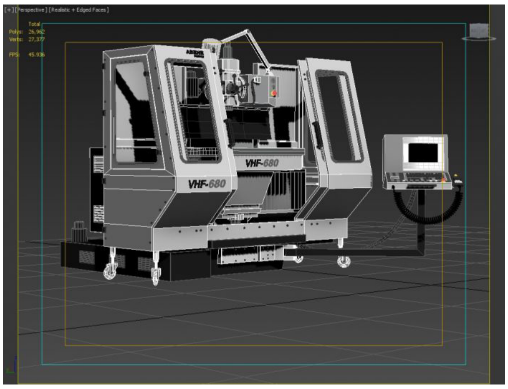

Fig. 5. Machining center model

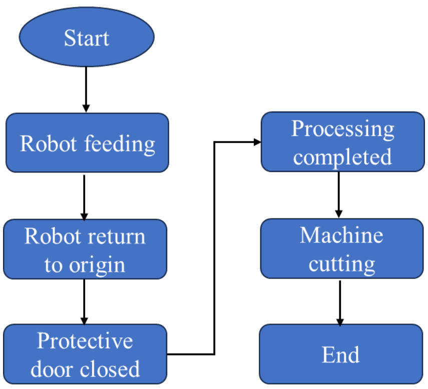

Fig. 6. Technological process

3.4 Transfer Module

The conveyor module includes conveyor belts, aluminum support bodies, servo motors, reducers, pulleys, rollers, sensors, and emergency stop devices, as shown in Fig. 7. The transmission module is an important means to connect the processing unit with the production line, sort non-conforming parts, and detect products. The material conveying line based on belt conveyor method is a continuous material conveying chain formed by four belt conveyors connected at the beginning and end, and equipped with measuring and sorting devices distributed on the conveying line. The photoelectric switch is used to detect whether there is a tray at the entrance of the tray assembly line, whether there is a tray at the photography station, and whether there is a tray at the robot grasping station. The Omron E3Z-D62 photoelectric switch is selected.

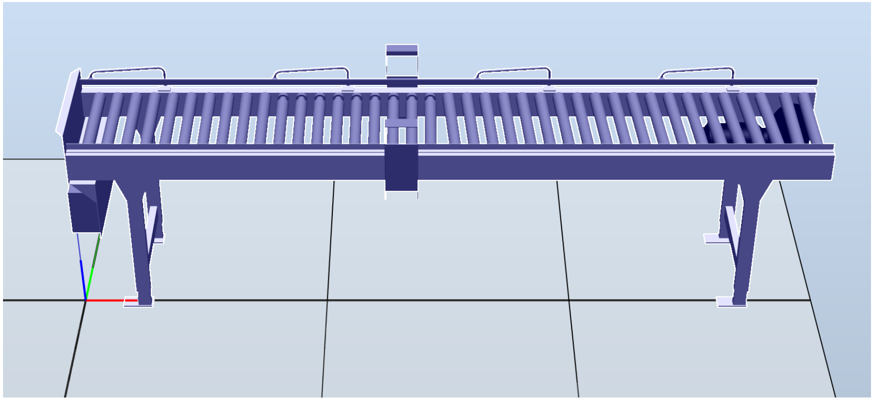

Fig. 7. Transfer module

3.5 Visual Module

The main function of the visual module is to use industrial cameras instead of human eyes to detect non-conforming products, effectively improving the detection speed and accuracy of the production line, and preventing misjudgment caused by artificial fatigue. Select an intelligent camera with model, equipped with a lens and backlight light source, and the main PLC controls the parallel robot to execute corresponding actions based on the target storage location. The camera has two interfaces, namely RJ45 network port and DB15 serial port. When connecting, use a crossover network cable to connect the camera and computer, as shown in Fig. 8.

Fig. 8. Visual system schematic

4 Data Collection and Mapping

For the digital twin system in this article, the data source exists in multiple workstations. Therefore, this article implements data collection and interaction based on the industrial Ethernet collection gateway and data aggregation platform. Conduct hierarchical architecture processing for on-site underlying data. This section mainly describes the data collection process of machining centers and industrial robots, while the principles of other data collection processes are similar and will not be described in detail [9]. The architecture is shown in Fig. 9.

