An Interactive MR System with Image Splitter 3D Display

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Abstract

Mixed-Reality (MR) is remarkable in many fields and Head-Mounted-Display (HMD) is considered as the main device for MR now. We propose that MR will be accomplished by using the stereoscopic display without glasses as well as HMD. We have developed a high performance stereoscopic display using our original Image Splitter which can provide left and right images to both eyes without special glasses. And we have applied this 3-D display to a Mixed Reality field. And we have attached the haptic device for our system. Operators can interact the virtual object by a real object easily with tactile feedback. This system will be suitable to training simulator system for example surgical simulator, aircraft maintenance simulator, industrial machine repair simulator and so on. This system will create the new training environment we can handle the various virtual situation with real tools in our own hand.

Key words: Image Splitter, Mixed Reality, force feed back, SPIDAR

1. Introduction

Recently, Mixed-Reality (MR) is remarkable in many fields, such as medical, games, multimedia, and attractions for the various events. MR technique is the concept that includes Augmented Reality (AR) and Augmented Virtuality(AV).[1][2] AR is to augment the real world by electrical virtual information, and AV is to augment the virtual world by real information. But the boundary between AR and AV is not defined accurately. MR is to create the new world combining the real and virtual world. Therefore the display we can see the real and virtual world is necessary for MR technique. Although we can use the various type of display for MR, Head-Mounted-Display (HMD) is considered as the main device for MR now. However most of the users feels that HMD is not comfortable, because it is too tight or too heavy.
We propose that MR will be accomplished by using the stereoscopic display without glasses as well as HMD.

We have developed a new high performance stereoscopic LC display (XGA3-D display) using our original Image Splitter™, which does not require special glasses to achieve a 3-D effect.[3] We have developed a prototype of virtual reality system with this 3-D display. Furthermore, we have applied our virtual reality system to a Mixed-Reality system.[4]

With our system, operator can interact the virtual objects by a real tool in our own hand easily. And it can provide us the tactile sensation by force feedback system.

2. 3D display with Image Splitter

2.1 Image Splitter 3-D display

Fig.1 shows the principle of the Image Splitter 3-D Display.[5] An optical filter named Image Splitter is composed by glass plate and covered by absorbent coat and it is attached on both face of the LC panel. The backlight side splitter is the high-reflection type and the viewer-side one is made of a low-reflection layer. The images on the LC panel are efficiently separated into right eye and left eye images by Image Splitter. It has an aperture for each two pixels and designed to provide the right and left eye image for both eyes through these apertures. A set of 3-D images are displayed on alternate columns of LCD. Observers can recognize the 3-D images without special glasses.

When the viewer is in the center position of the display, each eye perceives only one image without special glasses and then viewer recognize them as the stereoscopic images. In this principle, we use the double image splitter (splitter 1 and splitter 2) for the purpose of improving the quality of 3D-image, that is removing the moire or crosstalk which are peculiar problems to stereoscopic displays with no special glasses.

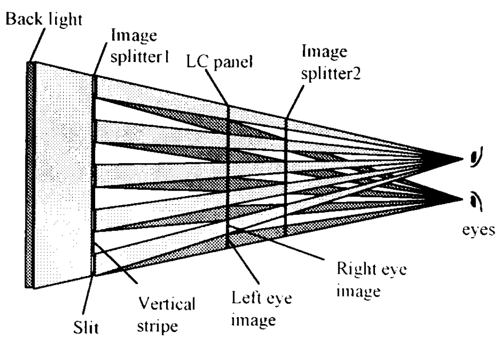

Fig. 1 Principle of Image Splitter

2.2 Characteristic of the Image Splitter

As Fig.2 shows the characteristic of the Image Splitter, the position 1 is at the front of display and it can provide us the normal stereoscopic image and it is the same with the position 3. But in case of the position 2, 4, the right eye image comes into left eye, and left eye image comes into right eye. This phenomenon is called pseudoscopic. When this phenomenon occurs, the observer can not see 3-D images.

