Training Platform for Continuous Casting Based on Multi-Model Interactions

Xuejing Gu¹, Kuo Kan¹ and Yucheng Guo²

¹ College of Electrical Engineering, North China University of Science and Technology, Tangshan City, China
² College of Mechanical engineering, North China University of Science and Technology, Tangshan City, China

Abstract. Currently, the human-computer interaction technology, as the core technology of virtual reality, has been developing rapidly. By analyzing the advantages and disadvantages of the mainstream interactive equipment used in today's market and combining the advantages of the equipment, this paper posed a continuous casting training platform with multiple interactive modes. In this platform, the keyboard and mouse interaction mode, contact interaction mode and VR device interaction mode could be simultaneously applied to continuous casting training, which enables to give play to the characteristics of different interaction modes. Comparing with the single interaction mode, it proved that this platform would improve the efficiency of user interaction and enhance the training effect, as well as to propose a reference for human-computer interaction mode.

1. Introduction
Human-computer interaction refers to that the virtual reality system which enables to interact with the "virtual" world object generated by the computer in a simple and natural way under the support of interactive devices[1]. It builds a more natural and harmonious man-machine environment through two-way perception between users and virtual environment, as well as to be the core link of virtual reality to provide users with experience and move towards application.

Human-compute interaction is the path of information exchange between users and computers. In an ideal state, human-computer interaction will no longer rely on machine language[2]. In the absence of intermediate devices such as keyboard, mouse and touch screen, human-computer communication can be realized anytime and anywhere, so as to realize the ultimate integration of people's physical world and virtual world[3]. However, with the limitation of technical status, this ideal is still could not be achieved. Therefore, in human-compute interaction, how to transform the user's behavior and state into the expression that the computer could understand and operate, and transform the computer's behavior and state as the feedback that the human could understand and operate, are the key points. However, virtual reality system trends to integrate increasingly more functions, and the single interaction mode would no longer meet all functional requirements, which seriously effects user experience. Therefore, this paper proposed this multi-interaction mode system and applied it in continuous casting training.

Continuous casting production is an important production process in metallurgy industry. The training process is characterized by various knowledge points, extensive information and difficulty in simulating the circumstance of site operation. It is difficult to cover all training contents in a single way. Therefore, based on the requirements of continuous casting training, this paper applied the keyboard and mouse mode, touch mode and VR mode based on HMD (helmet mounted device) simultaneously to one system. This system enables to improve user efficiency, increase user experience, achieve the
requirements of continuous casting training, and provide a reference model for man-machine interaction mode.

2. Human-computer Interaction Mode

2.1. Human-computer Interaction Equipment

How the user inputs the information and how the system displays the information are important for the human-computer interaction in virtual reality [4]. On the one hand, by stimulating people's vision, hearing and touch, interactive devices can output information to one or several sensory organs of user, provide immersion in virtual reality and enhance the authenticity of interaction. On the other hand, interactive devices provide users with a convenient way to control the virtual world. In interactive devices, it can be divided into output devices and input devices. Output devices can be divided into visual display devices, auditory output devices and force/touch output devices. Input devices can be divided into discrete input devices, continuous input devices and direct human input device.

In virtual reality human-computer interaction, the requirements of specific interaction technologies, the mutual restrictive relationship between input devices and output devices, and the complementarity between multi-channel interaction modes should be taken into account by the selection of output/input devices[5].

2.2. Analyzing Human-computer Interaction Modes

In human-computer interaction system, interactive device selection depends on interactive content. The interaction device determines the system interaction mode. A natural, smooth and convenient interaction mode makes the system function better. Common interaction modes contain keyboard and mouse interaction mode, contact interaction mode, voice interaction mode and VR equipment interaction mode.

1) The keyboard and mouse mode is the main interaction mode of today's computer interaction, and its operation mode has been widely accepted by the public. The adoption of such interaction mode will not increase the cognitive burden while using equipment. Its command that be input through keyboard and mouse makes system interaction smoothly and increases interaction efficiently[6]. However, its interaction mode does not provide users' immersion in the virtual world, and human interaction within the system will not be natural.

