Research on Control of Virtual and Real Drive System of Intelligent Factory Robot Based on Digital Twin

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Abstract. Traditional virtual and real robot drive systems use management methods, but due to the impact of the production environment, the system's command response speed is slow, which affects the control effect. To address this issue, this article proposes a control method for the virtual and actual drive system of intelligent factory robots based on digital twins. This method achieves high-speed interaction of the main control data of the driving system by setting up a data interaction scenario between the virtual and actual driving systems, and controlling the connections between the logical units and various modules. At the same time, by constructing control models of virtual and actual driving systems for robots, and combining virtual and actual driving interaction scenarios, the position and attitude conversion data of intelligent engineering robots are obtained. When sending instructions, smooth switching mode is used to control the virtual and actual driving systems of intelligent factory robots to achieve fast and dynamic response, and combined with smooth switching function to ensure the stable performance of the overall driving system. Through comparative experiments, the superiority of the driving system control method has been proven, which can be applied in practical life.

Keywords: Digital twins · Smart factory · Robot · Virtual reality driven · Control methods

1 Introduction

In the virtual and real driving process of the robot, because the robot and the driver are in different physical spaces, and the working environment of the robot is a dynamic and unstructured environment, there are certain safety hazards and operational risks [1] in the virtual and real driving process of the robot. In addition, most of the existing virtual and real driving technologies of robots adopt the master-slave control mode. The operation process is cumbersome and requires the driver to have some professional knowledge, so the human-machine interaction is poor. How to improve the safety of robot virtual and real driving and how to improve the human-machine interaction of

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robot virtual and real driving are the technical problems that need to be solved urgently. With the development of workshop digitalization, the demand for interconnection and intercommunication of various equipment in the manufacturing workshop continues to increase, so industrial systems, Internet of Things data analysis, data interaction and other technologies are gradually applied in modern manufacturing workshops [2]. At present, SCADAS is widely used in industrial enterprises. Through SCADAS, the operation status of equipment in the workshop can be monitored and the workshop can be feedback controlled interactively with MES. Now, due to the difference between the workshop equipment suppliers and the automation level, the communication protocols between these equipment are usually unable to communicate, which leads to the difficulty of workshop data interaction. For the data interaction of workshop equipment, in addition to analyzing and accessing the communication protocol used by the respective equipment, the monitoring and control of workshop equipment can also be realized by the way of embedded equipment collecting control signals.

Digital twin technology provides a new idea for virtual and real robot driving. The digital twin technology is used to establish the digital twin model of the robot and its working scene at the remote end. The communication link is used to connect the digital twin model at the remote end with the robot at the local end. The driver plans the movement path and posture of the robot at the local end through human-computer interaction equipment at the remote end, the local sensor feeds back the real-time status of the robot and its working scene to the driver, realizing remote control of the robot and real-time monitoring of the changes in the working scene [3]. The application of digital twin technology in virtual and real robot drive can overcome the restrictions of environment and space on robot application. Robots can be used in harsh environments such as high temperature, high radiation or inaccessible environments, instead of human beings to perform dangerous and complex driving tasks, improve driving safety and greatly expand the driving space [4].

Therefore, this paper uses digital twin technology to design the control method of virtual and real drive system of intelligent factory robot, and uses virtual and real drive interaction technology and target detection technology to plan the path and posture of robot, effectively improving the interactivity and safety of robot drive. This paper investigates the contradictory relationship between the dynamic response and steady-state performance of the controller, and proposes a new controller design method to solve this problem through smooth switching function. This method can use a signal controller to achieve fast tracking when the error is large, and an energy controller to ensure steady-state performance when the error is small. At the same time, the paper also introduces the advantages of sliding mode Variable structure control algorithm, and solves the steady-state chattering problem of sliding mode control by introducing smooth switching control. This study is innovative in improving the rapid response ability and steady-state performance of the system.

