The Floating Touch Stereoscopic Display System with Eye-tracking

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ABSTRACT

This paper proposes a floating touch stereoscopic display system combined with eye tracking. Floating touch mitigates the focusing conflict effectively compared to mouse operation other indirect ways. And eye-tracking can avoid display error caused by eye movement and interaction failure due to absence of motion parallax. It's demonstrated that the proposed system raised interaction success rate obviously especially people watch from the side.

1 Introduction

With the continuous breakthrough of LCD process technology, the PPI of display plane has increased year by year, and the stereoscopic display has ushered in a new development. The interaction mode of the stereoscopic display system has become one of the follow-up problems to be solved urgently. In the traditional stereoscopic display system, the interaction problem is not considered, and the operation usually is accomplished by mouse, which leads to serious focusing conflict. It means when you operate with the mouse, eyes usually focus on the surface of screen, however the parallax image on the screen meanwhile guides our eyes focusing in front of/behind the screen, which causes focusing conflict. Later, some stereoscopic display systems use wearable devices to realize gesture operation, but it is inconvenient and unreal [1,2]. After the somatosensory controller is widely commercialized, more and more stereoscopic display systems use Leap Motion or Kinect for interactive implementation, in addition to indirect touch [3,4], and even direct touch of virtual objects [5,6], This greatly enhances interactivity and immersion.

However, for the raster stereoscopic display, especially the stereoscopic display screen with narrow viewing angle, the viewing position is relatively fixed. Once the position changes due to interaction, serious crosstalk will occur, and the user's experience is not good. Meanwhile, because of absence of motion parallax, the position of the virtual object will also change from different view angle, and "real touch" cannot be realized. Based on this, this paper introduces a kind of floating touch stereo display system combined with eye tracking. The system has three-axis motion parallax, which means stereoscopic content changes with the position of the user, and achieve real touch interaction with high accuracy.

2 Method

2.1 System structure

The overall architecture is shown in Fig. 1. The stereoscopic display system proposed in this paper consists of a raster stereoscopic display screen, an eye tracking device, a gesture recognition device and a computer. A virtual space is pre-created on the computer, including dual virtual cameras and a hand model, a gesture recognition device model, a virtual screen, and a 3D model placed between the virtual screen and the dual virtual cameras for interaction. The size conversion standard between the real world and the virtual space will be obtained by ration of the virtual screen size corresponds to the real screen size. The relative position of the virtual screen and the gesture recognition device model is converted according to the positional relationship in the real world.

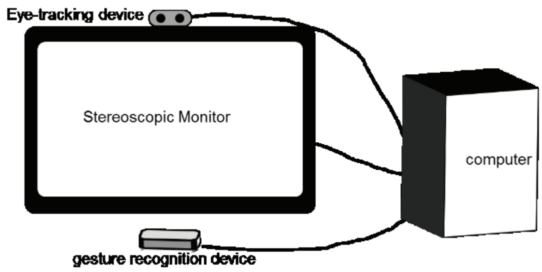

Fig. 1 System schematic diagram

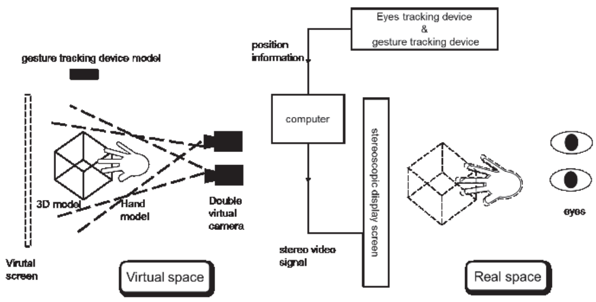

Fig. 2 System principle diagram

The working principle of the system is shown in Fig. 2. Eye-tracking is realized by eye tracking device. It will capture the projected position of the user's eyes on the screen and the distance from the screen and transmit it to the computer. By coordinate transformation, the computer determines the position of the dual virtual cameras according to the virtual screen. The image of the 3D model captured by the dual virtual cameras generates the disparity map according to the cylindrical lens parameters and transmitted back to the display for stereoscopic display.

