An Interactive Multi-Channel Display for Immersive Education

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Abstract

With the increasing technology of virtual reality, educational platforms are evolving for more effective and more immersive systems. A multi-channel display is one of the effective and immersive virtual reality systems for generating high-quality images and guaranteeing a wide view angle using multiple projectors. In this work, we present a multi-channel display system where a high resolution image is projected on a huge screen (its resolution is 4096 x 1536 and its effective resolution is 3200x1200) and we also propose interaction hardware which can recognize a user's motion and transfer it to the proposed multi-channel display system. Furthermore, we apply a seamless technique to this system in order to remove joint lines and to improve the quality of images. We implement educational contents for experiencing a CMOS manufacturing process based on the proposed multi-channel display system.

1. Instruction

The emergence of virtual reality technology and its great improvement have led to tools to realistically describe real world. Although, many education systems provide a wide range of benefits to students, the systems have some problems to be solved before accepting. One of these problems is that the systems do not provide immersion and the sense of reality to users. Therefore, the education system based on virtual reality technology can be a solution for immersive training because virtual reality systems enable users to experience phenomena in virtual environment which are difficult to be illustrated in real world. Furthermore, users can learn how to operate a target device in virtual world.
Virtual reality technology in its early stage has been focused on displaying and rendering the shape of a target object on 2D monitors or limited screens. These systems are not suitable for the following cases : 1) where visual contents are important; 2) where high resolution display is necessary; and 3) where a wide field of view is required. For these cases, researchers have developed multi-chanel display systems (Hereld et al, 1999, Yang et al, 2001, Chen et al, 2001, and Krishnaprasad et al, 2004) which can generate high resolution images and can fill up users' field of view with the images.
This paper proposes an interactive multi-channel display system where a high resolution image generates by binding images obtained from multiple low resolution projectors. Furthermore, we implement the educational contents on the proposed tile display system.

System Architecture

We constructed a multi-channel display system which provides immersive sensation to users. Figure 1 shows the hardware configuration of the proposed system. The system was implemented with a single PC and 2000 ANSI DLP projectors whose resolution is 1024 x 768. Two graphic cards were included in the single PC and each graphic card has two graphic output ports. Each graphic output port has a Graphics eXpansion Module(GXM) which connects a graphic output port to two visual displays. Therefore, our system generates huge and high resolution images by joining eight projection areas with a single PC as shown in Figures 1 and 2. As shown in Figure 1, eight small images are created by eight projectors in order to construct one huge image on the screen.
In this system, all parts for graphic rendering were implemented in a single PC. The graphic programming was car-

ried out by a program written in VC++ with Direct X. Wireless communication (Bluetooth communication) was used for data transfer in conjunction with the PC and remote devices. The wireless communication was achieved with 115,200 baud rate. For conveying user's motion or command to the PC, interaction hardware was developed. IR(Infra-red) sensors detect human's position and movement and the detected motion is transmitted to the computer via wireless communication.

Figure 1: Hardware system architecture

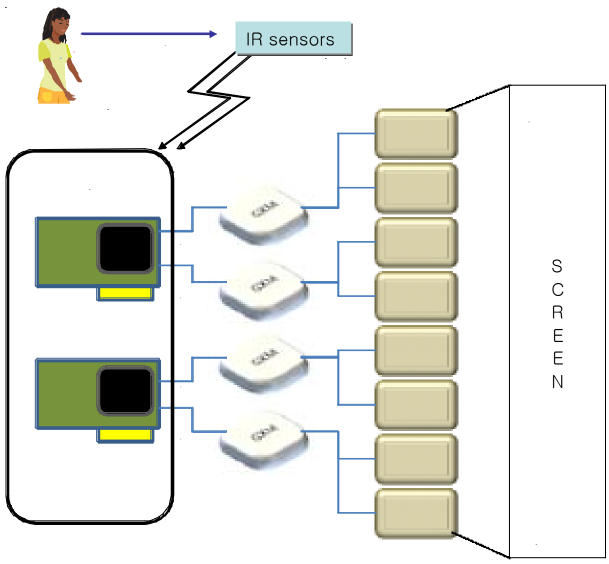


Figure 2. (a) Screen, (b) Arrangement of projectors

Figure 3 shows the signal flow of the proposed system. A user grasps an interaction hardware system and moves it for transferring his/her command to the PC. The signal for moving is transferred to the data receiving part in the PC and interpreted by the command interpreter. According to the user's command, virtual objects are displayed, rotated or moved by the graphic rendering part. After that, the rendered images are projected on the screen via GXM and projectors. Therefore, the user can experience the virtual images as the virtual images exist in real world

One of the most important factors in virtual reality is to convey the sense of reality to users. One of the conditions to increase the sense of the reality is to fill a user's field of view (FOV) with high resolution virtual images. Humans have an almost 180o forward-facing field of view (FOV) and 120o an effective FOV (Authur, 2000).

