Progress on Large, Wide-screen Image Presentation

- 4000-scanning-line TV aims at a medium that is provocative yet pleasing to the senses -

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Research and development continues on an ultrahigh-definition video system with 16 times the number of pixels of Hi-Vision (HDTV). Our work will explore future media beyond the confines of ordinary television. To examine the potential of such an ultrahigh-definition system, we fabricated a prototype camera, display, and audio devices.

1. Introduction

Digital terrestrial broadcasting started in Tokyo/Nagoya/Osaka in December 2003, and digital satellite broadcasting was launched in 2000. Both types of broadcasting feature Hi-Vision (HDTV) services, which means that HDTV is now reaching more households than ever before. Small video devices, such as ones on portable terminals, are also becoming very popular. People are using such devices to obtain information that they can use in their business and personal affairs, with an emphasis on convenience. At the same time, TV (audio-video media) is evolving in ways that truly enrich people's lives by providing them with more provocative images.

One desirable future media could be described as one that allows users to be "absorbed" in an environment created by an audio/visual presentation, where they would feel as if the subject being presented were actually at their location. Such a media would at least require large, wide-screen images that are beyond the capability of current HDTV to produce (Figure 1). Therefore, it is felt that the advent of ultrahigh-definition image technology integrated with multi-channel sound technology will break new ground for such a media.

Figure 1: Large, wide-screen video presentation conceptual image

With the aim of assessing the potential of new media, our laboratories are studying large, wide-screen video media presented on an ultrahigh-definition video system with 4000 scanning lines (hereafter referred to as the 4000-scanning-line system). This system has 16 times the number of pixels of HDTV. This article presents trends and issues related to this large wide-screen video media, especially as regards the developmental status of the 4000-scanning-line system.

2. Ultrahigh-definition Image Research

Research and development on ultrahigh-definition video systems and the large wide-screen video systems that incorporate them have flourished in recent years. One of the reasons for this trend is that digitalization has improved element technologies that in turn have made feasible high-speed, large-capacity data processing, transmission, and storage. Other significant reasons include the fact that specific commercial applications for large-screen video, such as digital cinema, have started to emerge. The following are examples of recent R&D on ultrahigh-definition video systems. NTT started work on a means of producing ultrahigh-definition images with approximately 2000 pixels×2000 pixels (horizontal× vertical) in the 1990s. Their purpose was to construct an integrated platform for video media, and they conducted a transmission experiment using an 8-million-pixel camera in 2002. The Ministry of Public Management, Home Affairs, Posts and Telecommunications (MPHPT) and the Communications Research Laboratory (CRL) jointly conducted a transmission experiment using three horizontally arranged HDTV displays for the 2002 FIFA World Cup, and CRL conducted another transmission experiment using an 8-million-pixel camera in 2003. The Lockheed Martin Corporation unveiled a motion picture camera system with an even larger number of pixels in 2000. This camera system has 4104 pixels×3138 pixels (12-million pixels) and operates at the 24-Hz frame rate designed for digital cinema.

Since the initial phase of HDTV development, or even prior to it, our laboratories have pursued research on human visual sensation and picture quality; many of our research results have contributed to television system designs in use today. In particular, our R&D on hardware for an ultrahigh-definition video system started approximately ten years ago, especially centering on its imaging technology, and we constructed a 2000-scanning-line camera system using an 8-million-pixel CCD in 2001.

Our ultrahigh-definition video research is distinguished by its aim to acquire comprehensive knowledge about video pictures, from small-screen to large-screen, and from low-resolution to high-resolution. The 4000-scanning-line system described in Section 3 is meant to be used as a tool to investigate the effects of such video images.

When a new video format is being developed, it is important to learn how the size and resolution of the display affect the perception of someone watching a video presentation. It was from this viewpoint that the initial HDTV research and development took place almost 40 years ago, with studies on various video formats and on subjective picture quality for high-resolution TV (the present HDTV). The results were used to make important decisions on the most appropriate format. These fundamental studies measured the perceived sensation of reality from wide-screen images by using psychophysical techniques. One example was a study in which an experiment evaluated the subjectively induced tilt angle of the coordinate axes when presented with a tilted stimulus display images. It is thought that a larger induced angle indicates that the image presents a stronger sensation of reality. The inducing effects start to appear around 20 degrees and reach saturation at from 80 degrees to 100 degrees. In a similar vein, our recent studies on the psychological effects of an ultrahigh-definition wide-screen video system are aimed at clarifying the relationship between perceived "potency" or "comfortableness" and viewing angle.