Gesture interaction is realized by gesture recognition device. The gesture recognition device detects the relative positional relationship between the hand and itself, and inputs it to the computer. The computer calculates the relative positional relationship between the hand model and the gesture recognition device model in the virtual space. Since the relative positions of the virtual screen and the gesture recognition device model are consistent with the mapping relationship in reality, the hand model captured by the dual virtual cameras and displayed on the screen will coincide with the real hand in the user's field of vision. Therefore, the interaction between the human hand model and the 3D model, in the eyes of the user, is the interaction between the user's hand and the floating 3D model, resulting in a "real touch" feeling.

2.2 System Prototype

The prototype of the stereoscopic system is shown in Fig. 3, which includes a 32-inch 8K cylindrical lens raster stereoscopic display screen, a Real-sense depth camera for eye tracking, Leap Motion for gesture recognition, and a computer host. Virtual space model is done in Unity (Fig. 4). Also, we developed a set of algorithm to accomplish coordinate system transformation in real time.

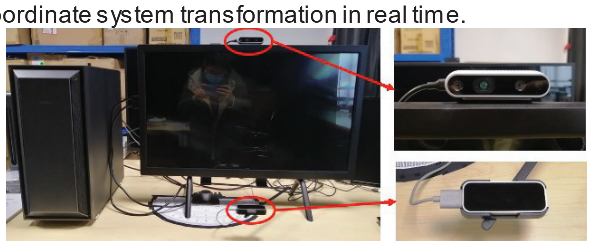

Fig. 3 System prototype

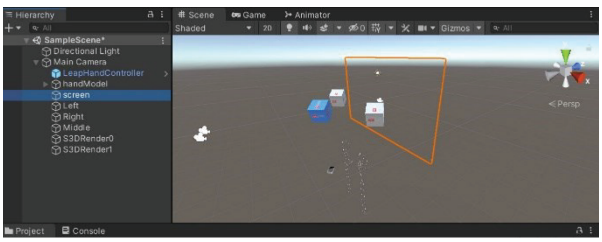

Fig. 4 The virtual space build in unity

2.3 parameter

The best viewing distance of the lenticular lens of the stereo display is 730 MM, and two viewpoints are arranged. The viewing angle is 10.5° in non-tracking mode. With eye tracking, XYZ motion parallax can be realized (Fig. 5), the best viewing angle is 25°(X)/39°(Y), and the Z axis is 0.5-1.2 M. If only the stereoscopic display effect in the center of the field of view is considered, and the viewing angle is up to 55°(X)/ 52.65°(Y), Z axis 0.45-2.2 M.

In addition, a tracking delay test was performed. A program is building for test, which shows a green dot representing the projected position of the user's eyes during eye-tracking. The tester faces the center of the screen and keeps a fixed distance from the screen, quickly moves his/her head to the left (or right) and then returns, and records the movement of the head and the green dot through high-speed photography. Record the head reentry time and the dot reentry time, and the difference between the two is the tracking delay time. The measured latency is about 150-160ms.

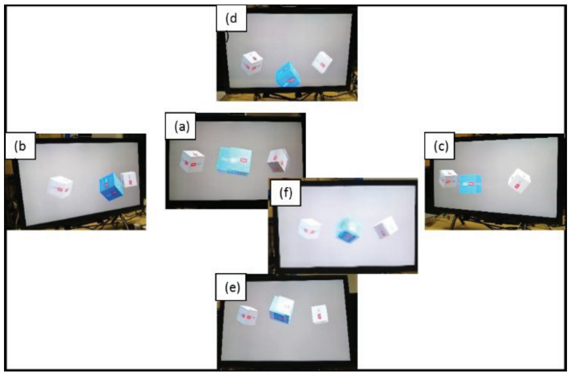

Fig. 5 Figure 5 Stereoscopic images at different positions. (a) Front; (b) Left; (c) Right; (d) Top; (e) Bottom; (f) Back

