Development of Mobile-type Full Parallax 3D Display using High-Density Directional Images

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Abstract

We introduce a mobile-type 3D display that achieves a full directional motion parallax and the real time interactions between the observer and the 3D image at the same time. These effects can be unique specified to the mobile-type 3D display.

1. Introduction

A natural 3D display is needed for the future communication network. The goal of our research is to realize a natural 3D display that achieves full directional parallax, large viewing angle, and natural interactions with the observer at the same time.

We adopted the high-density directional images to achieve our goal. Because this 3D display has a simple structure, a regular LCD display with a lenticular lens, it is quite small. Consequently, our 3D display can be used for mobile application. We build two prototypes of the 3D display. These prototypes both use a 7.2 inch LCD and a slanted lenticular lens. The first prototype presents 30 directional images in a viewing zone of about 30 degrees. Smooth motion parallax is achieved in this 30 degree region. The second prototype uses a camera and acceleration sensor embedded in the display to achieve full directional motion parallax and viewing zone enlargement. In this prototype, the horizontal viewing zone is enlarged to about 60 degrees and the vertical viewing zone is achieved in about 30 degrees while, in the first prototype, the horizontal viewing zone is about 30 degrees and the vertical motion parallax is not achieved. Furthermore, by generating the 3D images in real time according to the data from the camera or the sensor, the real time interaction between the observer and the 3D image can be achieved. Consequently, all desired elements are achieved at the same time in our display.

2. Relative work

Several conventional methods exist to realize 3D displays. One major approach is a stereoscopic display. A stereoscopic display creates a 3D image by showing different images to each eye of the observer. In this method, just two images are shown. Therefore, the viewing position in which a correct 3D image can be seen is limited. If the observer moves out of this area, the images are sensed by the wrong eye. This situation can make the observer tired or feel ill and is a critical weakness of the 3D display. To overcome this situation, the technique called "autostereoscopic display" [1] was proposed. In this method, the position of the observer is tracked and when the user moves outside the designed area, the images represented are changed dynamically to the correct 3D images. In this method, the user can avoid being in the wrong area and the motion parallax can be achieved. However, because only the two images are shown simultaneously when the stereoscopic display is used, the observer notices that the images are changed. This situation decreases the reality of the 3D image.

High-density directional images

Another 3D display approach that achieves a horizontal smooth motion parallax is called "high-density directional images [2]". In this method, the directional images, orthographic projections of 3D objects from different horizontal directions, are displayed in the corresponding horizontal directions. A slanted lenticular lens is set on the LCD display to yield the directional images. This permits the density of directional images to be extremely high and the realization of horizontal smooth motion parallax. Therefore, It is suggested that 3D display based on high-density directional images offers high-quality 3D images [3].

The principle of high-density directional imaging is shown in figure 1. In this method, one 3D pixel consists of 3N * M color pixels. A 3D pixel shows a full color directional image in N * M directions.

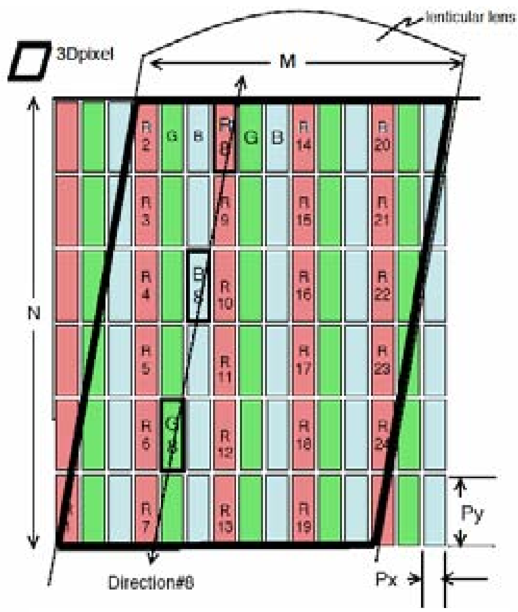

Fig.1 Components of a 3D pixel (M, N)=(4, 6)

3. First prototype of mobile-type 3D display

We prototyped the mobile type 3D display [4]. We adopted 7.2 inch LCD and slanted lenticular lens to realize the high-density directional images. Figure 2 shows the prototype; it's specifications are shown in Table 1.

Fig.2 Prototype 3D display

Table.1 Specification of prototype 3D display

The number of directional images	Pitch of each directional image	Viewing angle	Resolution of each directional image
30(M=5,N=6)	0.94[deg]	28.1[deg]	256x128

Full parallax 3D display

As shown in table 1, our prototype 3D display shows 30 directional images within the viewing zone of about 30 degrees; image pitch is less than 1 degree. This pitch is fine enough to realize smooth motion parallax. However, a 30 degrees viewing angle is not enough for the mobile-type 3D display because the position of the observer and the display will readily change. Note that the viewing angle and the smoothness of the motion parallax have a trade-off relationship because the total information to be represented is limited by the total resolution of the LCD panel. Consequently, it is difficult to enlarge the viewing angle of the 3D display using high-density directional images.

To overcome this limit we proposed two methods [5]. One enlarges the viewing zone while the other achieves vertical motion parallax. These two methods are based on the concept of the autostereoscopic display but the observer doesn't perceive the change in 3D images because only the images not sensed by the observer are changed. In addition, we confirmed that these images can be generated in real time. Consequently, real time interaction of the 3D image to the observer can be realized. These methods are briefly described below.

Enlargement of horizontal viewing zone

Our prototype 3D display has a (roughly) 30 degrees viewing zone. If the observer moves outside this zone, the repeating images are represented as shown in figure 3.