2) Touch mode is a physical constraint interaction mode. Touch mode devices are the kind of hardware which in the same shape and structure. Interaction is realized in combination with software. Comparing with traditional visual interaction and auditory interaction, contact interaction can make users feel more real, which plays an irreplaceable role in the interaction process. In particular, the contact interaction mode is used in the actual operation of educational training. The user's familiarity with the operation mode that acquired with its interaction mode is incomparable to other interactive methods.

3) Voice interaction mode is a natural interaction mode, especially designed for the status when user’s both hands are engaged. Voice input will become a valuable tool for virtual reality users. It liberates the user's hands and becomes a valuable tool in the virtual reality user interface. In virtual reality interaction, voice input is especially suitable for non-graphical command interaction and system control, that is, users issue voice commands to request the system to perform specific functions, change interactive mode or system state. However, the speech interaction pattern is limited by the speech recognition technology and other factors[7].

4) The HMD is the main interactive device of virtual reality today. Through the immersive helmet or VR glasses, users could be directly exposed to the virtual world, and provide a higher sense of immersion. This technology has been widely used in shopping, games, live broadcasting, health care, real estate, military and many other neighborhoods, which is the future development trend of virtual reality. However, the interaction mode of VR equipment is not perfect. Due to the limitations of hardware and software technologies, the shaking from the screen while VR headset is functioning, could easily cause users' vertigo, so users cannot use VR headset to operate in a long time[9].
3. Design of Multi-mode Interactive Mode for Continuous Casting Training Platform

The continuous casting process in the steel plant involves a lot of devices, and each step requires close connection, which is a difficult problem for students to learn. Although operating training systems related to continuous casting has been already existed in domestic and overseas, the system usually adopts a single interactive mode to train students. The training content is single and the interaction mode is fixed, which cannot fully meet the requirements of students' training in factories. This paper proposed a training system for continuous casting with multiple interactive modes. Through effective and natural human-computer interaction modes, students are trained and evaluated in various aspects, it enables to provide a new approach for operating continuous casting equipment operation training.

The system divides the training contents of continuous casting into three main modules: safety training module, basic knowledge module and practical operation training module. The three modules correspond to three interaction modes, VR device interaction mode, keyboard and mouse interaction mode and contact interaction mode.

1) Safety knowledge training. In the safety knowledge training, students' VR headset incarnates as internship workers roaming in the virtual factory workshop, and the controller buttons of the headset control characters move and UI interaction in the virtual scene. The system will trigger different safety scenarios according to the characters' position in the factory, so that students can acquire the treatment methods and relevant safety knowledge when the accident occurs. The interaction mode of VR headset is adopted to give users a better feeling of immersion and imagination and further to promote learning efficiency.

2) Test of basic knowledge. In the basic knowledge training, the basic knowledge of continuous casting will be presented in test style. The system generated production accidents randomly to examine the students. During the test, the students get the question information through the display screen, and then answer the question via the keyboard and mouse.

3) Practical training. In the practical operation training, the user triggers the control information by controlling the buttons on the same operation platform as the actual production site. Control information is passed into the system and decoded. The virtual device performs state conversion according to the decoded information, and the device status is transmitted to the user through the display screen. Finally, control of virtual devices is implemented in this way.

4. The System Realization

The software in the system is completed by Unity3D virtual reality engine. Unity3D, a professional game engine developed by Unity Technologies, is a development tool that supports up to 29 platforms, including Windows, Mac and Android. As a widely used virtual reality development tools, Unity3D use Direct3D and OpenGL as the graphics engine, JavaScript and C# as a scripting language. It can be imported into a variety of 3d model formats, embedded with NVIDIA professional physical engine PhysX, and supports a number of mainstream VR devices.

4.1. Design and Implementation of HMD Mode

The system uses HTC Vive to implement HMD mode. The device includes a helmet-mounted display and two handles.

1) How does HTC Vive device work?