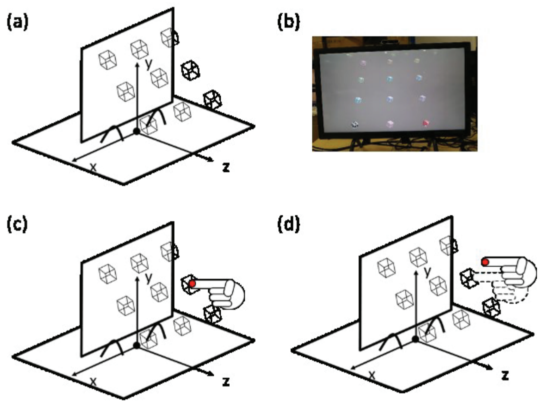

Fig. 6 Floating touch accuracy test. (a) cube array diagram; (b) Photography of cube array model displayed on screen; (c) With the hand model closed, cube position marked with fingertip (red dot) ;(d) With the hand model open, hand model position location marked with fingertip (red dot)

For the test of gesture recognition accuracy, a cube matrix is designed, whose spatial arrangement is shown in Fig. 6(a)&(b), and the size of the cube is about 2cm. Tester faces the center of the screen and maintains an optimal viewing distance from the screen. First, with the hand model closed, the tester locates the position of each cube center in space with the tip of the index finger and records the coordinate of fingertip (Fig. 6(c)). Then open the hand model, tester moves index finger to make the corresponding finger of the hand model move to the center of the cube, and record the coordinate of fingertip (Fig. 6(d)). Comparing the coordinate deviation of the two records before and after is the accuracy error of the floating touch. The results show that the accuracy error can be basically controlled within 20%.

3 Experiment

For demonstrating the improvement of the interaction experience by eye tracking, grasping tests were performed in tracking and non-tracking states, respectively. A test program was set up as shown in Fig. 7. The tester faces the screen form the middle, left and right, and tries to grasp each object and pull it for a certain distance. For each object, it will repeat 3 times. The times of successful grasps is shown in Table 1. It’s found that when facing the screen, the grasping success rate was relatively high in both tracking and non-tracking states. When facing the screen form the left and right sides, the success rate in the non-tracking state is significantly reduced. Compared with the overall success rate, it is about 50% in the non-tracking state, while it can reach more than 90% in the tracking state. And the tester expresses that in the non-tracking state, it is easy to observe ghosting when reaching out and grasping, which affects the interaction experience.

Table 1 Table of Number of successful grasps

w/o eyetracking			
Item	left	middle	right
lung	3	2	1
kidney	3	1	0
stomach	3	1	0
intestine	3	0	1
heart	2	3	0
liver	2	1	1
diaphragm	2	3	0

w/ eyetracking			
Item	left	middle	right
lung	3	3	3
kidney	3	2	3
stomach	3	3	1
intestine	3	3	3
heart	3	2	3
liver	3	2	2
diaphragm	3	3	3

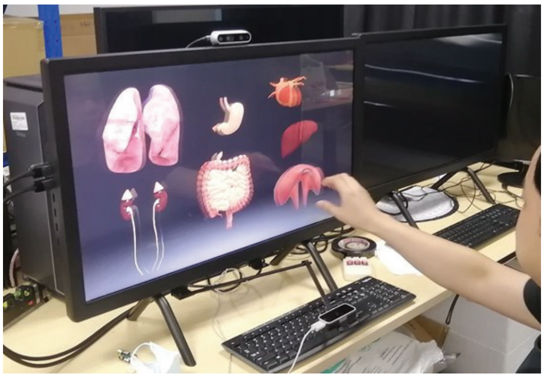

Fig. 7 Grasping test

4 Conclusion

In this paper, a floating touch stereo display system with eye tracking is proposed. The motion parallax of XYZ three axes is realized with eye tracking, and the maximum viewing angle can reach 55°(X)/52.65°(Y), the view distance is in 0.45-2.2 M (Z). For floating touch, accuracy error can be basically controlled within 20%. Besides, the correct stereoscopic effect can be seen from different angles due to the eye tracking, so that the interaction success rate has increased from 50% to more than 90%.

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