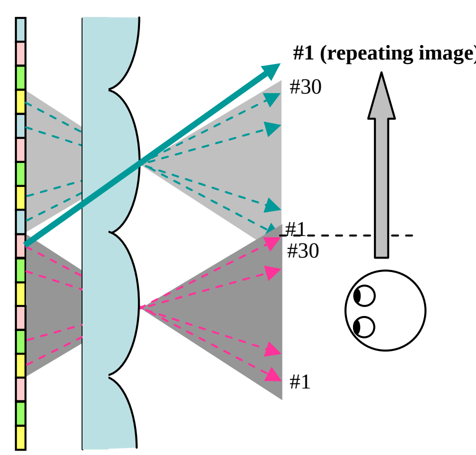

Fig.3 Repeating images

As shown in figure 3, if the user is in the viewing angle of the 3D display, the user senses ordinary 3D image which consists of 30 directional images. However, if the observer moves outside of the viewing angle (in the case of the observer moves to the direction of the arrow in figure 3), the scene shown once is repeatedly shown. Therefore, the observer can see natural 3D image only in the area without repeating images. To enlarge this viewing zone, the images are changed to match the position of the observer. That is, the images are replaced to suit the observer's movements.. For this purpose, the observer's position is detected by a camera set in the display and the movement of the display is detected by an acceleration sensor. The directional images presented to the observer are changed to match his or her position. The first prototype 3D display represents 30 directional images but only a few of them are sensed by the observer at any one time; only the images of the repeat zone are changed. Therefore the observer doesn't perceive the change in 3D images.

Vertical motion parallax

To realize natural 3D images, vertical parallax is as important as horizontal parallax. The vertical movements of the observer and the display are also detected and the directional images presented are changed to match these positions. So, vertical motion parallax is achieved in addition to the horizontal parallax. Consequently, full directional motion parallax is achieved.

Real time interactions

As described above, our display uses the camera and the acceleration sensor embedded in the display to detect the position or movement of the observer and the display. This data is used to realize the interaction between the user and the 3D image. The concept of the real time interaction is shown in figure 4.

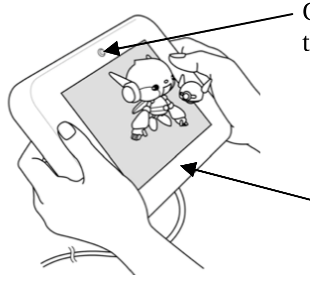

Figure.4 Real time interaction

To realize the real time interaction, the 3D image must be changed quickly enough to respond to the user's or the display's movement. The 3D image can be made by the rendering of 30 directional images and the synthesis of these directional images. We confirmed that if the 3D scene includes about 50,000 polygons, these processes run at about 30 [fps] by using OpenGL and a computer with Pentium(R) 3.2GHz CPU and GeForce 7800GTX. Figure 5 shows the appearance of the devices.

(a) Display module & camera (b)Wireless acceleration sensor

Figure.5 Devices

4. Results

We implemented a full parallax 3D display for mobile use with large viewing zone by using the two methods described above. One is the method to enlarge the horizontal viewing zone and the other is the method to achieve vertical motion parallax. The 3D image is changed dynamically in real time according to the position of the display or the observer, which are sensed by the camera and the acceleration sensor. Therefore natural and real 3D images can be presented because of the smooth and full directional motion parallax. (Figure 6)

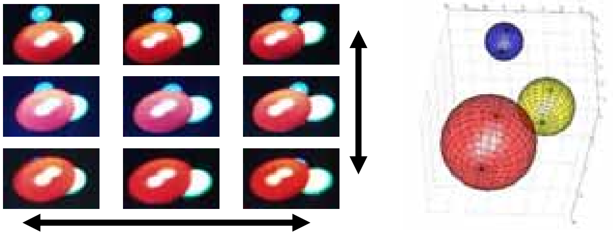

Figure 6: Full parallax images

In addition, because 3D image generation is done in real time, interactive 3D CG animation can be achieved. Figure 7 shows a 3D animation in which the CG character follows the user's movements. For example, the character tilts its head to the same side as the observer. These effects are done at the speed of 15 [fps]. Note that observer's face in the camera image is the reverse of the representation in the display.

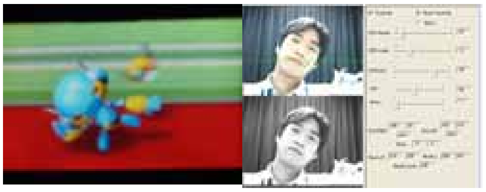

Figure 4: Interactive 3D image

5. Conclusion

A mobile-type 3D display based on high-density directional images method was proposed. This 3D display realizes smooth motion parallax, full directional motion parallax, and natural 3D interaction are achieved at the same time. These effects are unique to the mobile-type 3D display.

Our future works include the following. One is to investigate how to input real scenes, because this paper considered only 3D CG scenes. Another task is to estimate the “reality” of our 3D display.

6. References

1. K. Perlin, S. Paxia, and J. S. Kollin, “An Autostereoscopic Display”, ACM SIGGRAPH 2000 (2000).
2. Y. Takaki, “Thin-type natural three-dimensional display with 72 directional images”, Proc. of SPIE, vol.5664, 56-63. (2005).
3. Y. Takaki and T. Dairiki, “72-directional display having VGA resolution for high-appearance image generation”, Proc. SPIE 6055. (2006).
4. T. Horikoshi, M. Tsuboi, T. Hashiba, and Y. Takaki, “A Prototype of 3D Display for mobile use”, 3D image conference 2005, 45-48 (2005). (In Japanese)
5. M. Tsuboi, M. Fujioka, Y. Takaki, and T. Horikoshi, “Real Time Rendering for a Full Parallax 3D Display Using High-Density Directional images,” Proc. 13th Int'l Display Workshops , pp. 1379-1380, (2006).