There are four major screens for expressing virtual environment: (1) a wall type, (2) a cylindrical type, (3) a dome type, and (4) a CAVE type. Since the advantage of a multi-channel display system is to share a virtual environment among users, we decided to choose a cylindrical type screen which provides a wide FOV. However, when virtual images are projected on the cylindrical screen, it is necessary consider a complex calibration method for generating continuous images. Another problem is that the position of a target object is hard to be computed and to be presented on the cylindrical type screen. Therefore, in this work, we implemented a folded type screen which brings into relief the advantage and supplements the disadvantage of the cylindrical screen as shown in Figure 4. Since each sub-screen in the folded type is flat, the proposed multi-channel display system is not only easy to establish, to maintain, and to repair but also easy to calibrate. In Figure 4, each part (®Á~®Ó) is a projection area. In this symmetric screen, the angle of refraction between the left sub-screen (®Á, ®Î) and the middle sub-screen (®Í, ®Ó) is 120o. If the distance between a user and the screen is 1 meter, the field of view becomes about 160o.

Figure 3. Signal Flow of our system.

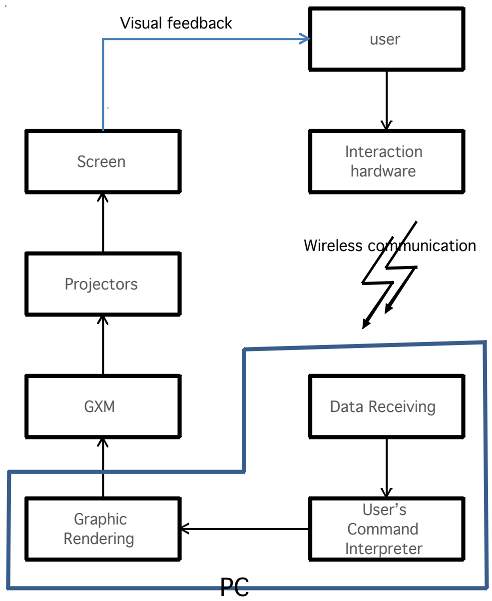
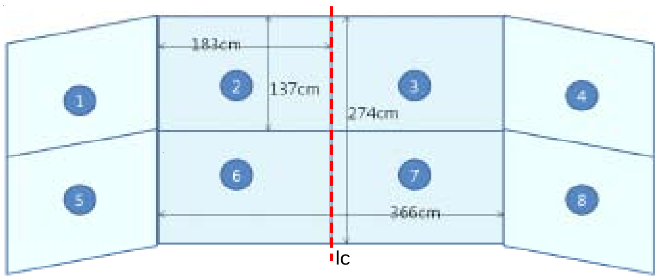


Figure 4. The shape and the size of the proposed screen.



2. Result

The graphic simulations were carried out by a program written in Visual C++ with direct X. As mentioned above, we used 8 projectors to create huge and high resolution images. Since projectors can be moved or rotated by a small amount of disturbance (for example, certain vibration, small impact, and/or etc.), we purposely overlapped the portions which the projectors undertook as shown in Figure 5. However, this installation causes an image to distort. For compensating this distortion, we conducted geometric calibration.

Figure 6 shows an example of geometric calibration procedure when four projectors employed in a multi-channel display. Figures 6(a) and 6(b) show the images before and after the geometric calibration, respectively. Consider the situation where four projection sub-images are overlapped and distorted according to the arrangement of projectors as shown in Figure 6(a). These overlapped and distorted sub-images need to be adjusted to the compensated region (bold rectangle portions (Figure 6(b)) through the calibration method.

Figure 5: Overlapped Projection.

