11.1: *Invited Paper:* An Autostereoscopic 3-D HDTV Display System with Reality and Presence

H. lsono, S. Komiyama
NHK Science and Technical Research Laboratories, Tokyo, Japan
H. Tamegaya
NHK (Japan Broadcasting Corp.), Tokyo, Japan

Abstract

This paper describes a novel 3DTV display system which incorporates an autostereoscopic 3D HDTV display, a sound system for 3DTV using a sound-image distance-control, a synchronized smell processor, and an active wind machine. By combining these technologies, the prototype 70-inch autostereoscopic 3D HDTV display system provides an extremely realistic experience for viewers.

Background and Objective

Research and development on 3DTV displays has been progressing in recent years. 3DTV display is a very promising technology which is expected to provide the audience with a more authentric immediate appeal through a sensation of reality and power greater than can be provided by the current 2D flat-image displays. For widespread acceptance of the next generation 3DTV displays in a range of consumer and professional application areas, they must be "glassless" 3DTV displays, and the image quality should be as good as state of the art 2D HDTV displays.

There are various approaches to produce autostereoscopic 3DTV display systems, many of which have been reported in recent years. Of these, the lenticular screen method [1] and the parallax-barrier method are being studied as promising 3DTV displays for early applications. Other glassless 3D displays including the electro-holography method [2] are not yet able to reproduce moving 3D color images of sufficiently good quality. Therefore, at the present time the lenticular screen method has the best prospects in terms of early application.

Over the past ten years we have developed several types of autostereoscopic 3DTV display systems, including a lenticular screen method [3][4] and an active parallax-barrier method [5]. In 1994, we succeeded in developing a large 70-inch diagonal, double-lenticular screen, and developed an autostereoscopic 3D HDTV system with high-resolution [6].

In this paper, we will focus on a prototype autostereoscpoic 3D HDTV display system with reality and presence. The objective of our research is to develop an improved version of an autostereoscopic
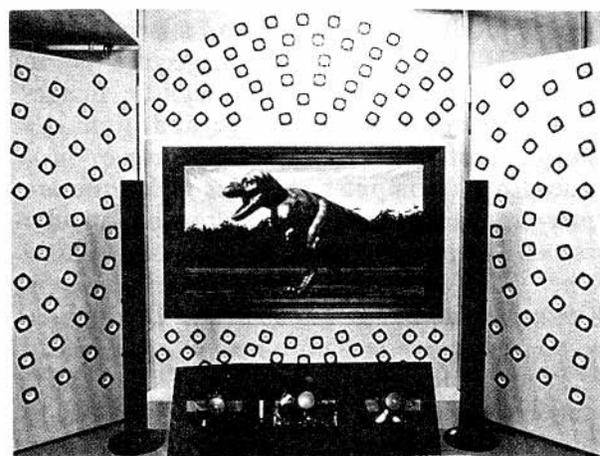

