Research on Virtual Reality System of Gantry Dual-arm Welding Robot

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Abstract. In order to promote the development of ship automatic welding, this paper applies virtual technology to gantry welding robot used in ship welding. A method of creating kinematic digital twins in virtual reality is proposed. This method can restore the motion state of gantry welding robot in real time in the remote virtual client. The working condition of gantry welding robot can be known by observing the remote virtual client. With the help of solid works and 3DMAX, this method establishes the virtual model corresponding to the real equipment. Assemble the model in unity3d, establish a virtual environment corresponding to the real environment, and develop the remote client. This method obtains real-time motion data from the field industrial computer and transmits it to the remote client through the Internet. The remote client carries out data processing to achieve the effect of synchronous movement with the scene. Through the case analysis, this method can be used for the kinematic modeling of the digital twin of gantry welding robot, so as to monitor the welding movement and improve the working environment of the staff. And it has good visual effect and immersion.

Keywords: Virtual reality, welding robots.

1. INTRODUCTION

In recent years, with the rapid development of computer technology, virtual technology has been widely used in various fields[1][8]. Including aerospace, medical, marine engineering and other fields, and promote the rapid development of these areas. With the rapid development of virtual reality technology, it has also been widely used in the field of robots. Wang Hui et al., Chinese Academy of

Sciences, applied virtual technology to the robot of rehabilitation training, which can make the rehabilitation process of patients more interesting and accelerate the rehabilitation of patients through VR virtual screen [9]. Yu Luo et al. from Beijing Petrochemical Research Institute applied virtual technology to pipeline welding robot, realized remote control of pipeline welding robot for welding, and improved the working environment of staff [10]. Wu Jianhua of Tianjin University of Science and Technology applies virtual technology to mobile robots, which can more easily realize the path planning of robots [11]. Hu Yulan and others use virtual reality technology to simulate multi-robot operation tracking, that is, using computer technology to generate realistic external environment and multi-mobile robot system, so that multi-robot system cooperative tracking is consistent with the actual environment in the virtual 3D environment. Researchers and observers can use their own sensory system or some corresponding control devices to generate the observed and interactive virtual system [12]. In the medical field, by adding realistic virtual technology and operating robots to complete prostatectomy, Francisco Popelia et al. promoted the development of remote surgery[13]. Unity3D is a powerful game engine, using the software can establish a realistic virtual screen, with a good immersion. In addition, the software provides a large number of APIs, and developers can call according to requirements, which reduces the development cycle and development costs. With the development of Unity3D, virtual reality has also been widely used in the industrial field [14]-[18]. In terms of robots, Ren designed a semi-physical simulation system for underwater robots based on unity3d, which realized the synchronization of virtual objects and robots, and realized the simulation experiment of robots [19]. Pan Junhao used unity3d to build robot model and simulation scene model. The simulation system of welding robot developed by using the virtual model. The simulation results show that the system can obtain good benefits in engineering and training [20].

According to previous studies on the application and effect of virtual technology, this paper applies virtual reality technology to gantry dual-arm welding robots used in the shipbuilding industry, thereby promoting the technological development and innovation of the shipbuilding automation industry. Ship welding industry is different from other industries is the welding robot working environment is complex and bad [21]. The composition of gantry welding robot is also complex, which is easily affected by the surrounding environment. Therefore, it is difficult to apply virtual technology to gantry welding robot. According to the situation of ship welding, the virtual reality technology is studied. This paper adopts C / S architecture mode. Using SolidWorks, 3D Max to establish 3D model. Establish virtual reality model in Unity3D and develop remote client. In the welding site, data acquisition and transmission. The gantry welding robot controller collects the motion data of the welding robot in real time through PLC and sensors. Transmit data to the host computer through LAN. The host computer transmits data to the remote virtual client through the Internet. After receiving the motion data, the virtual client performs visual processing and synchronous motion processing to achieve the synchronous work of the virtual and real gantry welding robot. Finally, the remote monitoring of gantry welding robot motion data is realized. And improve the working environment of staff. And has good visual effect and immersion. Development costs are also low and easier to spread.