Based on the above-mentioned psychophysical research findings, we constructed a prototype advanced TV system conveying a strong sensation of reality to the viewer. It was capable of clearly displaying images with a horizontal viewing angle of up to 100 degrees. In consideration of the standard viewing distance*, a 100-degree viewing angle requires approximately 8,000 pixels in a horizontal direction. Interoperability with the present HDTV system would also be desirable, and the use of commercially available HDTV equipment would make system implementation easier. These considerations led us to choose parameters appropriate for four times the number of pixels of HDTV, both horizontally and vertically, a progressive scanning scheme at a 60-Hz frame rate, and an aspect ratio of 16:9. The 4000-scanning-line system thus derives its name from the vertical pixel number (effective scanning line number) of 4,320. Figure 2 compares the spatial and temporal resolutions of the 4000-scanning-line system with that of current media. As a medium for video presentation, it greatly exceeds all conventional media in its spatial aspects and exceeds movie film in its temporal aspects.

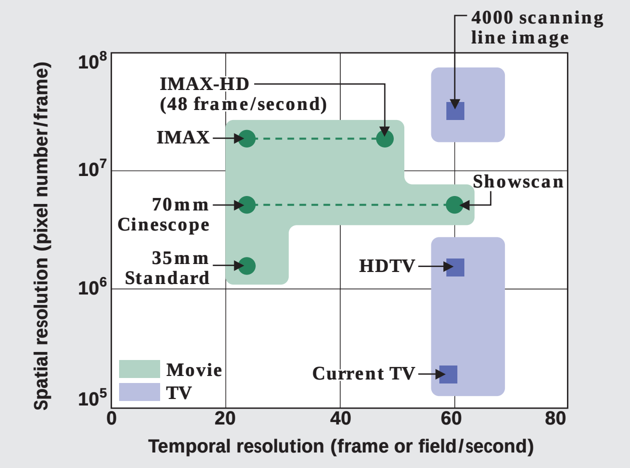

Figure 2: Resolutions of 4000-scanning-line system and other systems

* The distance at which the scanning line structure of a display starts to become unrecognizable by a standard observer (a person with 20/20 vision). Since 20/20 vision is the ability to distinguish a viewing angle of one arc-minute, the viewing angle needed to see a single scanning line or a single pixel is calculated as one arc-minute. Therefore, standard viewing distance is determined by the number of scanning lines in an image, represented in multiples of the picture height H. This means 3H for HDTV, and 0.75H for the 4000-scanning-line system.

3. Development Status at STRL

Figure 3 shows the overall configuration of the prototype 4000-scanning-line system. This TV system consists of the sub-systems for imaging, recording, transmission, and display, among which the development was prioritized on imaging technology (camera) and display technology (display), which are essential for future picture-quality studies. The merits of digitalization benefited the construction of transmission and recording systems, which are composed of HDTV devices aligned in parallel. We are also working to fabricate a multi-channel audio system for reproducing a three-dimensional sound image with a heightened sensation of reality that will significantly exceed the capabilities of conventional audio systems.

3.1 Camera and Display

The 4000-scanning-line system requires both an imaging device and a display device each with 32 million pixels. However, this technical hurdle is too high to clear at the present time. To overcome this restriction, the camera system employs the 8-million-pixel imaging devices