2 Design of Control Method for Virtual and Real Drive System of Intelligent Factory Robot Based on Digital Twin

2.1 Build Data Interaction Scenarios of Virtual and Real Driving Systems

This paper controls the connection between the logic unit and each module of the virtual and real drive system to ensure the high-speed interaction of the main control data of the drive system. At present, the main control virtual and real drive modes of common virtual and real drive system implementation schemes mainly include the following three types: FPGA virtual and real drive mode, which is a connection mode that can be used to configure the logic units and modules inside the virtual and real drive mode through Verilog HDL hardware description language to achieve custom configuration of circuit logic [5]. DSP virtual and real driving mode is a virtual and real driving mode specially designed for digital signal processing, which is mainly used to analyze, transform, filter, detect, modulate and demodulate the collected data. ARM virtual real drive mode is a microprocessor based on RSIC (Reduced Instruction Set), which reduces the difficulty of hardware design by using RSIC. In addition, the Cortex architecture series of ARM processors have rich interfaces suitable for general industrial control scenarios. Among them, FPGA is the most closely connected with hardware, and the virtual and real drive system using FPGA as the main control can achieve ultra-high speed data interaction. However, because of this feature, FPGA has no good versatility, and the flexibility of program design is poor. As DSP is a virtual and real driving mode designed for signal processing, it has strong data processing capability but needs highly optimized code, so it can only be developed using the development tools provided by the manufacturer [6]. In order to improve the universality of the system and reduce the difficulty of hardware design, this paper selects the ARM processor of Cartex architecture series as the main control virtual and real driving mode of the virtual and real driving system. In view of the difficulty of expansion of the existing virtual reality drive system, this paper has built a virtual reality drive interaction scenario, as shown in Fig. 1 below.

As shown in Fig. 1, the virtual reality driven interaction scenario built in this paper is divided into three layers, namely the perception layer, the network layer, and the application layer. The perception layer is responsible for collecting the signals of intelligent factory equipment, converting the physical signals into digital signals, transmitting them to the data processing gateway, and receiving data from the data interaction gateway to drive the equipment at the corresponding point [7]. The network layer is mainly responsible for the transmission and interaction of data between the physical entity world data of the data interaction system and the information simulation world. The application layer mainly analyzes the collected data, generates and issues decisions. The whole drive process takes ARM drive as the core of data processing and transmission, and uses a variety of point expansion modules to enhance the point where the system can collect data. In order to meet the needs of distributed drive management and control, WIFI chips and remote modules are added to realize a wide range of intelligent factory data interaction through wireless network communication. The system communicates with the upper computer through Ethernet to transmit data, upload the collected data and receive the control instructions of the upper computer. In the drive system, the network layer and the application layer communicate through Ethernet, and the server and client only

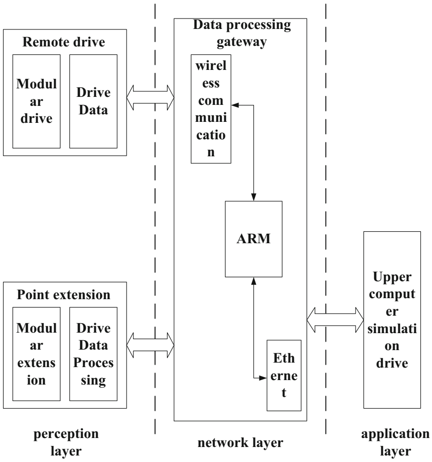

Fig. 1. Schematic diagram of virtual reality driven interaction scene

communicate with each other. You can make full use of the hardware performance at both ends of the architecture by reasonably allocating data processing tasks to the server and client. The front end is only responsible for displaying and transmitting request information through the browser, and the main system logic is from the server side. This architecture greatly increases the compatibility of the system, and the upper computer only needs to install a browser to realize the client. However, this architecture has higher requirements for server performance [8] because it places business processing logic in the server. Because in the virtual and real drive system designed in this paper, the data processing gateway is used as the server, and the ARM driver of Cortex architecture series is used as the master drive mode for the purpose of reducing costs and facilitating use, the performance is limited. Moreover, the purpose of this virtual and real driving system design is to collect and drive physical equipment, and the decision-making level is not the content of this system design. In this paper, the input circuit and output circuit are designed at one point, and then external switches or data latches are used to ensure that only one circuit works normally at the same time. By flexibly adjusting the functions of the virtual and real drive system, the data interaction of the production smart factory is realized.

2.2 Building Control Model of Virtual and Real Driving System of Robot Based on Digital Twins

In this paper, the virtual reality driven interactive scene is used to obtain the position and pose conversion data of intelligent engineering robots, which makes the whole control process more reasonable. In order to improve the human-machine interaction and safety of virtual and real driving robot, this paper designs a robot remote teaching system based on digital twin technology. First, the virtual robot pose is planned using the virtual and real driving method of robot augmented reality based on object detection. In the virtual and real driving digital twin model of robot, whether the virtual robot collides and interferes with the working scene or personnel is detected. If there is no collision and interference, the robot control command is generated and sent to the physical robot to control the movement of the physical robot [9]. The digital twin model is shown in Fig. 2 below.