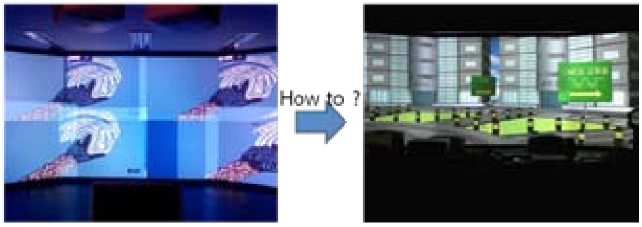
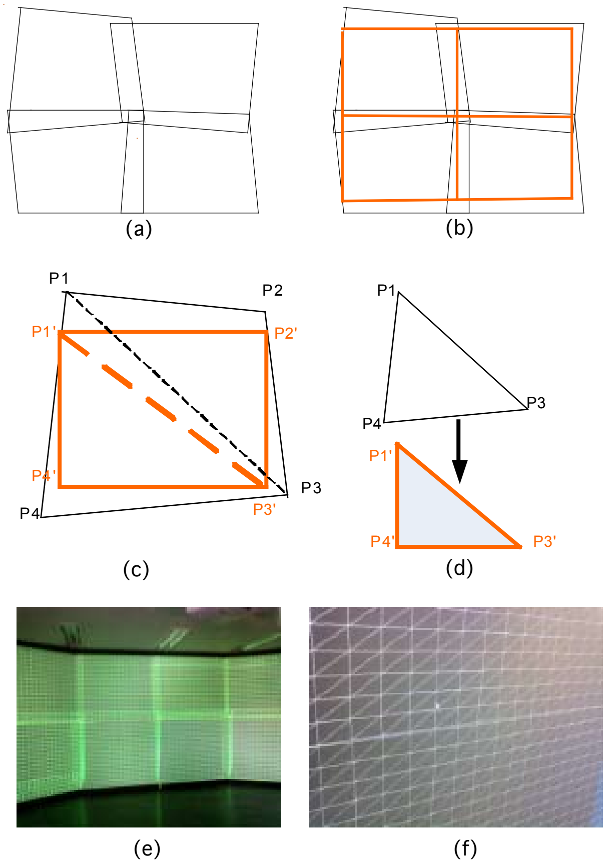


Figure 6. Geometric Calibration.



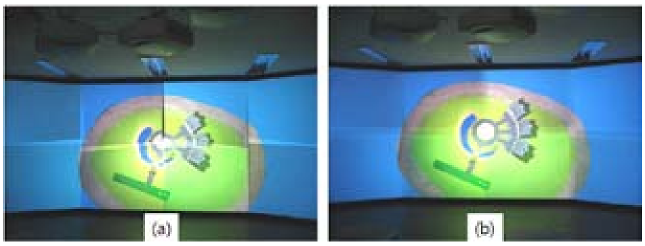
For compensation, original projection portions and the calibrated projection portions are divided into triangles, respectively as shown in Figures 6(c) and 6(d). After that, the position of each vertex was adjusted in texture buffer as shown in Figures 6(e) and 6(f). For this procedure, we calculated transformation matrix from the triangle (P1,P3, P4) in Figure 6(d) to the triangle (P’1,P’3, P’4) using equation 1. In Figures 6(c) and 6(d), let’s define the coordinate values of P1, P3, P4 as (x1,y1), (x3,y3), and (x4,y4), respectively. We also define the coordinate values of P1’, P3’, P4’ as (s1,t1), (s3,t3), and (s4,t4), respectively. Figures 7(a) and 7(b) show the results before and after the calibration method, respectively.

Figure 7. (a) Before and (b) after calibration

$$P_1 = (x_1, y_1),\quad P_2 = (x_2, y_2),\quad P_3 = (x_3, y_3) \tag{1.a}$$

$$P'_1 = (s_1, t_1),\quad P'_2 = (s_2, t_2),\quad P'_3 = (s_3, t_3) \tag{1.b}$$

$$M = \begin{bmatrix} m11 & m12 & m13 \\ m21 & m22 & m23 \\ 0 & 0 & 1 \end{bmatrix} = \begin{bmatrix} s1 & s2 & s3 \\ t1 & t2 & t3 \\ 0 & 0 & 1 \end{bmatrix} \times \begin{bmatrix} x1 & x2 & x3 \\ y1 & y2 & y3 \\ 0 & 0 & 1 \end{bmatrix}^{-1} \tag{1.c}$$