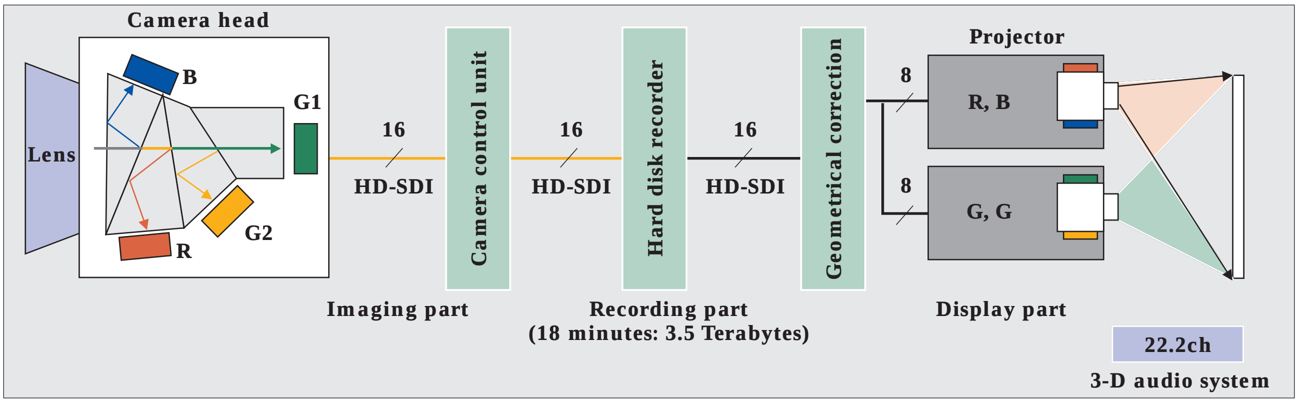

Figure 3: Overall configuration of prototype system

fabricated for the 2000-scanning-line camera system and adopts a four-CCD image acquisition scheme. Although for a while the display system lacked a display scheme with four LCD panels, we recently developed a technique to create a four-LCD panel system with two projector units. The display devices are 8-million-pixel liquid crystal on silicon (LCoS) devices. The use of four CCDs or LCDs in the camera and display devices meant that we could use a one-to-one signal transmission path configuration with a 16-parallel-HDTV serial digital interface (HD-SDI) structure.

The positioning accuracy of the two devices assigned for the color green greatly influences the resolution of this system. To improve the accuracy, a new technique to detect errors with high accuracy was devised for the camera and display. Other advances in the element technologies comprising the whole system are being made, including a technology to ensure uniform characteristics among the output signals at column parallel output devices and a contour compensation technology for the four CCDs of the camera, and a convergence correction technology for the two projectors of the display.

3.2 Three-dimensional Audio System

The 4000-scanning-line system is one step on the road the ultimate audiovisual system that will create a "a space surrounded by video and audio." Therefore, its audio system must also be at the appropriate level, i.e., far exceeding present systems. The technical requirements are as follows.

- Sound image localization at an arbitrary position on a screen.
- Omnidirectional sound image localization surrounding a listening location.
- Reproduction of a three-dimensional sound field with proper "listener's envelopment".
- Wide listening area with adequate sound quality.
- Compatibility with existing multichannel audio systems.

The audio reproduction scheme to satisfy these requirements is the 22.2 multichannel sound system shown in Figure 4. This sound system consists of a set of three-dimensional triple-layered loudspeakers (a total of 22 channels); a middle layer at about the height of the listening position (10 channels); an upper layer above the listening position (9 channels); and a lower layer below the screen (3 channels); together with super woofers (2 channels) for low frequency effects (LFE) installed below the screen. This audio system is well beyond the level of the multi-channel audio systems for theaters, for which there are a wide range of schemes, such as the 5.1 channel surround sound system. The video screen for the current 4000-scanning-line system is not a sound screen (allowing sound to pass through the screen) such as is installed in ordinary movie theaters. This prevents any loudspeakers from being installed behind the screen. To compensate for this, the system forms virtual sound images for three channels at the center of the screen, by using three horizontally aligned loudspeakers installed both above and below the screen to reconstruct audio signals at the same level and phase for the three front channels in the middle layer.