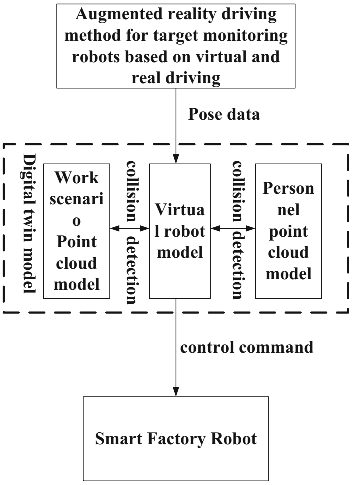

Fig. 2. Schematic diagram of digital twin control model

As shown in Fig. 2, the framework is mainly composed of physical unit and digital twin unit. The physical unit is composed of physical robot and working scene, robot control cabinet and RGB-D sensor, etc. The digital twin unit includes robot digital model unit and robot virtual and real drive unit. The physical unit uses the RGB-D sensor to obtain the geometric parameters and RGB-D images of the robot and its working scene, and directly reads the joint data of the robot in the current position and posture through ROS, and sends the acquired real-time data to the digital model unit; The digital model unit analyzes and processes the obtained geometric data, joint data, RGB-D image data, position and posture data, and establishes the digital twin model of the robot and its working scene. The virtual and real driving unit of the robot presents the pose data, twin model and collision detection results in real time in the computer, providing visual basis for the teaching staff to plan the pose of the robot [10]. The teaching staff observes in real time through the teaching platform, and uses the virtual reality drive of the object detection robot proposed in this paper to plan the virtual robot pose, sends the planned pose data to the collision detection model of the digital model unit, detects the collision interference between the robot and the object or person in the working scene during the teaching process, and generates control commands when there is no collision interference, control physical robot movement through ROS. According to the motion of the robot, the axial acceleration, angular velocity and other parameters of the robot are analyzed, and the formula is as follows:

$$\alpha(t) = \alpha \tag{1}$$

$$\varphi(t) = \frac{1}{2}\alpha t^2 \tag{2}$$

$$\omega(t) = -\alpha t + \alpha t^2 \tag{3}$$

In Eqs. (1–3), $\alpha(t)$ Is the angular acceleration; α Is a constant value; $\varphi(t)$ Is the angle; t Is the time; $\omega(t)$ Is the angular velocity. Segmental angular acceleration $\alpha(t)$ Is a constant value. Angular velocity $\omega(t)$ In the first section, the neutral line increases to the maximum value, and then in the second section, it decreases linearly to the static state. Rotation angle passed in section I and II $\varphi(t)$ Increase by parabola function. This type of running contour can achieve the shortest positioning time. By the preset ending angle φ_{Max} And the corresponding time point t can calculate the required angular acceleration constant or angular deceleration constant. For the sake of simplicity, the temporary transition phase that accelerates the formation and elimination of angular impact will not be considered [11]. The analysis shows that the ending angle is known φ_{Max} And the corresponding time t, the required angular acceleration or angular deceleration can be calculated. The maximum action range and maximum speed of the robot are shown in Table 1 below.

Table 1. Maximum Action Range and Maximum Speed of Robot

project	Maximum action range	Maximum speed (rad/s)
J1	±180°	3.20
J2	−60°–120°	3.08
J3	±180°	5.23
J4	−60°–80°	4.15
J5	±180°	6.54
J6	±135°	6.54
J7	±360°	10.47

As shown in Table 1, $\varphi_{Max} = 180° = \pi$, $\omega_{Max} = 3.20$ rad/s, it is known that the angular velocity curve has the same area in two stages, then:

$$\varphi_{Max} = 2\left[\frac{\alpha}{2}\left(\frac{t}{2}\right)^2\right] \tag{4}$$

In Eq. (4), φ_{Max} Is the maximum angle range of the end angle. The drive model of intelligent factory robot is simplified. The length of the connecting rod axes J1, J2, J3, J4, J5, J6, J7 is ln, the radius is rn, and the mass is mn. There is a servo motor and driver at each node. The rotation direction of each shaft is as follows: J1, J7 and J4 rotate around the shaft itself, J2, J3, J5 and J6 rotate around the mechanical arm J2, J3, J5 and J6 respectively, and the angle of Ji is θi, the counterclockwise rotation direction is the positive direction, and the horizontal included angle of the robot drive is:

$$\theta_3' = \frac{\pi}{2} - \theta_2 - \theta_3 \cos \theta_7 \tag{5}$$

$$\theta_5' = \theta_3' - \theta_5 \cos \theta_4 \tag{6}$$

In formulas (5, 6), θ_3' Is the angle between J3 and the horizontal line; θ_2 Is the corner of J2; θ_3 Is the corner of J3; θ_7 Is the corner of J7; θ_5' Is the angle between J5 and the horizontal line; θ_5 Is the corner of J5; θ_4 It is the corner of J4. In this paper, the robot drive is divided into different modules, and different robots are controlled by different drive systems. Digital twin modeling is carried out in the No. 2 drive system. The RGB D image of the working scene is obtained by using the RGB D sensor for 3D reconstruction. The conversion matrix between the RGB-D sensor coordinate system and the robot base mark is obtained by hand eye calibration [12]. The robot virtual model is fused with the point cloud model of the working scene to complete the digital twin modeling. Build an augmented reality drive platform in No. 1 drive system. The RGB sensor acquires the RGB image of the working scene, completes the augmented reality registration according to the conversion matrix between the RGB sensor coordinate system and the robot base, and superimposes the virtual robot onto the actual working scene. In the No. 1 driving system, the robot augmented reality driving method of object detection proposed in this paper is used to plan the position and pose of the virtual robot. The planned pose data is sent to the No. 2 drive system for collision detection, including collision detection between the robot and the work scene based on the octree model, and human-machine minimum distance detection based on human skeleton node recognition. The pose data without collision interference will be generated into robot operation instructions to control the physical robot to execute driving tasks.

2.3 Control the Smooth Switching Mode of Virtual and Real Driving of Intelligent Factory Robots

With the help of digital twin technology, this paper controls the robot to stably complete the task of the drive system, and controls the smooth switching mode, so that the robot can quickly respond dynamically while the virtual and real drive systems issue commands, and combines the smooth switching function to ensure the overall stable performance of the robot drive. The dynamic response and steady state performance of a single controller are often contradictory, and the controller with fast dynamic response is often accompanied by poor steady state performance [13], and vice versa. In this paper, the controller is designed from the perspectives of signal and energy, and the smooth switching function is designed, so that the robot control system can use the signal controller to track quickly when the error is large, and the energy controller to ensure the steady state performance when the error is small. The smooth switching function plays a role in smooth transition. At the same time, it has the rapidity of signal control and the stability of energy control. Sliding mode variable structure control is a typical signal control with fast response because of its simple algorithm and fast response speed. A new sliding mode control is proposed in this paper, which further improves the fast response of the system [14]. The chattering problem of sliding mode control in steady state is always difficult to solve, and smooth switching control also provides another solution to eliminate chattering. Hamiltonian control studies the variation of system energy. After the system reaches steady state, the energy dissipation is given priority, which can make the system have good steady state performance. The smooth switching control scheme is shown in Fig. 3 below.

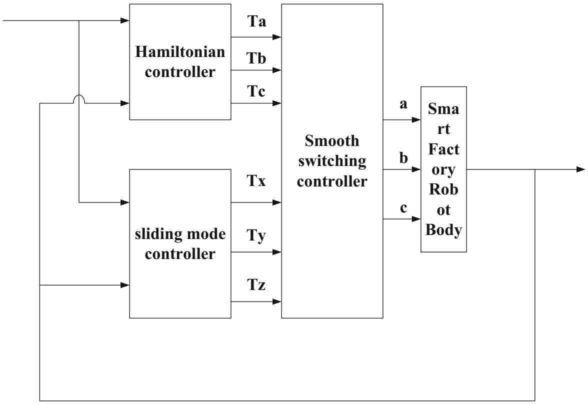

Fig. 3. Schematic diagram of smooth switching control scheme

As shown in Fig. 3, Ta, Tb and Tc are the output commands obtained by the Hamilton controller; Tx, Ty and Tz are the output commands obtained by designing the sliding mode controller from the perspective of signal; a, b and c are the input torque of the robot. Because of its simple algorithm structure, fast dynamic response, strong robustness to unknown disturbances and parameter deviations, sliding mode control improves the control effect of the system through the approach law. Exponential approach law, power approach law and double power approach law are important control indicators. The double power approach law is described as:

$$S = -k_1|s|^{\alpha}\text{sgn}s - k_2|s|^{\beta}\text{sgn}s \tag{7}$$

In Eq. (7), S Is the law of double power approach; k_1 、 k_2 Is the distance between the sliding surface and the driving system; sgn$s$ Is the symbolic function of the sliding surface; β Is a constant value. In this paper, the scale function is introduced σ, when σ when the value is different [15], the control effect of the drive system is different. The smooth switching function is expressed as:

$$Q(s) = \begin{cases} \exp(-\left(\frac{|S|-1}{\sigma}\right)^2), & |S| > 1 \\ 1, & |S| \le 1 \end{cases} \tag{8}$$

