Industrial Robot Training Platform Based on Virtual Reality and Mixed Reality Technology

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Abstract With the steady implementation of the national strategy of "Made in China 2025", industrial robot education has achieved phased development. Many universities have opened majors in robot engineering. The problem that accompanies it is that there are many industrial robot brands in the industry. There are many model differences in the integration industry, and the investment in purchasing a stable industrial robot is enormous. At the same time, improper operations during industrial training may cause serious accidents. We have designed a set of industrial robot training platforms based on VR technology and MR technology. And it solved the problem of the shortage of teaching resources caused by the high purchase cost of industrial robot training equipment and potential safety hazards.

Keywords Virtual reality · Mixed reality · Industrial robot · Virtual simulation · Experiment platform

1 Introduction

Common virtual simulation training platforms generally consist of analogue remote controls and display terminals. There are two problems [1]. One is that they still cannot meet the resource requirements of multi-person teaching scenarios. And the VR Web platform designed in this paper can improve that by increasing the number of servers and bandwidth. It is suitable for synchronous learning with a large number of people. The second is that no real environment information is introduced, and the

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learning process lacks realism. So, it is impossible to intuitively feel the limitations of the integrated environment on the size parameters and working space parameters of the industrial robot, resulting in the selection of the design of the integration scheme. Inconvenience, this paper designed a system based on MR technology, which can let the operator intuitively feel the simulation effect of the integrated solution in the real production environment.

2 Web Simulation Platform Based on Virtual Reality Technology

2.1 Solution Introduction

This paper is a web simulation platform based on virtual reality technology. This platform is designed with B/S architecture and is compatible with various terminal devices used by students. All training programs on the platform can run on the web browser of the student user terminal. It allows students to access the training platform through Internet terminal equipment more conveniently (as shown in Fig. 1).

Fig. 1 Web simulation platform interface

2.2 Interactive Mode

The interactive objects in this platform are mainly industrial robots, workpieces and factory environments. Students participating in the training can walk between different production areas in the factory environment, and they can choose to learn to operate different industrial robot equipment and experience various industrial robot integrated application procedures.

All industrial robot equipment models use real size data and operating procedures, and the rendering effect is real. Consistent with the real situation, users can control the robot by two methods of manual operation and programming operation (as shown in Fig. 2).

In different integrated applications, students need to select equipment. Only after selecting the correct applicable equipment, the industrial robot model will appear in the production environment, and then other operations can be continued.

During the training process, the system will give feedback and record when students make illegal operations such as making the robot run to the working limit, collision with the environment or workpiece, code programming errors (as shown in Fig. 3).