Built by HTC and Valve, the HTC Vive includes a helmet display, two handles and two positioners that adopt Lighthouse technology to locate the helmet and the handle.

The helmet display has two high-performance displays, each works in 90 frames per second. The two images are slightly offset to create a sense of depth visually. The monitor can be viewed at up to 110 degrees, covering most of a person's vision field. The helmet has a position sensor and an infrared sensor. The position sensor is used to detect the deflection of the helmet relative to its own coordinate axis. The infrared sensor measures its position in space by capturing the laser emitted by the locator. The helmet also has a 3.5mm standard audio cable connection. As a wireless motion controller, the handle can help the user to carry out auxiliary operations, as well as position sensor and infrared sensor.

HTC Vive's Lighthouse positioning technology can pinpoint the location of the helmet and the handle. The locator contains an LED array and two vertically arranged laser transmitters that work
alternately. The locator emits four set of signals in sequence with the interval in 10ms, each signal respectively indicates the beginning of scanning, and the end of vertical laser scanning, horizontal laser scanning and scanning. When the helmet and handle receive the laser, the system records the time difference and calculates the position and motion track of the relative positioner between the helmet and handle. The head-to-head tracking effect of the helmet display is very important for immersion.

2) Implementation of roaming function

Working with the HTC Vive in Unity requires the SteamVR plug-in. To produce the dual-monitor images for the 3D helmet display, the SteamVR_Camera needs to replace Unity's Camera. In addition, components representing the sound equipment need to be integrated into CameraRig. For the gamepad control, SteamVR_ControllerManager need to be added, then create two sub-game objects under this game object, add the SteamVR_TrackedObject script, and add two handles in the SteamVR_ControllerManager script.

In the virtual environment, movement and rotation of avatar which on behalf of user are controlled by using handle's touch pad and trigger. Avatar's position is changed by pressing the touch pad. Viewpoint switch is triggered by pressing the trigger and touching the pad.

The code for moving is listed as follows:

```csharp
if (device.GetPress(SteamVR_Controller.ButtonMask.Touchpad)) // When you press the trackpad
transform.Translate(device.GetAxis().y * Time.deltaTime, 0, -device.GetAxis().x * Time.deltaTime); // Move the position according to the position of pressing the touch pad
```

4.2. The Implementation of the Keyboard and Mouse Mode

The system hardware users a standard set of keyboard mouse to realize the keyboard mouse interaction mode.

1) How do the keyboard and mouse work?

The keyboard is a command and data input device for the computer which is to be used to operate the equipment. It sends commands or data to the computer in form of English letters, numbers, punctuation, etc. Keyboard contains full coding keyboard and non-full coding. The recognition function of the full-coded keyboard is completed by hardware. By identifying whether the key is pressed and which key is pressed, the fully coded circuit produces the unique coding information (such as ASCII code). The non-coding keyboard is realized by software, which uses simple hardware and a set of special keyboard coding programs to identify the location of keys, and then the CPU converts the location code into corresponding coding information through the table lookup program.

Mouse is the computer’s input device, computer display system is the vertical and horizontal coordinates of the indicator. The use of the mouse is to make computer operations more convenient and quick, in place of the cumbersome keyboard commands. Its working principle is to detect the displacement of the mouse pointer by the photoelectric sensor below it, convert the displacement signal to the electric pulse signal, and then control the movement of the mouse arrow on the screen through the processing and conversion of the program.

2) Realization of keyboard and mouse interaction mode

The system first records the currently triggered keyboard and mouse events before performing an interactive mode. The class in Unity that records mouse keyboard events is Input, where Input.GetMouseButtonDown(0) represents the left mouse button press event (0 represents the left mouse button, 1 represents the right mouse button). Input.GetKeyDown(KeyCode.*) represents the keyboard press event (* stands for keyboard letters).

In Unity, UGUI is used for keyboard and mouse interaction of UI. Controls commonly found in UGUI include Text, Image, Button, Slider, and other key-mouse interaction modes. When using UGUI, first add Canvas in Unity. All controls must be drawn in a Canvas, instead of drawing elsewhere. To realize Button click event, first put Button control into the Canvas and make it to be a child of the Canvas. Button control contains a Collider that can detect a mouse click event at any time. The corresponding button event is triggered when the button control is clicked.