In Eq. (8), $Q(s)$ It is a smooth switching function. The design of virtual and real drive system of intelligent factory robot is similar to that of permanent magnet synchronous motor, and the equivalent magnetic circuit method is generally used to analyze and design the motor in engineering. The equivalent magnetic circuit method is simple and can meet the design requirements after several iterations. However, in the analysis and processing, the permanent magnet should be considered as a magnetic source to participate in the calculation of the equivalent magnetic circuit. At the same time, due to the diversity of the rotor magnetic circuit structure and the complexity of the magnetic field distribution, it is difficult to describe the real magnetic field situation only by relying on a few concentrated parameters. Therefore, the magnetic circuit calculation can only be used to estimate the initial scheme and compare similar structures, and cannot obtain some key coefficients such as magnetic leakage coefficient, pole arc coefficient, etc. In order to improve the accuracy of the design, this paper uses the field circuit combination method to design the virtual and real drive system of intelligent factory robots. The field circuit combination method is to use the electromagnetic field numerical calculation (finite element method) to obtain the magnetic leakage coefficient, calculate the pole arc coefficient and other parameters that cannot be obtained in the calculation of the magnetic circuit method, and then combine the magnetic leakage coefficient, calculate the pole arc coefficient and other parameters into the equivalent magnetic circuit to modify, improve the accuracy of the calculation results and reduce the dependence on empirical data, therefore, the field circuit combination method has the advantages of the equivalent magnetic circuit method and the finite element method, and can effectively combine the magnetic field and magnetic circuit. During the operation of the robot drive system, there are not only the input and output of signals, but also the increase and decrease of mechanical energy. Therefore, PMSM and robot can be regarded as the devices for signal transformation and energy transformation. Based on the point of view of signal transformation, the controlled object is regarded as a signal transformation device that converts the input signal into the output signal. The control principle is to quickly converge the error signal to 0. The controller based on this control concept is called the signal controller. The PCH control method studies the relationship between the energy transformation of the system and the change of mechanical energy from the perspective of the energy transformation of the system. Its control principle is that the total energy of the digital twin technology makes the system meet the requirements of control objectives through damping injection and other rules. The controller based on this control concept is called energy controller. After being controlled, the virtual and real drive system can detect signals in time, quickly adjust the position and speed of the robot, and has good dynamic performance. The drive system management and control method based on digital twin technology can minimize the loss of the system, realize energy optimization control when the system is in steady state, and have good steady state indicators. In this paper, feedback linearization control is used to control the virtual and real drive systems. The key point is to accurately convert the nonlinear system into a linear system using the existing methods, so that the linear system method can be used to solve the control problems faced by the nonlinear system.

3 Experiment

In order to verify whether the control method of the drive system designed in this paper has practical value, this paper conducts an experimental analysis of the above methods. The conventional control method of virtual and real drive system of intelligent factory robots based on point cloud model, the conventional control method of virtual and real drive system of intelligent factory robots based on convolutional neural network, and the control method of virtual and real drive system of intelligent factory robots based on digital twins designed in this paper are used to control robots and select the best control scheme. The specific experimental preparation process and the final experimental results are shown below.

3.1 Experiment Preparation

In the virtual reality drive system of the robot, the data processing gateway is mainly used as the server to receive and send data, and can access additional point signals through wired and wireless ways. The data processing module is based on the independent control chip to expand the interface of the gateway to achieve the purpose of accessing data to the virtual and real driving system of the robot. The main function of the driver module is to improve the driving ability of the signal expansion board to drive high-power equipment, and play an isolation role to prevent high-power equipment from burning the data processing module. The remote terminal is a client that transmits and receives data with the gateway through wireless communication technology, and also adds a wired communication module, which can further increase the number of access points by connecting the expansion board card. In industrial equipment, the most important thing to access control is PLC, whose power supply is 24 V. In order to facilitate the installation of the gateway, a voltage conversion module is designed.24 V direct power supply is used to realize voltage conversion through 24 V–5 V step-down circuit. This paper selects XL2596S-ADJE1 as the voltage conversion chip, which can set the voltage output through the voltage stabilizing feedback circuit to improve the stable 5V3A output, which is the most recommended power supply mode for the data processing gateway. The voltage conversion chip has a control pin (ON/OFF) through which the output of the chip can be controlled. Therefore, the design adds a normally closed switch on this pin to enable it to provide a switching function in addition to the 24 V–5 V function, which facilitates the quick restart of the data processing gateway when the gateway fails to work normally due to errors. Under the condition of normal operation of the virtual and real drive system, this paper configures the parameters of the experimental environment, as shown in Table 2 below.