Furthermore, the observers will view the display from different angles, but the display shows the only one pair parallax image for both eyes. So observers can not move their head in front of the display. When they interact the virtual object by a mouse or a joystick, they can not move their head or body. This causes the lack of the reality.

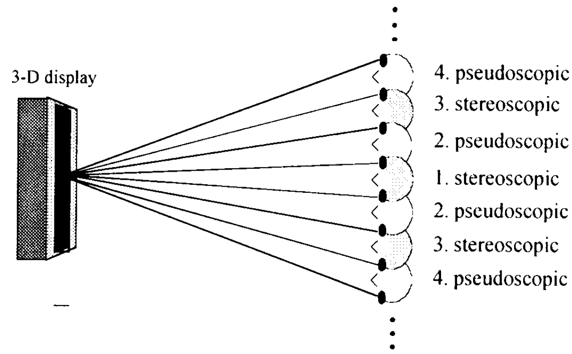

Fig. 2 The Characteristic of the Image Splitter

2.3 Head Tracking System

This display is equipped with the Head-Tracking-Sensor to prevent the pseudoscopic (Fig.3). This sensor detects the position of the observer's head (viewpoint) and sends the signal to the image switching circuit. In case of the position 1, 3 in the Fig.2, the display shows the each images to both eyes. But in case of position 2, 4 in the Fig.2, the circuit switches these images to show to inverse eyes. As a result the display shows the images for both eyes without pseudoscopic.

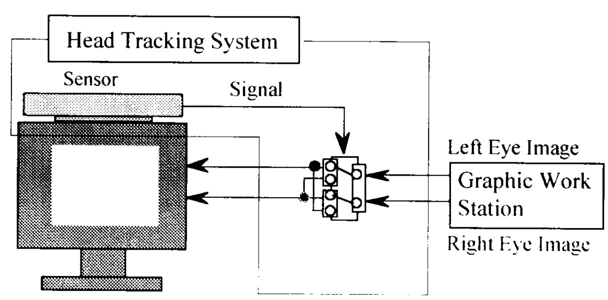

Fig. 3 Head Tracking System

2.4 High Resolution

We had developed a 4, 6, 10 inch Image Splitter 3-D displays. The resolution provided to each eye is about half a NTSC resolution. We developed a new high performance 14.5inch 3-D display (XGA 3-D display) with high resolution about NTSC for each eye. In addition, by optimizing the aperture ratio of the Image Splitters, we have achieved a moire-less autostereoscopic display. Table 1 describes the specification of the Image Splitter 3-D display. And Fig. 4 shows the XGA 3-D display.

Table 1. Specification of the Image Splitter

Screen size	14.5 inch
Display type	Double Image Splitter
Number of pixels	1024X768 (XGA)
Optimum viewing distance	Approximately 60cm
Input	Analog RGB
Luminance	Approximately 350cd/m^2

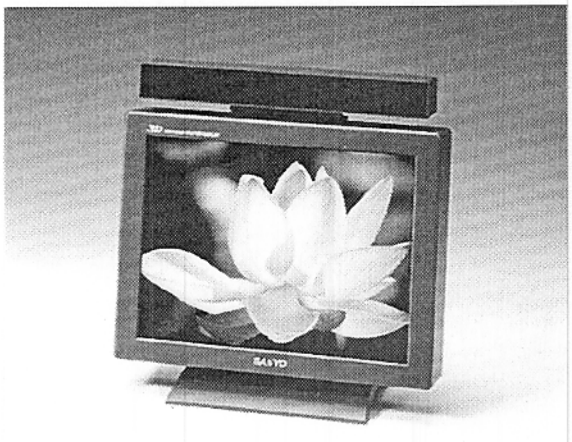

Fig. 4 XGA 3-D display

3. Structure of Mixed Reality Environment

3.1 Mixed Area

Fig.5 shows the area where the virtual and real objects are mixed together. The display width is about 22cm and the optimum viewing distance is about 60cm.