2. METHOD OF CREATING KINEMATIC DIGITAL TWINS IN VIRTUAL ENVIRONMENT

2.1 General Idea of the Method

The general idea is shown in Figure 1. This method mainly realizes the synchronous movement of the virtual environment and the actual environment. This method adopts the C/S architecture mode. In the C/S architecture mode, the data processing is completed in the application layer, and the transmission layer only needs to transmit the motion data, which can reduce the delay. This method is mainly composed of four parts: one is the development of a virtual monitoring end, which mainly realizes the establishment of a virtual reality environment, the development of a UI interface, some auxiliary modules and other functions. The second is to collect the field data in real time. The third

is to send the collected data to the remote virtual monitoring terminal through the Internet according to a certain protocol format. Fourth, complete the data receiving and processing in the virtual environment and realize the synchronous movement with the real environment.
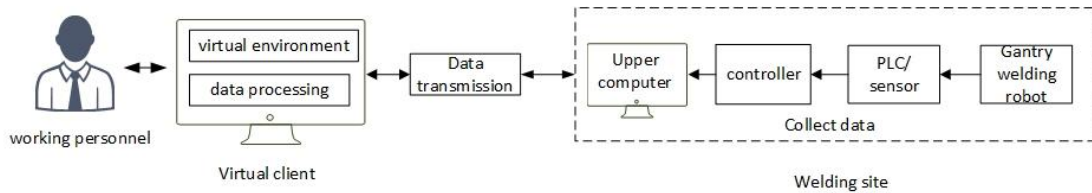

Figure 1：General idea of the method.

2.2 Establish 3D Virtual Environment

The establishment of virtual environment is to establish a 1:1 virtual environment according to the real-world environment. The establishment of virtual environment is the first step of the whole method. The proximity between the virtual environment and the actual environment determines the accuracy of restoring the working condition of the actual equipment and the immersion of the staff.

SolidWorks is a software specially used to draw three-dimensional models. It is widely used in industrial fields, especially in mechanical industry. Its advantage is that it can easily and quickly establish an accurate three-dimensional model. This method uses SolidWorks as a modeling tool. However, the 3D model drawn by SolidWorks cannot be used by Unity3D, so 3DMAX 3D model software should be used as intermediate software to process and convert the model. Save the model drawn by SolidWorks a .STA format, which can be imported into 3DMAX. In 3DMAX, the unimportant components of the model are reduced to reduce the memory occupied by the model. This can ensure that the virtual client uses less memory during development, increase its operation efficiency and reduce latency. After processing in 3DMAX, save as .FBX format and import into Unity3D.

After the model is imported into Unity3D, the relationship between each model is independent and does not conform to the actual motion relationship. Therefore, according to the actual motion relationship, the parent-child relationship between models is designed. The design principle is that the motion of the parent object will drive the child object to do the same motion, while the motion of the child object will not affect the parent object. In addition, as a powerful engine software, Unity3D supports lighting, material, audio and other functions. It can be added and adjusted according to the needs to achieve the same effect between the virtual environment and the real environment.

Figure 2: Process of drawing 3D model.

In order to increase the immersion and use experience of staff and better realize the remote monitoring of welding process. The multi view function is added in the virtual client to monitor the welding process of gantry welding robot through different views.

2.3 Collect Real-time data

The Gantry welding robot consists of three parts: the gantry welding robot body, controller, and teaching pendant. Gantry robot body: it is composed of a driver, transmission mechanism, joints,
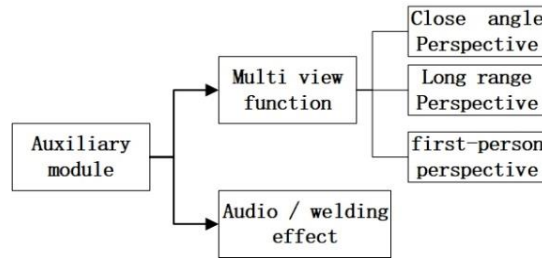
internal sensors, etc.

Figure 3: Auxiliary functions of virtual environment.