Table 2. Parameters of Experimental Environment

name	Model/version
Hardware	
operating platform	Ubuntu 18.04
CPU	Intel(R)xeon(R) CPU E5-2650 V4@2.20 GHz
GPU	TITAN xp 1288Mi B
Graphics card	NVIDIA-SMI432.00
Software	
CUDA	10.2
CUDNN	7.6.5
Pytorch	1.8.0
Pycharm	2018.3.2
Python	3.7

As shown in Table 2, this experiment uses the server training and experimental yolov5 model, and uses the Pytorch deep learning framework to train and experiment the yolov5 model. Convert the weight file obtained from the deep learning framework training, and then call it through the DNN module of Opencv to ensure that the control scene of the entire virtual and real robot drive system is more urgent to meet the actual industrial needs. The virtual reality driven data interaction system aims to comprehensively collect the data of the equipment in the production workshop and realize the digital abstraction process of the workshop. The control signal transmission between workshop equipment is electrical signal, and the current is mostly when the equipment transmits analog signal. Due to the complex working environment of the workshop, there are a large number of high-voltage lines on the site, and the voltage of various electromagnetic sensors is vulnerable to interference, which leads to the distortion of the collected data and affects the operation of the equipment. Using current signal as analog control signal can better ensure the accuracy of control. The range of equipment signals is variable. The range of electrical signals output by different equipment produced by different manufacturers is different, and their corresponding physical meanings are also different. Common ranges are 0–5 V, 0–10 V, 0–20 mA, etc. If you want to collect data from devices with different ranges, you must also use those that support various ranges. The number of equipment is large and scattered. With the increase of digitalization of manufacturing workshops, the number of sensors is increasing. It is necessary to collect physical quantities of many points at the same time. And because the processing equipment such as machine tools, robots, etc. are dangerous, the equipment must be installed with a suitable safety distance, which leads to the distribution of the data to be collected in the whole workshop is far away. This paper takes the intelligent factory inspection robot as an example to analyze its structure, as shown in Fig. 4 below.

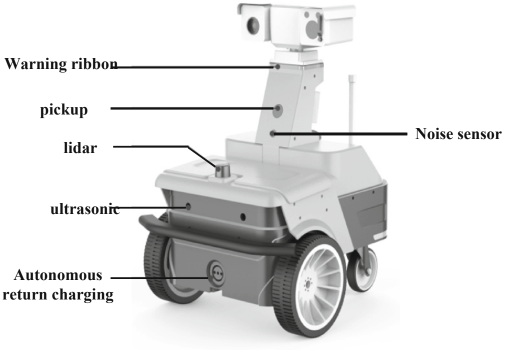

Fig. 4. Structure diagram of intelligent factory patrol robot

As shown in Fig. 4, the structure of the patrol robot includes not only basic components such as warning ribbons, pickups, laser radars, ultrasound, autonomous return charging, noise sensors, but also components such as pan tilt, gas detectors, antennas, light strips, and interface panels. In the process of robot driving, there are relatively many virtual and real signals, and there should be enough digital and analog acquisition channels, at least 64 digital channels and 8 analog channels, to ensure the data interaction effect of the driving system. The digital channel of the data interaction system needs to support two modes of high-level trigger and low-level trigger. The analog quantity channel of data interaction system supports 0–5 V and 0–20 mA analog quantity. In the virtual reality drive system of the robot, the data processing gateway is used as the server, and the ARM processor of Cortex architecture series is used as the main control chip for the purpose of reducing cost and facilitating use, so the performance is limited. Moreover, the virtual and real driving system of the robot is designed to collect physical equipment and drive physical equipment, and the decision-making level is not the design content of the system. In this way, the C/S architecture puts the business processing logic on the client side, which more meets the design goal of the system. Because the C/S architecture only needs to transmit interactive data, when the amount of data is large, the communication pressure of using the C/S architecture is less, which can ensure the real-time performance of the system data. Therefore, this paper chooses to use C/S structure as the data interaction structure between system layers, and uses B/S structure to assist in monitoring the working state of wireless terminals. In this paper, during the driving process of the intelligent factory inspection robot, the camera imaging is used to transform with the coordinate system. The conversion relationship is shown in Fig. 5 below.

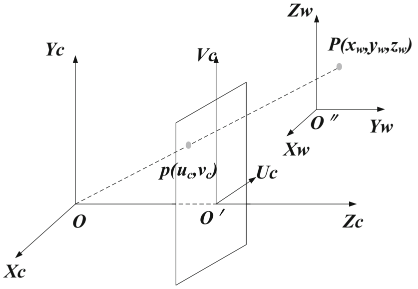

Fig. 5. Schematic diagram of the relationship between imaging and coordinate system conversion