Fig. 2 Two operation modes of the teaching pendant

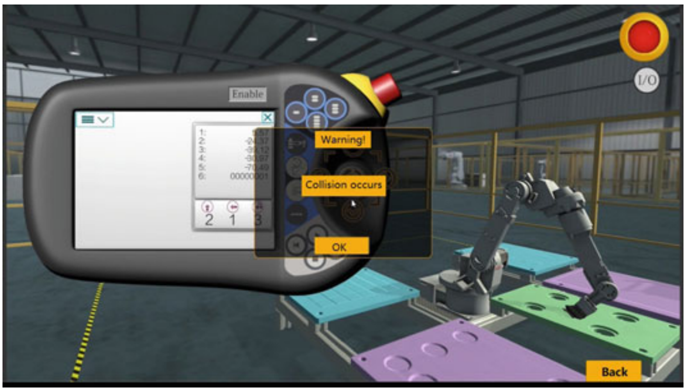

Fig. 3 Prompt for incorrect operation

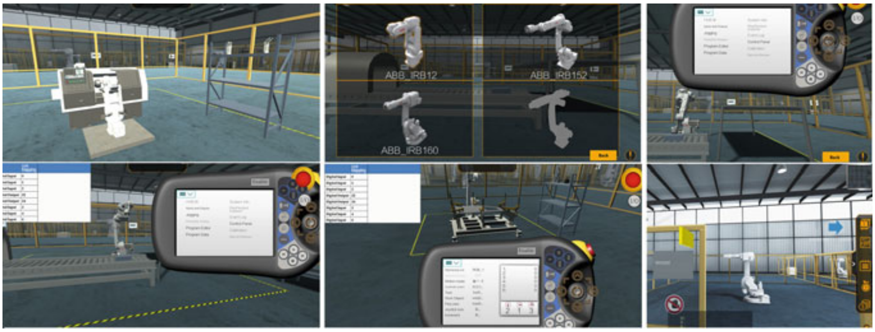

Fig. 4 Training task scenario

2.3 *Practical Training Tasks*

When evaluating each project, users should strictly follow the operation process of the real system integration project. Error operations will be promptly reminded and recorded. It will deduct ten points for each error, and each step has three chances. Opportunities for correction, all procedures can be correct before entering the next operation step. If users accumulate five errors, they need to reenter the test. After submitting the project task, students can continue to the next project. The simulation platform designed in this paper mainly arranges four training items of essential operation, handling, welding, and loading and unloading (as shown in Fig. 4).

3 Real Environment Interaction System Based on Mixed Reality Technology

3.1 *Introduction to Mixed Reality System*

MR technology is a computer vision technology that directly overlays virtual images onto real physical space. And it uses gestures, sight, gaze and other methods to interact with virtual objects. The rendering effect is as close as possible to how people interact with the real physical world [2].

In this system, the selected terminal equipment is HoloLens of Microsoft Corporation. HoloLens is a portable head-mounted holographic computer device developed by Microsoft. The front of the device is sensors-related hardware, including processors, cameras and microprojection devices. The microprojection devices can directly project images into the human eye to form holographic images. Also, the HoloLens provide gesture interaction functions, allowing users to interact with digital Holograms interact [3].

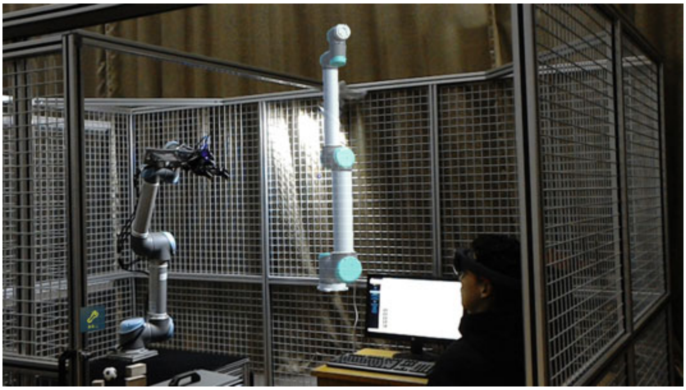

Fig. 5 Virtual device mapping in a real production environment

The model placement function of the system can place the entire virtual object in the scene on the surface of the actual object, thereby enhancing the authenticity of the system. It utilizes the device's unique spatial mapping capability (spatial mapping). After the spatial mapping function turning on, the system will continuously scan the surrounding environment and quickly update the object grid information to sense the real object. At this time, the position coordinates of the line of sight projected on the spatial mapping grid can be assigned to the entirety in the scene. The virtual object moves the line of sight following the movement of the spatially mapped grid. After the system maps the simulation model to the real production environment, users can genuinely and intuitively experience the integration effect of the device (as shown in Fig. 5).

3.2 Drag-Teaching Based on Human–Machine–Environment Interaction

The traditional industrial robot operation methods are mainly remote control of the teach pendant and code programming. This system provides a new drag-teaching method, which can make it more convenient for users to test the effect of robot movement in the environment.

After analysing the system's needs for gesture interaction in different scenarios, "Air Tap" and "Tap&Hold" were selected as the main gesture interaction methods [4]. Clicking gestures can realize a variety of functions in the system, such as viewing model information in the component observation scene, animation demonstration of the assembly path under the automatic assembly module and so on. The dragging gestures mainly implement the functions of manipulation and navigation in the manual assembly mode.

Fig. 6 Drag teaching

When the user stares at the end of the robotic arm, he can click to confirm by the gesture to start drag teaching and then use the gesture to drag the robot to move (as shown in Fig. 6).