The controller is the core of controlling the movement of the gantry welding robot. It is composed of computer software, hardware, and some special circuits. It has the function of collecting and storing data and information. The servo control of each joint is realized based on the kinematic model. Various data information during the movement of the gantry welding robot is stored in the controller. The process of the gantry controller collecting data information is shown in Figure 4.
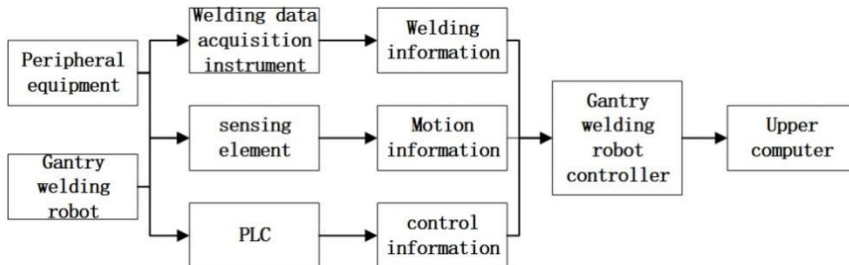
Figure 4: Data acquisition process of controller.
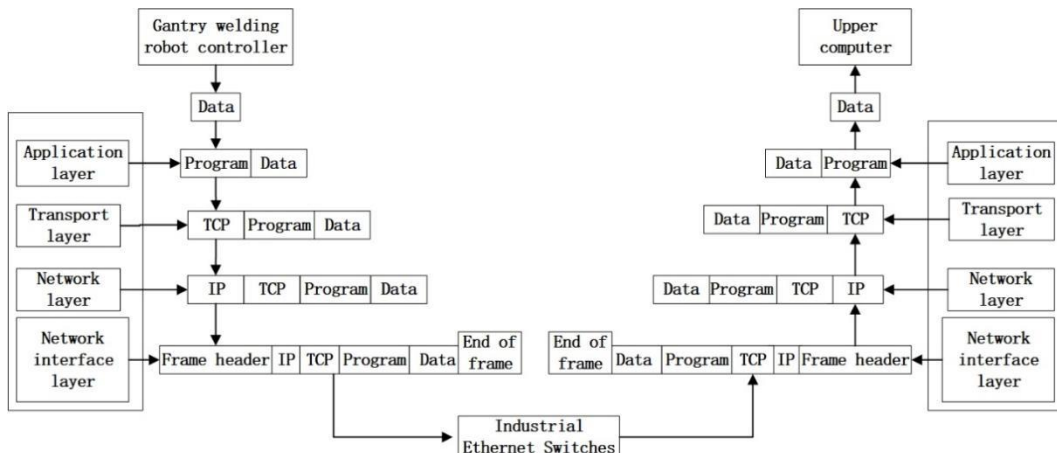
Figure 5: Data acquisition process of upper computer.

The premise of collecting the data in the working process of a gantry welding robot is to establish a communication connection with the controller of the robot. At present, the communication link

between the host computer and the gantry welding robot controller is mainly established based on the TCP/IP protocol. In the process of data acquisition, the gantry welding robot controller sends the data to the application layer. The application layer adds the necessary control information to form the message flow down to the transmission layer, the transmission layer adds the control information to form the message segment down to the network layer, and the network layer adds the control information to form the IP datagram down to the network interface layer. The network interface layer encapsulates the IP datagram into frames and transmits the data to the host computer through the physical layer interface in the form of a bit stream. Each layer in the upper computer completes the decoding of different forms of data according to the agreed protocol to realize the data collection. As shown in Figure 5.

2.4 Send Real-time Data

In order to realize the remote monitoring of a gantry welding robot, the upper computer needs to send the data information to the remote monitoring end in real time. The upper computer and virtual device use the TCP protocol for data transmission. The needs of the host computer and remote virtual client are realized with the help of the server. On the host computer, initialize a socket and send a connection request to the server. After the connection is established, start the thread to send data. On the host computer, the data is packaged into data packets according to the protocol format. A data packet includes a packet header and a packet body. The header is used to distinguish control information, motion information, and welding information. The enclosure stores data information. After the data is packaged on the upper computer, it is sent to the server. Initialize a socket on the server side, bind it with the IP address and port number of the server, start the thread to monitor the request of the upper computer in real time, and wait for the communication connection with the upper computer. After the connection is established, start a new thread to complete the data receiving and forwarding functions and send the data to the virtual client.
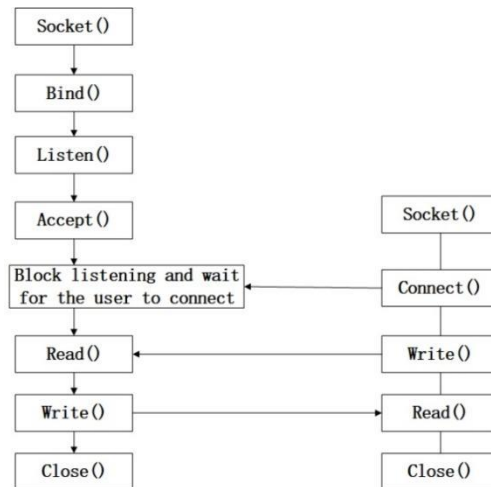

F**igure 6:** Sending data to remote virtual client.