Fig. 1 Photograph of 70-inch autostereoscopic 3D HDTV display with reality and presence.
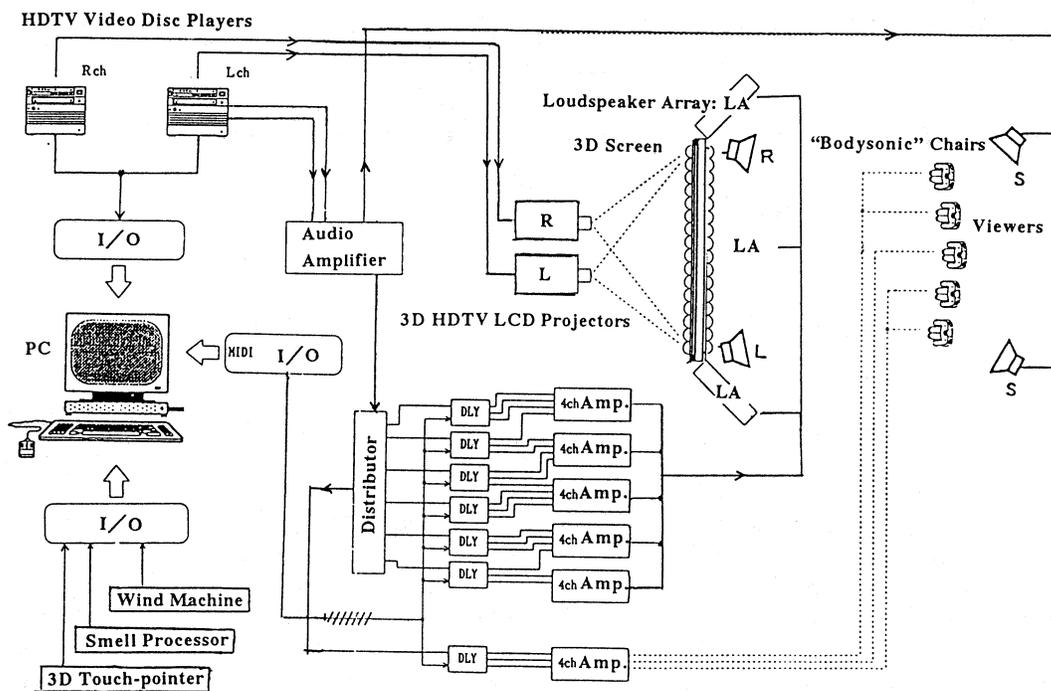
Fig. 2 A functional block diagram of a prototype autostereoscopic 3D HDTV display system.

3D HDTV display system that provides an extremely realistic experience for viewers, and to demonstrate the possibility of enhancing reality and presence by stimulating the other-senses of human beings.

Basic Design Concept

The basic design concept of the whole 3D display system is to provide an extremely realistic experience for viewers while they are watching the autostereoscopic 3D HDTV display. To achieve this, we thought of combining a high-resolution 3D HDTV image, 3D sound system, a real wind, an aromatic environment, and a 3D touch-pointer. **Figure 2** details the architecture of a prototype autostereoscopic 3D HDTV display system. The operation of the whole system must be carefully synchronized at appropriate times together with smell, wind, 3D sound and corresponding 3D HDTV images. The function of the whole system is controlled by a personal computer using a time-code signal.

Autostereoseopic 3D HDTV Display System

3D Image Display

Reproducing 3D images on a large screen using HDTV LCD video projectors is an effective means of providing realistic images with high-resolution. Left-eye and right-eye images shot with two HDTV cameras or produced by a computer graphics technique are rear-projected behind a double-lenticular screen by a pair of HDTV LCD video projectors. The HDTV LCD video projector employed in this system uses three 5.5-inch a-Si LCD panels, each having 1.5 million pixels, to produce an incredible high-resolution picture. These LCD panels are normally operated in white mode to produce a high-contrast picture of 150:1, and are illuminated by a high-intensity 575 W metal halide lamp.

3D Screen

In the conventional double-lenticular screen, two lenticular screens and diffusion layers were bound

together, making it difficult to justify their positions before molding and impossible to realign after. We resolved these problems by adopting separable screens with a "hollow structure" that ease gap control and alignment between the two screens. The pitch of the double-lenticular screen, 0.7mm, is determined to prevent moir patterning due to the interference between the LCD panel and the lenticular screen. The autostereoscopic 3D display system using a conventional single-lenticular screen requires highly accurate positioning of the video projectors, whereas the double-lenticular model has little influence on the position of stripes on the diffusion layer. The positioning allowance of the prototype 3D display system is improved 100 times when compared with the conventional model with a single-lenticular screen.

Fig.3 Principle of sound-image distance control for 3DTV.

Sound System for 3D TV

Are conventional sound systems like stereophony or quadraphony suitable for 3DTV system? If not, what kind of sound systems for 3DTV display are required? However, an audio system that would be suitable for 3DTV has scarcely been discussed. For example, the properly localized sounds from the vocalist's mouth in the 3D visual image would greatly enhance the realism of the 3DTV images. However, to localize a sound image at the corresponding 3D image between a screen and viewers is almost impossible for conventional sound systems. A new technology is necessary, therefore, to produce a sound image at any position where the 3D visual image is located. The basic idea of sound-image distance-control used here is: *"If a small area has much higher sound pressure than other areas in a sound field we perceive the sound image there"*.