As shown in Fig. 5, O is the camera concern for robot imaging; O′ is the center of the image plane; O″ is the center of robot base coordinate system; P (uc, vc) is the actual position coordinate of the robot drive; P (xw, yw, zw) is the three-dimensional coordinate driven by the robot after the conversion of the base coordinate system. The virtual and real driving technology of industrial robots is different from the traditional servo system. It does not need to use mechanical transmission components such as belts (pulleys), gears or cams. External loads can be directly connected with torque direct drive motors. The use of virtual and real driving technology has many advantages, which can improve the accuracy and repeatability. Compared with a "high-precision" planetary gear, the repetition error of a standard virtual reality driven rotating motor is less than 1 arc second. The backlash of the planetary gear can reach 1 min of arc, which may cause the load to move 1 min of arc for the absolutely stable drive motor. Therefore, the precision of direct drive motor structure is 60 times higher than that of traditional motor structure. After the virtual and real driving technology improves the precision, the machine can produce higher quality products. While the end actuator of the virtual robot model follows the attitude teaching device, the attitude teaching device acquires the attitude of the attitude teaching device in the northeast sky coordinate system through the inertial sensor module, transmits the attitude data generated by the attitude teaching device to the computer through the Bluetooth module, and controls the attitude of the robot end actuator, the teaching staff adjusts the posture of the virtual robot terminal by adjusting the posture of the posture teaching device, and observes and adjusts in real time through the AR visual interface to achieve the expected posture.

3.2 Experimental Results

Under the above experimental conditions, this paper makes the intelligent factory robot move to any position in the factory, and records the required and actual coordinates of the robot. Compare the coordinates of the conventional control method of virtual and real drive system of intelligent factory robots based on point cloud model, the coordinates of the conventional control method of virtual and real drive system of intelligent factory robots based on convolutional neural network, and the coordinates of the control method of virtual and real drive system of intelligent factory robots based on digital twins designed in this paper. The closer to the reference coordinates, the better the control effect of robot virtual and real drive system. The experimental results are shown in Table 3 below.

Table 3. Experimental Results

Drive times	Coordinate/mm	Coordinates/mm of conventional control method for virtual and real drive system of intelligent factory robot based on point cloud model	Coordinates of conventional control method for virtual and real drive system of intelligent factory robot based on convolutional neural network/mm	Coordinates/mm of control method for virtual and real drive system of intelligent factory robot based on digital twin designed in this paper
1	reference resources	(262.0, 313.6, 687.0)		
	measure	(262.5, 313.8, 685.0)	(261.0, 312.6, 687.8)	(262.0, 313.6, 687.0)
2	reference resources	(383.4, −260.6, 323.1)		
	measure	(381.4, −265.6, 326.1)	(382.4, −260.5, 321.1)	(383.4, −260.6, 323.1)
3	reference resources	(314.4, −386.8, 641.1)		
	measure	(318.4, −387.8, 646.1)	(312.4, −384.8, 641.6)	(314.4, −386.8, 641.1)
4	reference resources	(379.5, −268.3, 254.8)		
	measure	(379.1, −268.0, 249.8)	(376.5, −268.8, 252.8)	(379.5,-268.3,254.8)
5	reference resources	(469.0, −23.4, 441.4)		
	measure	(469.9, −28.4, 440.4)	(470.8, −25.4, 441.4)	(469.0,-23.4,441.4)

As shown in Table 3, the smaller the difference between the robot driving position coordinates and the actual position coordinates, the better the control effect will be in the process of virtual and real driving control of the robot. If other conditions are consistent, after using the conventional control method of virtual and real drive system of intelligent factory robot based on point cloud model, the reference coordinate of the robot is (262.0313.6687.0), and the actual position coordinate of the robot is (262.5313.8685.0). In this three-dimensional coordinate, there is a difference of 2.0 mm from the reference coordinate. The error between the actual position coordinates and the reference position coordinates of the other four times is about ±5.0 mm, which shows that the control effect of the robot is poor and cannot meet the control requirements of the virtual and real driving system of the robot. After using the conventional control method of virtual and real drive system of intelligent factory robot based on convolutional neural network, the actual position coordinate of the first drive was (261.0312.6687.8), which had errors (1.5, 1.2, - 2.8) with the reference position coordinate. The other four drive coordinates also had errors of varying degrees with the reference position coordinate, which affected the robot control effect and needed further improvement. However, after using the virtual and real drive system control method of intelligent factory robot based on digital twins designed in this paper, the actual position coordinate of the robot driven for the first time is (262.0313.6687.0), which is consistent with the reference position coordinate in height. The other four drives are the same as the reference position coordinate, which can ensure the control effect of the robot, it meets the control requirements of the virtual and real drive system of intelligent factory robots.

Further analyzing the performance of the method proposed in this article, the two datasets were randomly divided into three groups, with the driving control speed as the comparison indicator. The test results of the three methods are compared as shown in Table 4

Table 4. Drive Control Speed/ms

group	Control Method for Virtual Reality Drive System of Intelligent Factory Robot Based on Point Cloud Model	Control Method of Virtual and Real Drive System for Intelligent Factory Robot based on Convolutional Neural Network	The virtual and real drive system of the intelligent factory robot designed based on the digital twin brothers
1	37	57	12
2	39	59	13
3	45	62	11
4	55	66	14
5	56	68	12

According to the analysis of Table 4, the space segmentation speed of the method in this paper is the fastest, with an average of 12.83 ms, while the driving control speed of the control method of the virtual reality drive system of intelligent factory robots based on the point cloud model and the control method of the virtual and real drive systems of intelligent factory robots based on Convolutional neural network are slower, with an average of 48.33 ms and 62.83 ms, respectively. This shows that the method in this paper is applied to drive control, It can achieve efficient management and control of industrial robots, which is conducive to rapid production.