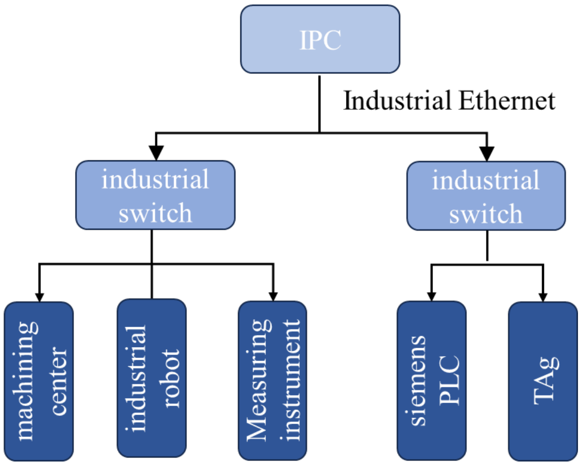

Fig. 9. Architecture

4.1 Processing Center Data Collection

Choose to conduct secondary development of Fanuc CNC machine tools through industrial Ethernet based on FOCAS development package. The FOCAS development package is designed for the HMI underlying development of Fanuc CNC systems. Fanuc officially provides the corresponding application program interface function instruction library, which enables communication between the application program and the CNC system by calling the dynamic link libraries FWLB32DLL and FWLIB64DLL in its function library. It mainly includes the following main functions:

1) For CNC machine tool spindle load, spindle speed, and servo axis position coordinates, absolute/relative coordinates

Read data such as axis name and feed rate.

2) Implement related operations such as uploading and downloading NC programs.

3) Access the program directory and read to implement DNC machining.

4) For relevant parameters, tool offset, axis coordinate values, macro program variables, and error compensation data, Wait for data reading.

5) Manage tool life by using the tool life management function to calculate tool compensation, tool revolutions, and tool information.

6) Collect and read various operational history information and fault alarm information.

4.2 Thermal Data Collection for Industrial Machinery

By utilizing the powerful communication function of the PC SDK, functions such as robot internal motion information, signal reading, controller file operation, and program control can be achieved. First, create a $C^{\#}$ executable program and add ABB to the program Robotics Controllers PC.dll dynamic link library, when the robot system is turned on, uses the network scanning method NetworkScanner() to search for the robot system. The information collection is shown in Table 1.

Table 1. Industrial robot data sheet

Parameter or function	Correlation function
Connected/Not connected	IsConnected()
X/Y/Z axis coordinates	RobTarget()
6 joint positions	JointTarget()
Operation log	Geteventlog_infro()

4.3 Data Mapping

Real time mapping of virtual models is achieved by collecting and triggering data in physical space through virtual platform services to achieve corresponding predetermined actions. This article uses the MQTT protocol to achieve data forwarding function, and implements lightweight protocol application for server-to-client communication based on the publish/subscribe mode. The role division in the protocol is shown in Table 2.

Table 2. Role differentiation

Module	Role	Affect
Ethernet gateway	Publish	Collect information and send large packets to the server
Server	Broker	Receive data
Visual interface	Subscribe	Data mapping to digital models

5 Design and Implementation of Data Monitoring System

Based on the research content and system functional requirements analysis of this article, combined with the digital twin system for production measurement process monitoring, the functional application implemented in this article can be divided into three major unit modules for the monitoring needs of complex product production processes.

1) The digital twin basic unit module provides model and data support for the implementation of the entire digital twin system application. The basic unit module manages modules such as model, data, multi task scheduling, and process flow;

2) Digital twin simulation control unit module;

3) The digital twin real-time monitoring unit module is mainly divided into device status monitoring, 3D virtual scene twinning, processing monitoring, data model comparison, and fault diagnosis modules.

5.1 System Development Environment

1) Hardware configuration: Industrial computer UNO-2484G: mainly provides hardware support for collecting, communicating, and processing data from various devices; ACP-4010 4U rack mounted server, LFT550P-DH2 splicing display screen: able to achieve visual real-time monitoring of system integration; Equipment configuration: CNC machining center α - D21LiB, ABB IRB-4600, Equal500 comparator, Ar8106 five axis three coordinate measuring machine;

2) The development and running environment of this system is as follows: operating system: Windows 10; Development Platform: NET; Development languages: XAML, C #, C++; Development tools: Visual Studio 2019, WPF form application; Model processing: SolidWorks, 3Ds Max, Unity 3D engine.

5.2 Design and Implementation of Simulation Control Module

The multi-step simulation debugging of devices in the simulation control module is achieved by combining the 3D virtual scene surround navigation and WPF form mentioned above to achieve system integration functions. Add multiple fixed camera cameras in Unity3D, and switch the simulation and debugging interface of a single mechanical device by selecting the perspective type ViewType. The simulation image is shown in Fig. 10.