Such a small high-pressure point can be produced by using many loudspeakers arrayed on a plane and many delay lines [7]. **Figure 3** shows how a near sound image is produced by a two-dimensional loudspeaker array. An audio signal is fed to the loudspeakers by the delay lines with specified delay times so that each sound wave focuses on one point. The sound wave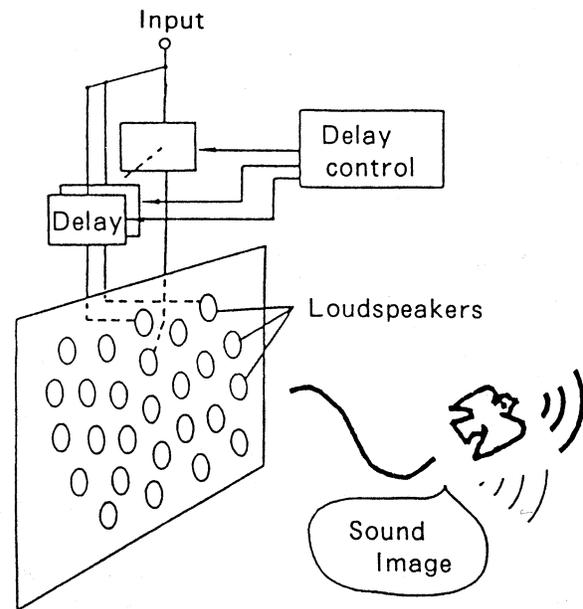s are summed coherently and produce a small high-pressure zone there. A virtual sound image is reproduced at the focal point of the loudspeaker array with startling reality and stability. The perceptual distance of the sound image is easy to control by changing the sharpness of focus and its focal position.

We developed a prototype loudspeaker array consisting of 170 small speaker units on a plane (3.6m X 1.8m) to control the distance of the sound image, in real time, using SMPTE time codes, many digital delay lines, and a personal computer.

In addition to the sound-image distance-control, this autostereoscopic 3D HDTV display system offers a new sound experience through its "bodysonic" audio system which allows the listener's body to actually feel the vibrations instead of merely hearing the audio.

Synchronized smell Processor and Active Wind Machine

By synchronizing with 3D HDTV images and sound, six kinds of smell and real air flow are authentically recreated by a multitude of nozzles with an electric
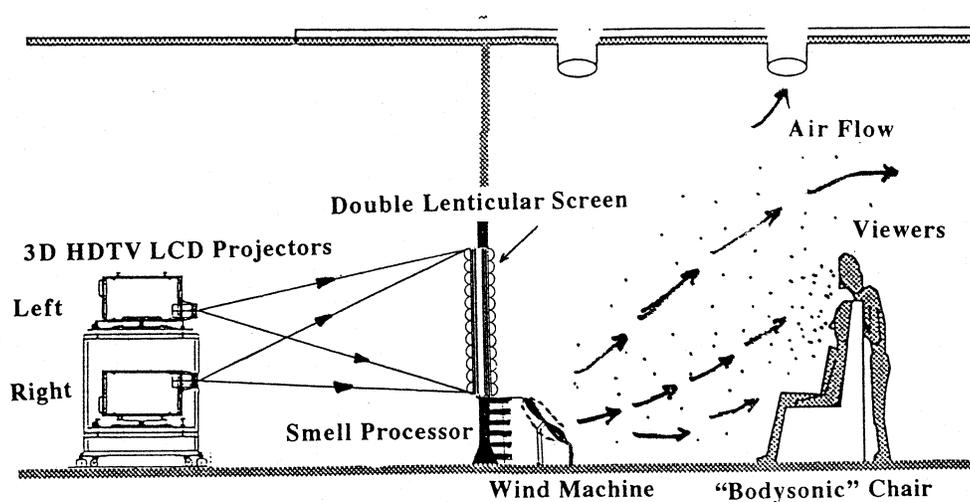
Fig.4 Cross section view showing the path of the wind and smell system.