2.5 Receive Real-time Data

After receiving the data packet sent by the host computer, the server forwards it to the virtual client through the Internet. The virtual client receives and processes the data, achieves the effect of synchronous welding with the site, and realizes data visualization. A data buffer is designed in the virtual client to store the data stream from the server. Judge the data stream length of the buffer in the virtual client. If it is longer than the length of a packet, read it; otherwise, wait for it to be read.

After reading a data packet, first read and judge what type of message its packet header is, and then read the data stored in the packet body. The read data is used to realize visualization and synchronous welding.
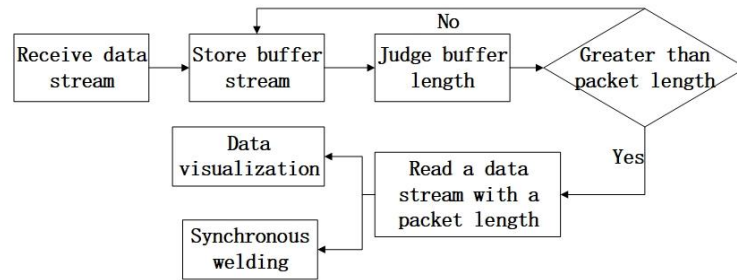
Figure 7: Data received by virtual client.

2.5.1 Data visualization

The visualization of data is realized through the UI interactive interface designed by unity3d. The UI interactive interface is not only the medium to realize the interaction between staff and virtual client, but also the means to realize data visualization. The friendliness of the UI interaction interface affects the staff's sense of experience. The obtained information is judged and classified through the packet header. According to the role of information in the welding process of a gantry welding robot, it is divided into control information, motion information, and welding information. According to the three types of information in unity3d, UGUI is used for the development and design of UI interfaces. The control information is mainly developed using the button and inputfield () components of UGUI. Motion information and welding information are visualized using the text component of UGUI.
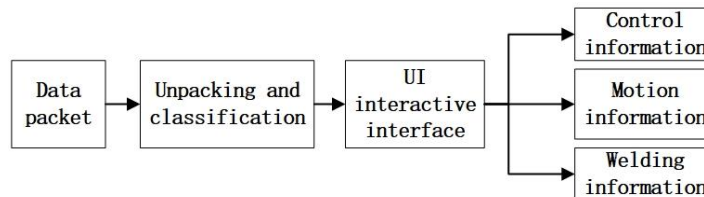
Figure 8: Data visualization.

2.5.2 Synchronous motion based on real-time data

After the data is received and analyzed, the obtained welding data is processed in the virtual client, and finally, the synchronous welding is realized in the virtual monitoring system to achieve the effect of remote monitoring. In unity3d, both the Update () function and the Fixedupdate0 function can be used to update information. The difference is that the refresh time of each frame of the Update () function is not fixed, and the refresh speed will be affected by the currently rendered object. If the currently rendered object occupies a large amount of memory, the refresh is slow; When the memory occupied by the currently rendered object is small, the refresh is faster. The refresh time of each frame of the fixedupdate0 function is fixed, and the refresh cycle can be set in the fixed time step. In order to reduce the delay to an acceptable range, the text selects the fixedupdate0 function and sets the refresh cycle to 0.02s.