4.3. The Realization of the Contact Interaction Mode

The system uses the same operating station as the production site to realize the contact interactive mode.
1) Continuous casting console hardware equipment
The operation platform of continuous casting refers to the operating equipment which is placed on the working site of continuous casting and used to control the technological process of continuous casting manually. It consists of an operating table and control buttons, indicator lights and measuring instruments. Indicator lights and measuring instruments are used to display the status and data from continuous casting production site and are not used for manual operation. The control button is used to control the production process of continuous casting. The control button consists of two types: button and knob. The button can be pressed or pushed, and the knob can be rotated in 45 degrees to the left or right while sending data to the system.

2) Signal transformation of the system
In the system, 51 MCU is used to collect data, which will be sent to the upper computer through the serial port. First define the data protocol according to the actual needs, that is, start byte with ¥, then 2 bytes for status bit of P0,P1 port, and finally end byte with #bit . Then, the microcontroller collects the state from the data register of P0 and P1 in real time and assigns the value to the pre-defined variables. In this step, the hardware is connected to each IO port of P0 and P1 by the console, so as to simulate the generation of control signal. Finally, these variables are formed into an array, through the single chip serial port to send into array.

In the Unity3D engine, it receives the data sent by the serial port of the single chip computer, and decodes the data, and drives each single virtual device to move according to the code. When the individual monomers are running to the specified position, a limit signal needs to be generated, with the integer "1" representing the finite bit and "0" representing the infinite bit. The limit signal here is consistent with the limit signal of the equipment in the real continuous casting workshop. In the industrial field, the limit device such as photoelectric switch is adopted, which is generated through object collision in the virtual scene. System will waiting for the subsequent data sent by the microcontroller after decoding till the end of the task.

5. Demonstration of System Operation
The training platform of multi-interaction mode system is shown in Fig.1. A1 shows the mouse-keyboard operating equipment, and A2 and A3 illustrate the operator using the mouse and keyboard to answer the questions that generated by the system, as well as the results while the questions are answer correctly. B1 shows to operate equipment via the operation console, B2 and B3 show the operator pressing the button and cutting gun working in the virtual scene for cutting. C1 shows VR equipment, and C2 and C3 show operators use VR handle to control the movement, and there will be different safety knowledge tips when moving to different position.
6. Summary
This paper analyzes the advantages and disadvantages of each interaction mode used today. According to the requirements of continuous casting training, keyboard and mouse mode, touch mode and HMD mode are applied to the continuous casting training system. The results show that the platform improves the user interaction efficiency, increases the user experience, realizes the requirements of continuous casting training, and provides a new method for human-computer interaction mode.

7. References
[1] Li C L 2017 Research on human-computer interaction in virtual reality system. Zhejiang University
[2] Zhang F J, Dai G Z, Peng X L 2016 Overview of human computer interaction in virtual reality SCIENCE CHINA Information Sciences. 1711-36.
[3] Dix 2016 human-computer interaction
[4] Lazar J, Barbosa S D 2016 Introduction to human computer interaction Acm Conference Extended Abstracts on Human Factors in Computing Systems. 933-5.
[5] Chang-Chun Y E, Chen L Q 2016 A prototyping-based experimental scheme of human-computer interaction course.
[6] Yoshioka K 2018 Development and psychological effects of a VR device rehabilitation program: art program with feed back system reflecting achievement levels in rehabilitation exercises. International Conference on Kansei Engineering & Emotion Research. 538-46.
[7] M. Hamidia, N. Zenati, H. Belghit 2016 Voice interaction using gaussian mixture models for augmented reality applications International Conference on Electrical Engineering.
[8] Budhiraja P, Miller M. R., Mod A. K 2017 Rotation blurring: use of artificial blurring to reduce cybersickness in virtual reality first person shooter.