fan located just below the 3D screen. **Figure 4** illustrates the cross section view showing the path of the wind and smell system. It enables the viewer to better appreciate the scenery of 3D images such as beautiful forests, flowers or rugged coastlines. The system easily and quickly provides real "wind and fragrance"-experience for viewers. As the story unfolds on the screen, viewers can enjoy some sensation of fragrance and an effectual wind from the different locations in the 3DTV program. We found that some sensation of smell and real air flow provide an extremely realistic experience for viewers. However, the air with smell molecules in the room should be quickly removed before being recycled into the 3D theater.

3D HDTV Program

In 1994, Media International Corporation (MICO), HD/cg N.Y. and NHK Science and Technical Research Lab. collaborated on a short 3D HDTV Computer Graphics program entitled ***"Stereosaurus" [8]*** which was first demonstrated at the NHK Open House. The "Stereosaurus" depicts carnivorous dinosaurs chasing herbivorous dinosaurs, both of which lived on the North American Continent approximately 70 million years ago. Computer graph-

ics was an effective and efficient way to produce 3D images. With computer graphics, visual points are determined freely and precisely. In the "Stereosaurus" , we also created a localized 3D sound image corresponding the 3D HDTV CG images by using a sound-image distance-control in addition to the "bodysonic" sound system, which allows the listener's body to actually feel the vibrations. Furthermore, some sensation of smell and real air flow are authentically recreated in combination with 3D HDTV image and sound. The "Stereosaurus" gave an extremely realistic experience for viewers.

Conclusion

We described a prototype, 70-inch, autostereoscopic 3D HDTV display system with reality and presence. To provide an extremely realistic experience for viewers, we developed an autostereoscopic 3D HDTV display system, 3D sound system using a sound-image distance-control, a synchronized smell processor, and an active wind machine. The integration of high-resolution 3D HDTV image, 3D sound, real wind and aromatic sensation resulted in an extremely realistic experience for viewers. To demonstrate an actual effect of reality and presence in the autostereoscopic 3D HDTV display system, we pro-

duced the 3D HDTV CG program entitled "stere-osaurus". This autostereoscopic 3D HDTV display system that showed a pronounced improvement in resolution and reality has many applications such as entertainment and virtual reality environment systems.

56(1995)

References

[1] **R.Börner**:" Autostereoscopic photography and video projection of parallax-stereo-panoramagrams onto large lenticular screen" Japan Display'89, pp.40–43, 1989.

[2] **S.A.Benton et al**.:" Electronic display system for computational holography" proc. SPIE, 1212, Practical Holography IV,pp. 1212–1220 (1990)

[3] **H.Isono, et al**.,:" 50-inch Autostereoscopic Full-color 3D TV Display System" , Proc. of the SPIE, Vol. 1669,pp. 176–185(1992)

[4] **H.Isono, et al**.,:"Autostereoscopic 3D TV Display System with Wide Viewing Angle". the 13th IDRC, VIQ-P2, pp.407–410(1993)

[5] **H.Isono et al**:" Autostereoscopic 3D LCD Display Using LCD-generated Parallax Barrier", Japan Display'92, pp.303–306(1992)

[6] **H.Isono et.al**.: " A novel autostereoscopic 3D HDTV display system: Creating a superb sensation of reality and presence" the 15th IDRC, S36-2, pp.795–798(1995)

[7] **S.Kondyama et al**.:" Distance control of sound images by a two-dimensional loudspeaker array" J.Acoust. Soc.Japan(E), vol. 13, No.3, pp. 171–180(1992)

[8] **H.Tamegaya et al**.:" Production of 3D HDTV Computer Graphics", IDW '95, Vol.3, pp.53–