For the motion data of each joint of the welding robot, the virtual welding robot moves according to the data obtained in each frame, and the motion effect of synchronous welding can be achieved. The rotational motion of each joint along the axis of the virtual double-arm welding robot is mainly realized by the Translate () function in Unity3d. The linear motion of the gantry in the X and Y

directions and the cantilever in the Z direction mainly depends on the Move () function in Unity3d.
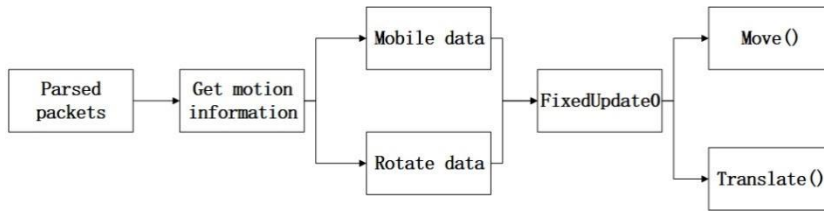

Figure 9: Synchronous movement of virtual and real equipment.

3. METHOD OF CREATING KINEMATIC DIGITAL TWINS IN VIRTUAL ENVIRONMENT

Taking a workpiece welded into small and medium-sized ships as a case study Firstly, the virtual environment of the gantry welding robot is established. As shown in figures 10 to 12, Figure 10 shows the gantry welding robot in the real world. Figure 11 shows the 3D model of the gantry welding robot established by SolidWorks. Figure 12 shows the corresponding virtual environment established in unity3d. Figures 13 to 14 show the parent-child relationship of the manipulator allocated in unity3d according to the motion relationship of the real world. Finally, the same motion effect as the actual model is achieved. Figure 15 shows the movement data of the gantry in the X, Y and Z directions collected by the upper computer from the initial position of the gantry to the beginning of welding. The x-axis in the figure represents real time. The initial time is 3:05 and the end time is 3:10-50 seconds. Figure 16 shows the movement data of the virtual client gantry. The value of the x-axis represents real time (the data in the middle of the x-axis will be omitted from 3:00), in which the initial time is 3.05:60 milliseconds. The end time is 3:10, 50 seconds and 63 milliseconds. Fig. 17 shows the motion data of one group of mechanical arms collected by the upper computer. Fig. 18 shows the motion data of the corresponding manipulator in the virtual environment. The results show that the movement trend is the same, and the delay is about 60 milliseconds. Fig. 19 shows the visualization effect of data in the virtual client and the effect of synchronous welding. Figs. 20 to 22 show the monitoring of the welding process with the help of the multi-view function of the client. Figure 20 shows close monitoring. Figure 21 shows remote monitoring. Figure 22 shows the effect of first-person observation.

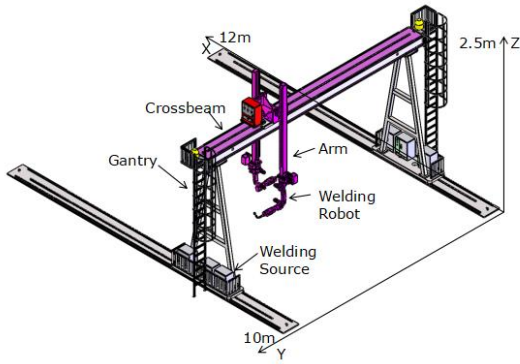**Figure 10:** Actual environment model.
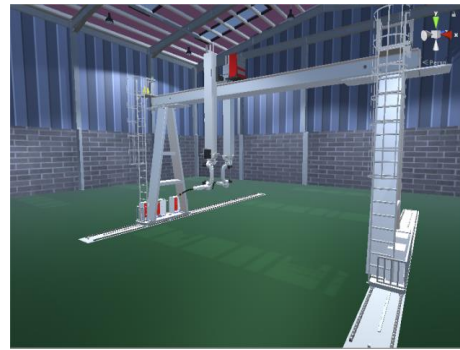
Figure 11: Works Solid 3D model.