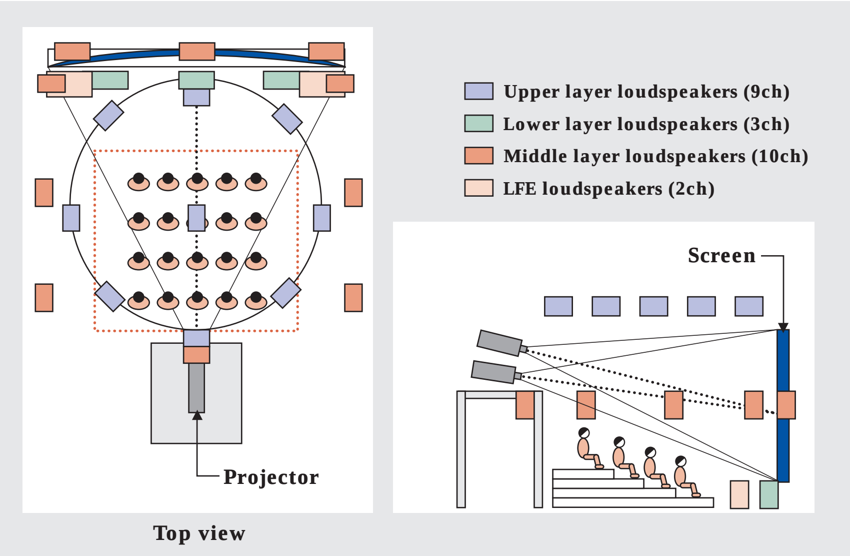

Figure 4: 22.2 channel audio system

This system constructs a basic sound field by using ten loudspeaker channels located in the middle layer. The middle layer has two channels in the front and back on both sides of the audience seats, enabling smooth anteroposterior sound image movement. The bottom layer and top layer loudspeakers play an important role in sound image localization and sound image movement in the vertical direction. This is especially true of the overhead loudspeaker installed in the ceiling of the central seating area. This has a unique acoustic effect, being so effective in some cases, such as when sound is to be localized at the zenith, that it is sometimes called the "Voice of God." The top layer loudspeakers are important to obtain good perception of reverberation and surrounding sound for a wider coverage of the audience. When reflecting sound and reverberation sound are reproduced using solely the side loudspeakers, the reproduced sound from the wall-mounted loudspeakers becomes too loud at listening locations near the walls, causing deterioration of the reproduced sound field.

4. Future Work

4.1 Hardware Development

The issues related to the hardware for a large, wide-screen video media are listed below.

- Increasing the pixel number for imaging and display devices

There are two types of approaches: one method is to increase the number of pixels by reducing the unit pixel size without increasing the device area, and the other is to increase the number of pixels by enlarging the device area while maintaining the unit pixel size. Including the optical system, either method has merits and drawbacks, requiring a thorough examination before the system design process can be decided.

- Response to higher data transfer rate

The data transfer rate for ultrahigh-definition images will be extremely high. For example, the data transfer rate for the 4000-scanning-line system described in Section 3 is 16 times that of HDTV (24 Gbps). Dealing with such data will necessitate some type of parallel processing. There will be an issue in suppressing the nonuniformity, since analog processing circuits exist within a device or in neighboring areas in both the imaging and display devices.

- Transmission and recording technology

The transmission path and recording media will have to be improved to make them suitable for ultrahigh-definition images. A high-efficiency coding technology will also be needed.

All of the above-mentioned items require sustained development of related element technologies.

4.2 Psychological Effects Investigation

The assessment tests described in Section 2 were conducted under rather restricted conditions, necessitating that more data be obtained in order to determine a suitable format for the system. Many other possible influences may exist besides the viewing angle aspect, such as pixel number and display size, and the effect of motion pictures. Developing a method to accurately gauge a psychological effect such as the sensation of reality is also a significant issue. The 4000-scanning-line system will prove to be a powerful experimental tool for conducting fundamental research in areas such as these.

While large, wide-screen images present a stronger sensation of reality or sensation of immersion to a viewer, a concern is that watching such moving pictures might cause a sort of motion sickness. This can be explained qualitatively based on knowledge that our peripheral visual field is closely related to postural control or spatial cognition mechanisms. However, our present understanding of the relation between physical parameters or video content and such motion sickness is not adequate. It is thought that a thorough examination must be made on motion sickness induced by watching moving pictures, to ensure that TV system doesn't have undesirable effects.