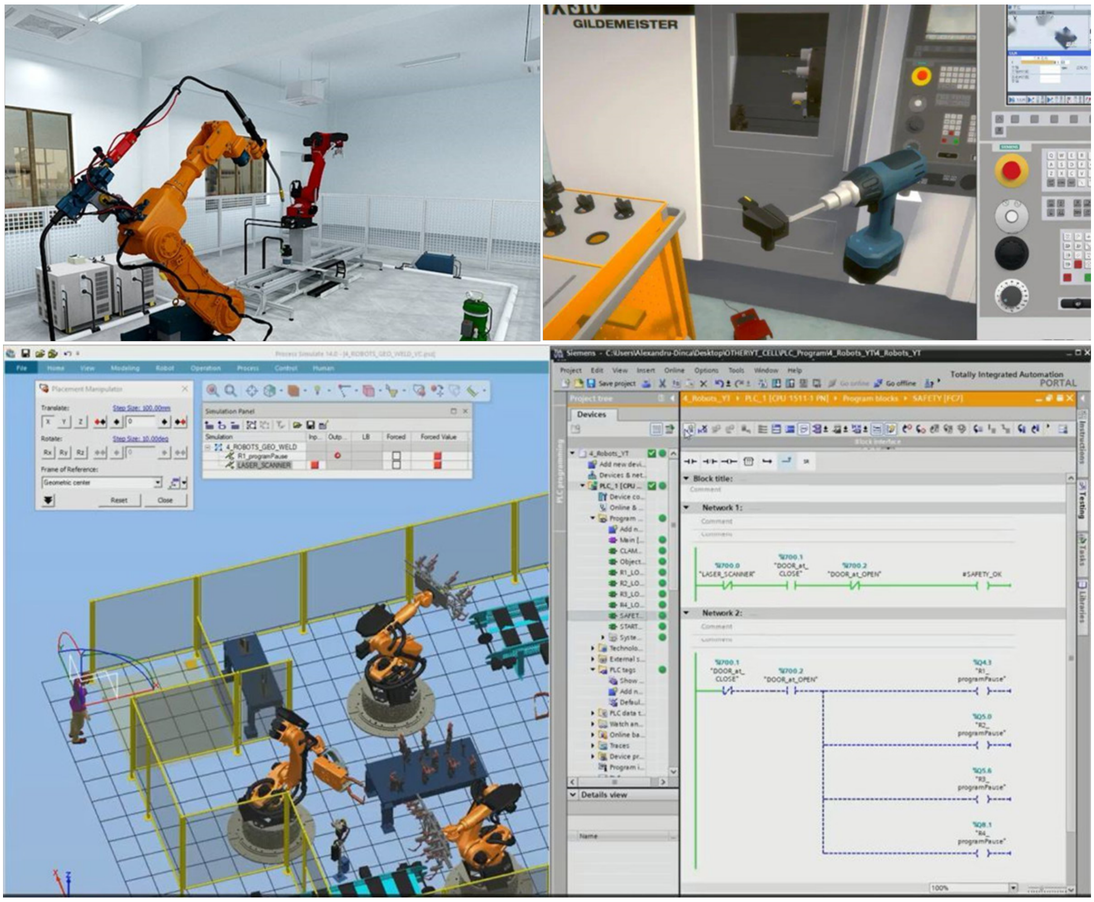

Fig. 10. Simulation result

5.3 Design and Implementation of Real Time Monitoring Module

The digital twin real-time monitoring unit aims to achieve full scene perspective monitoring of virtual space and integrate visual analysis of various data, including digital twin signage, production information signage, and equipment status signage. The machining center is in a stopped state, running in MDI mode. The program name O1 has been completed, and the absolute coordinate X/Y/Z of the machine tool is dis-played. The running time of the CNC machining center and the error reporting time are also recorded; The relevant data of ABB robots, including the six joint coordinates of the robot in the Cartesian coordinate system, operating in manual decelera-tion mode, as well as information on running time and faults, and the real-time monitoring interface of industrial robots and machining center systems is shown in Fig. 11.

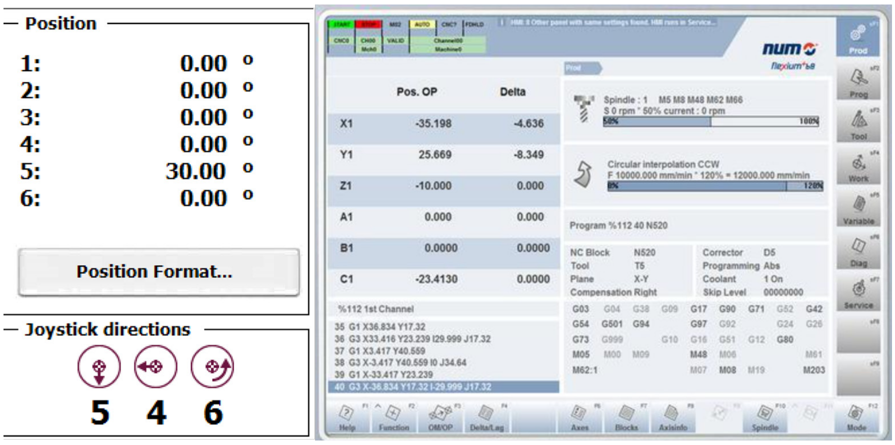

Fig. 11. Equipment status operation data

6 Conclusion

This article has completed the design of a digital twin system for a digital production line and implemented the completed data mapping. Through the method proposed in this article, remote debugging and simulation of virtual devices can be achieved, which can save production costs. In the future, based on the research in this article, technologies such as big data analysis and artificial intelligence decision-making will be added to further improve production efficiency.

7 Acknowledgement

Research on workshop Equipment Operation Monitoring and Fault Warning Method Based on Digital Twin (2020425).

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