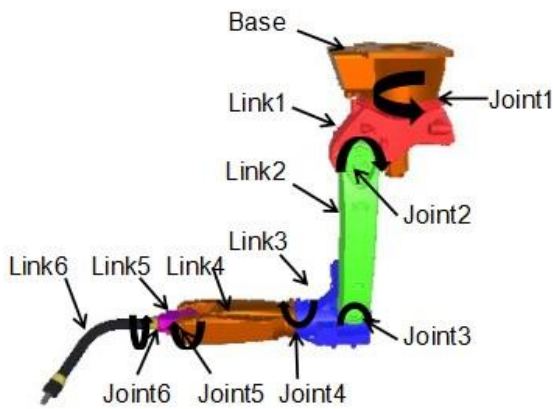

Figure 12: Virtual environment.
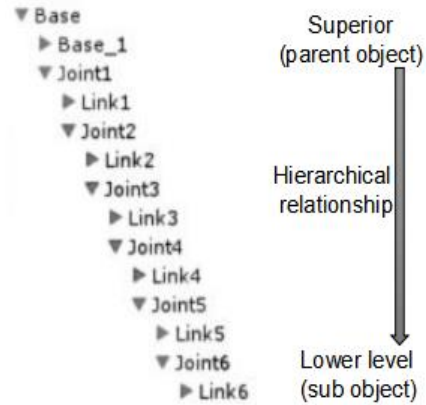

Figure 13: Real hierarchy.

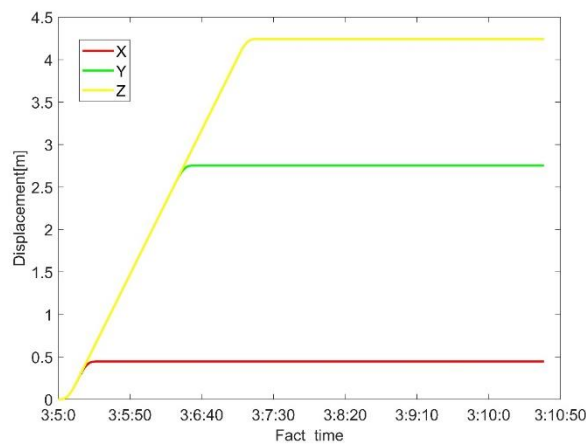**Figure 14:** Unity3d hierarchical relationship.

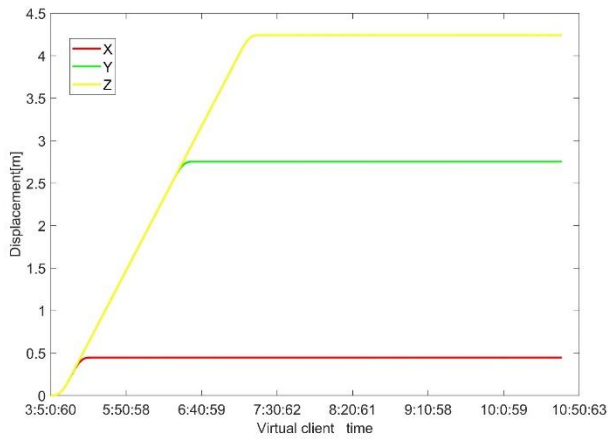**Figure 15:** Gantry movement data collected by upper computer.
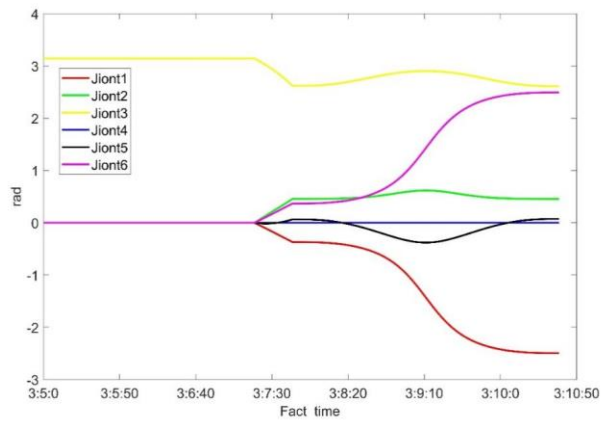
Figure 16: Gantry movement data of virtual client.