4.3 Free Viewing Distance

Ultrahigh-definition images, which are most effective in large, wide-screen video presentations, will also present a new possibility for a relatively small display. To clarify this idea, let us consider the relationship between viewing distance and display size with the help of Figure 5. The figure depicts the relationship between viewing distance and display size with the standard viewing distance condition being the straight line. Given a display size, the pixel structure cannot be distinguished at any viewing distance that falls on the right side of the straight line.

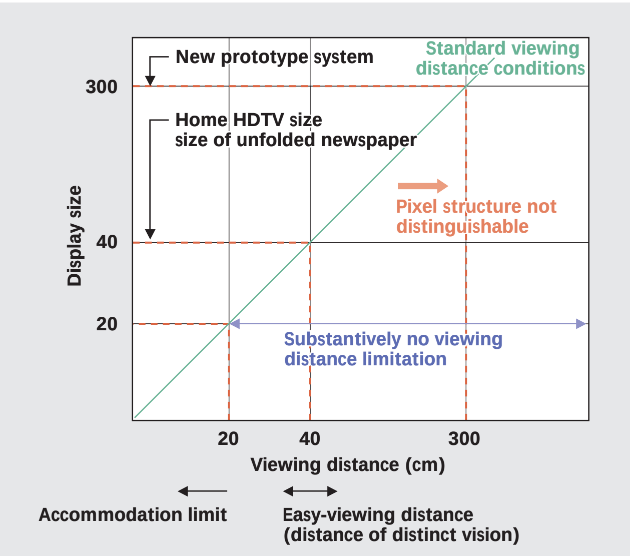

Figure 5: Viewing distance and display size for 4000-scanning-line system

It is said that the natural distance for a human to observe an object distinctly, such as when reading a piece of printed material held in the hand, is around 40 cm, which is called the distance of distinct vision. For the 4000-scanning-line system, the display size at which this distance of distinct vision becomes the standard viewing distance is an approximately 40 inches. This is equivalent to the size of a present home HDTV display, or an opened-up newspaper. Assuming that a display of such a size could be observed from a distance of 40 cm raises a number of potential applications. One possibility is that by watching the entire screen from a distance of about 2 m, the viewer would experience an effect similar to viewing HDTV, but getting closer to the display, to about 40 cm (maintaining the same image) the viewer could view a portion of the image with much more clarity. Such freedom in selecting the viewing distance without any concern for picture quality is not possible with conventional video systems, and it may have useful applications in medicine, education, or art appreciation.

A display size of 20 inches would have a standard viewing distance of 20 cm, which is close to the accommodation limit (near-point of accommodation) at which no pixel structure can be distinguished at any distance. Thus, the 4000-scanning-line video system would effectively have a free viewing distance capability. This type of video presentation on a flexible display device would be the equivalent of a gravure printed magazine able to show motion pictures.

4.4 Standardization

The fact that digitalization allows more flexibility than the old analog format in dealing with multiple video standards has not changed the importance of standardization as a primary means to encourage the diffusion of technology. On the contrary, in an environment where many standards can coexist, standardization is more essential in the sense that they would unify the ideas on which the standards are based. The Study Group 6 (SG6) Task Group 6/9 (TG 6/9) at the International Telecommunication Union Radiocommunication Sector (ITU-R) sets research on Large Screen Digital Imagery (LSDI) as a point on its agenda. This research also covers video standards using a number of scanning lines that are integral multiples of HDTV (1080 lines), as well as multi-channel audio systems. Our laboratories will contribute to this standardization process.

5. Conclusion

This article described the trends in large, wide-screen video media, especially as they relate to STRL's ultrahigh-definition 4000-scanning-line video system.

It can be said that video media expands human vision, and thus a wider and larger screen would satisfy the basic human desire to receive as much information as possible. Development of an actual system capable of fulfilling this desire will span many fields and will flourish in the future. Our work will essentially aim at realizing a media that is provocative yet pleasing to the senses, and the technologies described in this article will be the foundation of this effort.

NHK will present its 4000-scanning-line system at the 2005 World Exposition, Aichi, Japan

Experimental equipment for the 4000-scanning-line system

New 4000-scanning-line camera system