4 Conclusion

Since the birth of the first generation of robots, robots have been widely used in machinery manufacturing, automobile and ship manufacturing, electronic and electrical processing industry, rubber and other raw material processing industry, medicine and food processing industry and other fields. At present, robots have been widely used in welding and grinding, machining and assembly of mechanical parts and other fields. Most of the traditional robot driving programming methods use the drive box to import the robot running program or manually control the robot to perform the driving task. Although this robot driving method can make the driver visually observe and adjust the robot driving posture, the driving efficiency is low. In the actual production environment, because the driver and the robot are not necessarily in the same physical space, and are restricted by the uncertainty and complexity of the working environment, the traditional robot cannot complete the driving task independently; In addition, due to the poor environmental awareness of existing intelligent robots, there are potential safety hazards in the process of autonomous task execution, which makes it difficult to achieve safe and reliable autonomous programming of robots. Therefore, it is necessary for drivers to monitor the status of robots and changes in their working scenes in real time through devices such as vision sensors, and remotely control the robots to execute driving tasks. Therefore, this paper uses digital twin technology to design the control method of virtual and real drive system of intelligent factory robots. From the driving scene, control model, control switching mode and other aspects, we can better drive the robot and truly improve the control effect of the robot.

References

1. Kl, A., Pr, B., Csk, C., et al.: Real time exploited BLDC motor drive BLDC motor drive in lab view virtual instrumentation environment. Mater. Today Proc. (3) (2021)
2. Long, D., Xu, R., Liu, J., et al.: Enterprise service remote assistance guidance system based on digital twin drive. Mob. Inf. Syst. **2021**(8), 1–9 (2021)
3. Visnic, B.: Real-time processors help drive the zonal E/E REVOLUTION. Automot. Eng. **6**, 9 (2022)
4. Wang, P., Luo, M.: A digital twin-based big data virtual and real fusion learning reference framework supported by industrial internet towards smart manufacturing. J. Manuf. Syst. **58**(1), 16–32 (2021)
5. Saito, K., Akagi, H.: A real-time real-power emulator for a medium-voltage high-speed electrical drive: discussion on mechanical vibrations. IEEE Trans. Ind. Appl. 1 (2021)
6. Jiang, Y., Li, M., Guo, D., et al.: Digital twin-enabled smart modular integrated construction system for on-site assembly. Comput. Ind. **136**(6), 103594 (2022)
7. Fan, L., Li, H.J.: Research on optimization of frequency conversion harmonic based on three-phase power supply. Comput. Simul. **40**(1), 6 (2023)
8. Qing, Z., Liguo, Z., Yulin, D., et al.: From real 3D modeling to digital twin modeling. Acta Geodaetica et Cartographica Sinica **51**(6), 1040–1049 (2022)
9. Yang, F., Feng, T., Xu, F., et al.: Collaborative clustering parallel reinforcement learning for edge-cloud digital twins manufacturing system. China Commun. **19**(08), 138–148 (2022)
10. Semeraro, C., Lezoche, M., Panetto, H., et al.: Digital twin paradigm: a systematic literature review. Comput. Ind. **130**, 103469 (2021)
11. Aheleroff, S., Xu, X., Zhong, R.Y., et al.: Digital twin as a service (DTaaS) in industry 4.0: an architecture reference model. Adv. Eng. Inform. **47**, 101225 (2021)
12. Bhatti, G., Mohan, H., Singh, R.R.: Towards the future of smart electric vehicles: digital twin technology. Renew. Sustain. Energy Rev. **141**, 110801 (2021)
13. Jafari, M., Kavousi-Fard, A., Chen, T., et al.: A review on digital twin technology in smart grid, transportation system and smart city: challenges and future. IEEE Access (2023)

14. Sasikumar, A., Vairavasundaram, S., Kotecha, K., et al.: Blockchain-based trust mechanism for digital twin empowered industrial internet of things. Futur. Gener. Comput. Syst. **141**, 16–27 (2023)
15. Uhl, A., Schmidt, A., Hlawitschka, M.W., et al.: Autonomous liquid-liquid extraction operation in biologics manufacturing with aid of a digital twin including process analytical technology. Processes **11**(2), 553 (2023)