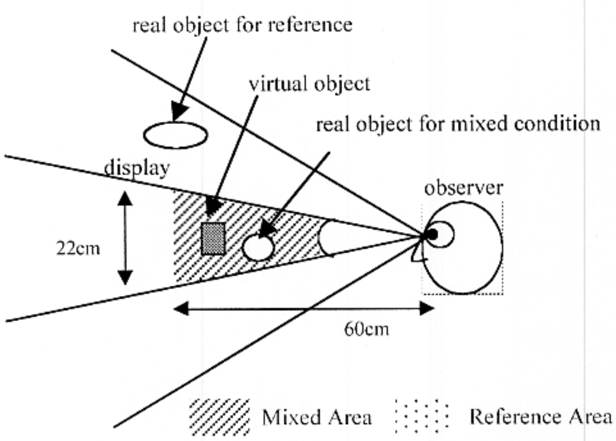

Fig. 5 Mixed Area

The angle α is

$$\sin\frac{\alpha}{2} = \frac{11}{60}$$

$$\alpha = 21.13°$$

The virtual and real object are mixed in the virgule area. We can put the real object in the reference area. If we put it outside of the mixed area as shown in Fig.5, the virtual object can be perceived closer to the observer, in short the depth perception is emphasized.

3.2 Occlusion between Virtual and Real Object

With our MR system, virtual object is always overlapped by real object. It causes the contradiction of occlusion between virtual and real object. And because of this contradiction, operators can not recognize the 3-D images.

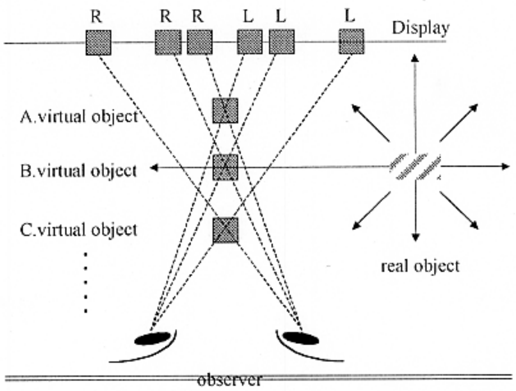

Fig. 6 Occlusion

Applying the Image Splitter 3-D display to the MR, there are real object between the observer and the display. As illustrated in the Fig.6, there are three cases.

A: The virtual object is behind the real one

B: The virtual and real object are same depth

C: The real object is behind the virtual one

We have examined the visual perception of the context about virtual and real object for these cases. In the case of C, according to the subjective evaluation, most of the subjects can not perceive the context of these objects. In addition, we have examined the accommodation of the subject's vision system in these conditions. In case of C, a disorder occurs more often than other cases. This result suggests that when we apply the Image-Splitter 3D display to MR, we should avoid the virtual objects to be nearer to the observer than real object.

4. SPIDAR

~ SPace Interface Device for Artificial Reality ~

SPIDAR is the force feedback system and composed by the frames, strings, motors and rotary encoders.[6] Strings are centralized from vertexes of the frames where the motors equipped. To roll up the strings by the motors, SPIDAR generates the force and tactile sense.

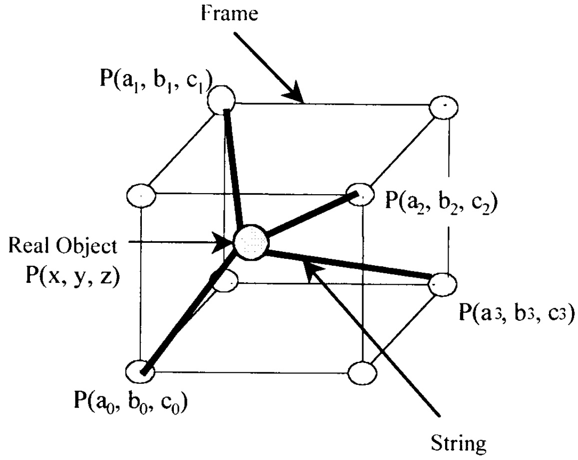

Fig. 7 SPIDAR

The rotary encoder determines the coordinate of the pointer by detecting the variety of the string. To add the initial value and variety of the string cumulatively, it can get the string length. From these equations, the coordinate of the pointer (x, y, z) is determined. As illustrated in Fig.7, The coordinate of the four vertexes are (a_i, b_i, c_i) $(i = 0{\sim}3)$, and the length of the string is $l_i (i = 0{\sim}3)$. From the following equations, the coordinate of the pointer, namely the tip of the stick, is determined.