3.3 Model Setting and IK (Inverse Kinematics) Solution

Unity3D is one of the most powerful virtual reality development engines on the market. It provides a variety of API functions required for HoloLens development. It is controlled by programming with C# language. The combination can realize the development of model observation, virtual assembly operation and 3D scene management functions in the virtual assembly system. However, its ability to build models is minimal. Therefore, you need to use professional 3D modelling software to build the model before system development. Then established model is imported into the Unity3D development environment through format conversion [5]. The specific model establishment and the format conversion process are shown in Fig. 7.

After importing models, you need to add a "Robot Controller.cs" script to the parent level of the robot model and then add relevant content to the variables in the script. Then modify the values of various parameters. Next, add the CCDIK component and the Turret component. Add the "IK Target" object to the "Target" under the CCDIK component. If it does not exist, create a new one. Set the "MaxIterations" value to 80 and "Use Rotation Limits" to "true". Add a bone node for "Bones". Set the "Weight" of a single bone node according to the robot joint number setting. Refer to Motoman HD20. The smaller the value, the less the solution relationship

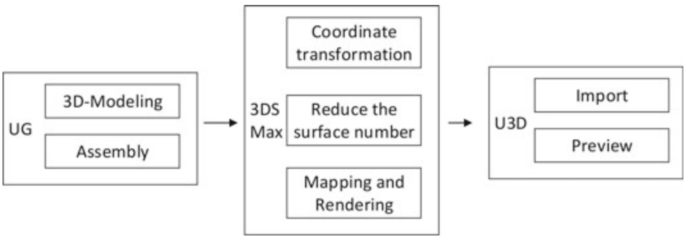

Fig. 7 Model establishment and format conversion process

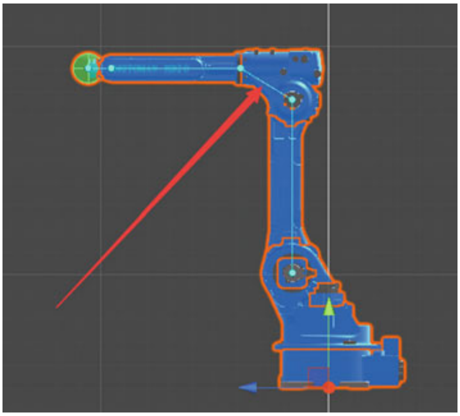

Fig. 8 Screenshot of the development environment interface

calculation If Bones are created successfully, you can see a blue line running through these critical nodes in the robot (as shown in Fig. 8).

Next, set an angle limiter for each node, add a rotation limit hinge component for each node, and set use limits to true or false, which based on the actual robot joint rotation limit angle setting. Finally, set the maximum and minimum rotation angle.

After the inverse dynamics is set, set the Turret component for the chassis. The target is the same as the CCDIK Target. Parts are the rotation tracking key point. The number of critical points in the range of “Size” is the same. (Notice: There is no perfect inverse dynamics algorithm, especially for unrestricted angle rotation joints. Therefore, when dealing with unrestricted angle rotation joints such as robotic chassis, a Turret component needs to be set separately. It is wrong to set the chassis as a part of IK. So, we can see that the six-degree-of-freedom robot has only set 5 critical nodes in the reverse dynamics setting, and the shoulder key node is used as a Turret component.)

At the same time, it should be noted that when the RobotController component is implementing network-broadcasting, it will depend on NetworkIdentity component. So, make sure that the two components are in the same GameObject, and the Animation component, CCDIK component, and Turret component are all indispensable.

4 Conclusion

This paper combines the VR technology and the MR technology to carry out the design of the industrial robot training platform and research on critical technologies. The main conclusions are as follows:

(1) The web simulation platform based on virtual reality technology has good authenticity and immersion, and the learning, training and assessment functions improve the efficiency and effectiveness of training.
(2) The use of spatial mapping technology will better integrate virtual machines and the real environment. At the same time, this paper has developed a drag-teaching method based on human–machine–environment interaction. It can be used for rapid verification operations and experimental teaching, thereby improving training efficiency.
(3) Using virtual simulation technology as a cognitive tool for students can enable students to interact with machines and the environment intuitively. And it effectively improves the quality of practical teaching, stimulates students "interest in learning and indeed improves students" practical operation ability. Provide professional teachers with a platform that integrates virtual machine models and real environments to better serve professional teaching.

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