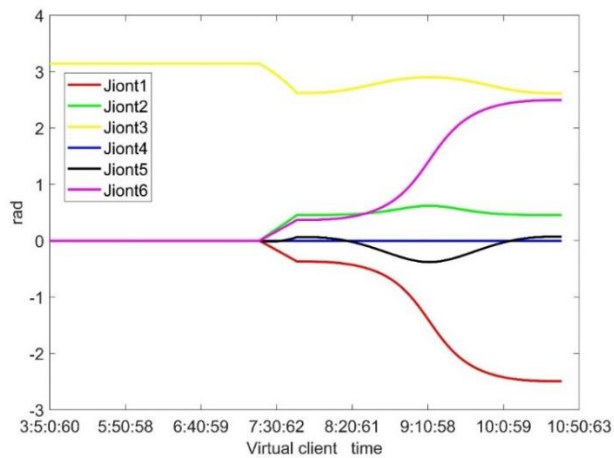**Figure 17:** Upper computer collects rotation data of manipulator.
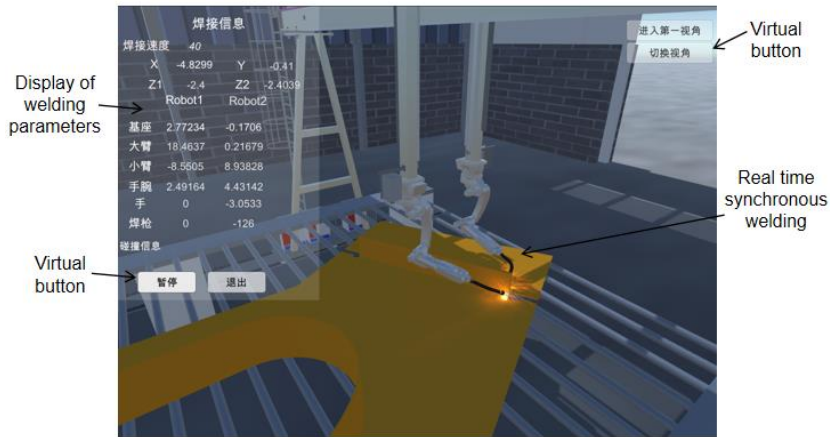

Figure 18: Rotation data of virtual client manipulator.
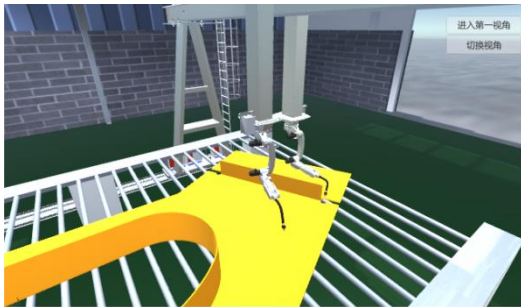
Figure 19: Restore effect of virtual client.
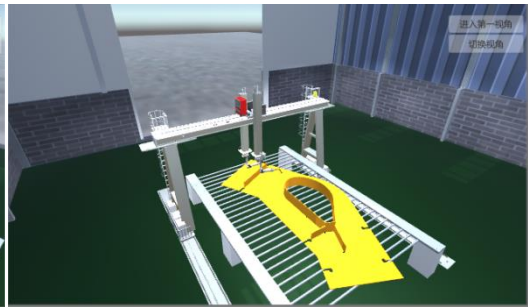

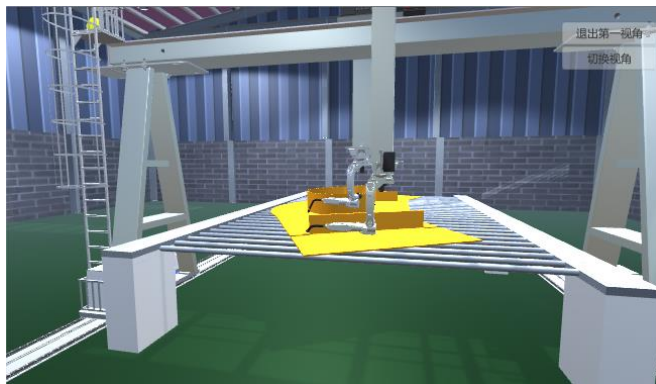**Figure 20:** Close perspective.　　**Figure 21:** Long perspective.

Figure 22: First person perspective.

4. CONCLUSION

In this paper, virtual technology is applied to ship welding to realize the monitoring of gantry welding robot in ship welding. Based on the real-time motion data of gantry welding robot, a method to

create the motion of gantry welding robot in virtual environment is proposed. Realize the synchronous movement and monitoring of virtual and real welding robot. With the addition of virtual reality, the display of welding data has a good visual effect. Through the multi perspective function, the staff's sense of immersion is increased. The method includes four steps: one is to establish a virtual environment; Second, real-time data acquisition; The third is the reception of real-time data; Fourth, the visualization and synchronous movement of real-time data. This paper only studies the motion data of gantry welding robot. In the future, we can add the research on welding information and weld formation, so as to realize the comprehensive monitoring of gantry welding robot welding process.

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