$$(x-a_0)^2+(y-b_0)^2+(z-c_0)^2=l_0^2$$
$$(x-a_1)^2+(y-b_1)^2+(z-c_1)^2=l_1^2$$
$$(x-a_2)^2+(y-b_2)^2+(z-c_2)^2=l_2^2$$
$$(x-a_3)^2+(y-b_3)^2+(z-c_3)^2=l_3^2$$

The rotary encoder converts the variation of the string length into the coordinate of the pointer. To restrict the motion of the stick touching the virtual object generates the force and tactile sense.

In our system, to control the strings fixed to the tip of the stick generates the force and tactile sense.

5. System Description

Fig.8 suggested our Mixed Reality system.
Our system is composed by four parts, 3-D display, SPIDAR, Head-Tracking-System and Graphic-Workstation.
Graphic Workstation makes CG for both eyes.
The Head-Tracking-Sensor detects the viewpoint and Video-Switch-Circuit switches the right and left eye images to prevent pseudoscopic.
SPIDAR detects the position of the pointer and generate force and tactile sense.

SPIDAR makes it possible to interact the virtual object by the real object in our own hand.

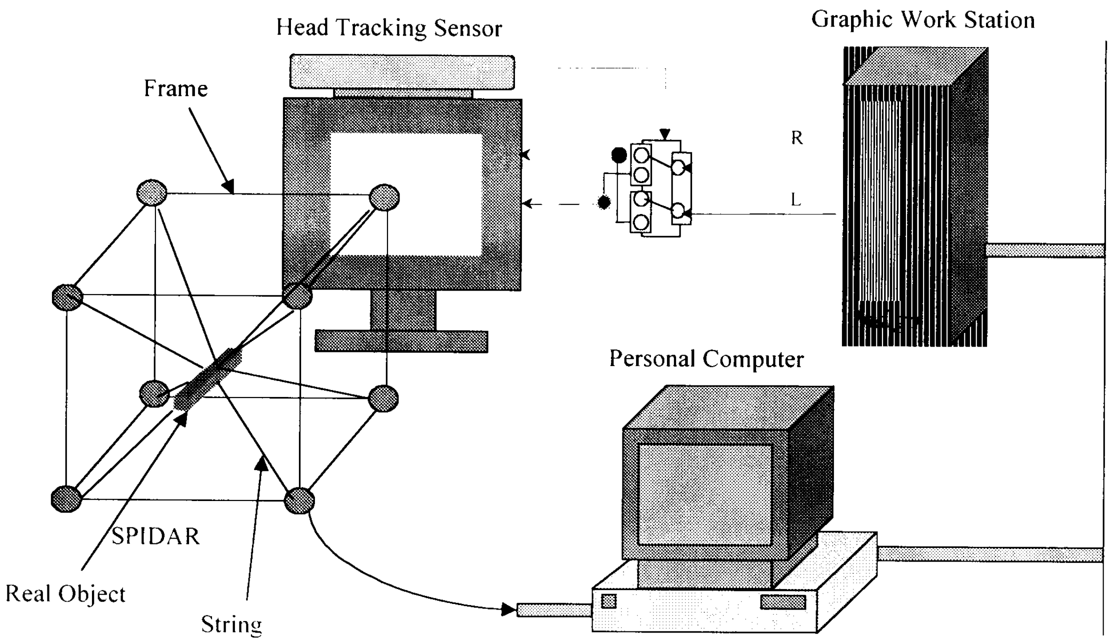

Fig. 8 MR system

Fig. 9 shows how to interact in this MR environment. We can have the real object as the tool like as a surgical knife, a hammer, a spanner, tweezers and so on. As the first stage of our prototype, the real object is the simple stick this time. We can move this stick anywhere in front of the 3D display without the constraint, although it is supported by the string which is controlling by the SPIDAR. Meanwhile we can see the virtual stereoscopic images on the 3D display without glasses. When we push the virtual object by the tip of this stick, we can feel tactile sensation by the constraint SPIDAR controlled the tension of the string. Fig. 10 shows the situation the subject operates the system in the MR environment.