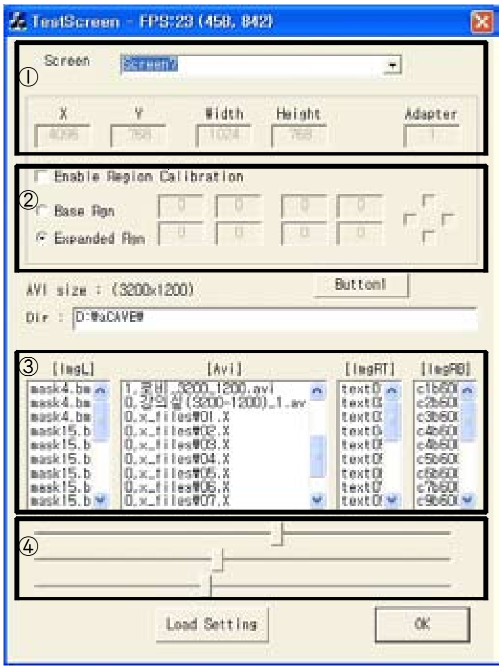


3. Authoring tool

We implemented a virtual silicon island (VSI) where users can learn semiconductor manufacturing processes. Users arrived at the VSI and walked in one of the buildings where they can study the semi-conductor manufacturing process. We already developed a VSI authoring tool [7] in order to easily create, edit, and play semiconductor contents. A user can insert or delete the semiconductor manufacturing components through the VSI authoring tool. However, there are no buttons or bars to rotate, translate, and scale up/down a target object and there is only movie clip in the previous virtual reality platform. In this work, we developed interaction hardware and software in order to control a virtual object. To this end, we constructed virtual models with 3DMAX and then we convert 3DMax file into x file format to easily load it in directX graphic library. Therefore, in this authoring tool, we can play movie clips and also load virtual models.

The previous VSI authoring tool [7] consists of a screen control part(①), a calibration part(②), and a contents control part(③). The screen control part allows a user to determine the size of an image. The calibration part adjusts the overlapped and the projective regions. In the contents control part, multimedia objects based on movie clips are displayed. Once multimedia contents are registered in the contents control part, a user can control and play them on the huge screen by just clicking a mouse or pressing a keyboard. In this work, we added an interaction part(④) to the previous authoring tool in order to rotate, magnify, reduce, and translate the virtual object.

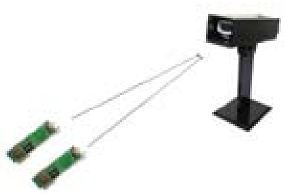
Figure 8. VSI authoring tool



4. Interaction.

In this work, we focused on developing interaction hardware which recognizes and analyzes a user's motion and transfers it to virtual environment. We attached infrared LEDs to the interaction hardware and mounted a tracker on the PC. If a user grasps the interaction hardware and moves it, the tracker receives signal from the infrared LED and recognizes the user's motion. For more accurate interaction, we conducted a calibration between an IR tracker and the screen. The calibrated data was transferred to a main PC to operate the interaction hardware as shown in Figure 9. This interaction hardware can be used for not only recognizing the user's motion but also controlling the authoring tool.

Figure 9. Interaction Hardware



A user can rotate a virtual image in our multi-channel display with the interaction hardware. If the first slide bar is moved to the right with the interaction hardware, the virtual image is rotated along the x-direction. When a user moves the second slide bar to the right, the image is rotated along the z-direction. The third slide bar is for zooming the image. Figure 10 shows the rotated or magnified images. Figures 10(a) and 10(b) show an initial semiconductor image and the rotated images, along the x-direction respectively. Figures 10(c) and 10(d) illustrate the scaled images and Figures 10(e) and 10(f) are the rotated images along the z-direction. With this interaction hardware, a user can write characters on the screen as shown in Figure 11.

Figure 10. Interactive virtual platform.

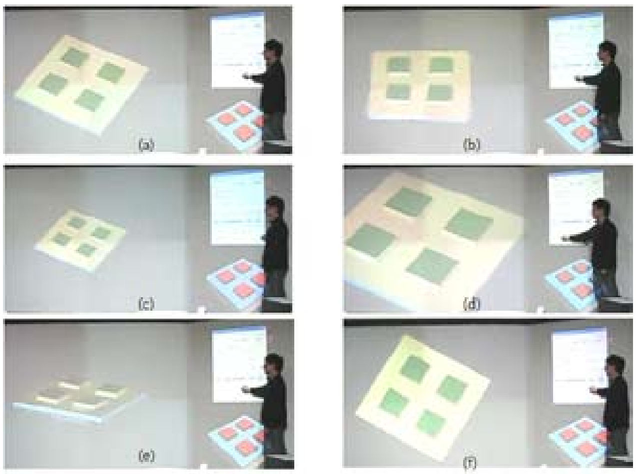


Figure 11. Writing characters on the screen.

5. Conclusion.

A virtual reality system becomes a more user-friendly interface than the other systems in education fields. In this work, we developed the multi-channel display system for educating semiconductor manufacturing processes and conducted calibration in order to compensate the distorted image and to increase the sense of reality. Moreover, we present natural interaction technology for effective lecture with the proposed platform.

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