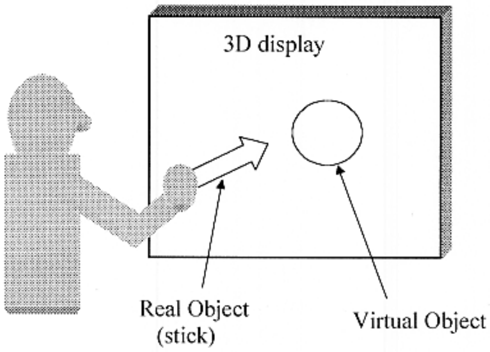

Fig. 9 Interaction in the MR environment

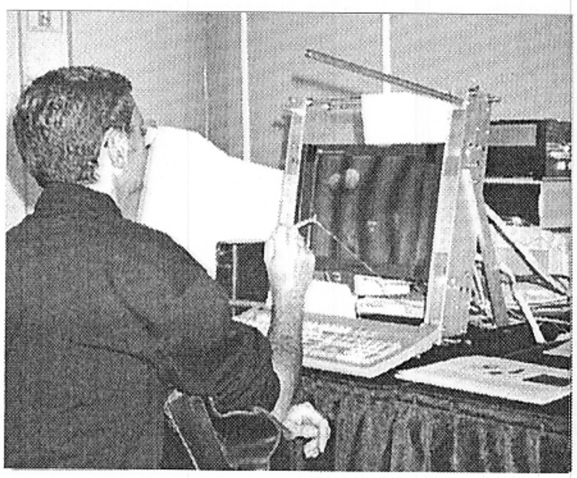

Fig.10 System Operation

6. Virtual Billiard

We have developed a Virtual Billiard game. Operators can stick balls in the Virtual World in front of the 3-D display by the real tool, and feel the force and tactile feedback. When the operator stick the virtual balls, the balls move around. It becomes more realistic than previous system to generate these senses. Fig 11 shows the graphic display as the virtual billiard game.

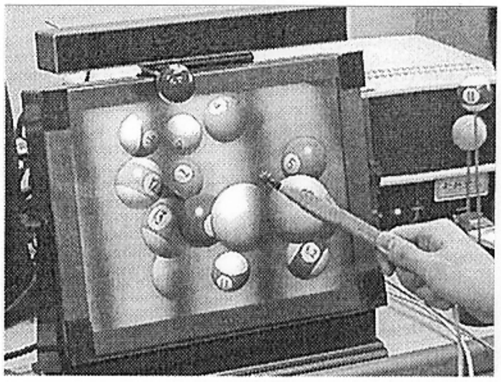

Fig. 11 Virtual Billiard Game

7. Conclusion

We have developed a MR system using Image Splitter which can generate the tactile feedback by SPIDAR. And we released the virtual billiard game as the first attempt about the MR environment. In our environment, we can the virtual stereoscopic images without glasses and see the real object by our own eyes. Also we realized the new world both the virtual and real object was mixed in the same world. Operators can interact the virtual object in the virtual space that is created in front of the Image Splitter 3-D display by real object, and can feel the tactile sense too. We have verified that observers can recognize 3-D images when the virtual and the real object are mixed. We are going to develop the system to satisfy the requirement of the practical use. This system will be suitable to training simulator system for example surgical simulator, aircraft maintenance simulator, industrial machine repair simulator and so on. This system will create the new training environment we can handle the various virtual situation with real tools in our own hand

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