Research and Development of 3 Dimensional Imaging Media Technologies in Korea

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Abstract – Several 3 dimensional image display systems were recently developed in Korea. These are a holographic video system based on pulse laser illumination, an 8-view 3 dimensional image system capable of displaying computer generated 3 dimensional images and multiview 3 dimensional imaging systems based on moving aperture and holographic screens of both transmission and reflection types. All these systems require no special glasses to watch and works impressively.

1. Introduction

The increasing demands on 3 dimensional (3-D) image generation and displaying for the amusement and education, scientific visualization, animation, visual communication and many other purposes indicate that it will be one of major research subjects in the future. The currently available 3-D image generation and displaying technologies are mostly based on stereoscopic images having binocular parallax[1]. Multiview 3-D and holographic video are the more advanced 3-D technologies than the stereoscopic, however, they are still in the burgeoning stage. The stereoscopic images are displayed with a specific spatiotemporal format to be viewed through a special eye glasses or optical plates with different optical characteristics[2]. Since the stereoscopic image corresponds to the image seen by our eyes at a fixed position, viewing zones where the stereoscopic image can be seen to our eyes is very small and the image provides only depth feeling, i.e., no moving parallax. So there is not enough rooms for our eyes to move. The viewing zone size for each eye in the stereoscopic imaging systems utilizing eye glasses is the same as each active element size of the glasses. When eyes are slightly away from the viewing zone, no image or no stereoscopic image can be seen. The viewer should fix his or her eyes to the corresponding viewing zones to watch the stereoscopic image clearly. Consequently, the eyes can be tired quickly. One way to ease this problem will be enlarging the viewing zones by providing moving parallax with many scenes from different viewing directions. In this case, the viewer's eyes or body can be easily moved to other positions in the viewing zone and new scenes corresponding to the new eye positions are appeared. As the number of scenes from different directions increases, the image looks more realistic and the viewer will feel more conveniences. The 3-D imaging systems having this kind of performance is called as the multiview 3-D imaging system (MIS). The MIS gives both binocular and moving parallaxes. The holographic video is a kind of a super multiview 3-D system. Its image generation and display methods are based on the holographic technique[3].

In this paper, some of recently developed 3-D imaging technologies in Korea, such as the multiview 3-D imaging systems based on moving aperture[4] and holographic screen, a pulse holographic video system and methods of making full color holographic screens[5] of both transmission and reflection types are introduced. The holographic screen is a kind of image projection screen which has an optical power to make viewing zones for viewing the multiview images.

2. The Multiview 3-D Imaging System with a Camera Array

The realization of the MIS requires high speed electronics and image display devices, and a image projection screen for viewing zone forming. The total amount of data required for MIS is linearly proportional to the total number of views to be transmitted. For the case of 8 views MIS, if each view has NTSC resolution (6MHz), the total bandwidth of the signal required for the MIS is 8 $\times$ 6MHz $\simeq$ 48MHz. When this signal is digitized with 256 gray level, the data rate becomes 96Mbytes/sec. When 3 primary TV colors (red, green, and blue) are considered, the electronics should process 3 separate 96Mbytes/sec data channels at the same time. This is too large amount of data to be transmitted through the currently available data transmission line. Even if this amount of data is transmitted, this data should be reprocessed in real time to be displayed on the display devices. The display devices need to be operated to 480Hz field rate for 8 view images. The image projection screen is an optical element which can form viewing zone(s) for the 8 view images. The eye glasses for the stereoscopic images can not be used for the multiview images. Optical plates like lenticular and parallax barrier are good for the contact type stereoscopic image display but not for the multiview images without supporting of eye tracking devices. Fresnel lens and holographic screens are currently known optical plates for viewing multiview image[3]. However, these plates can be used only for the projection.

Currently known MIS can display up to 28 view full color images on the Fresnel lens[6]. This system is limited to display reduced images and one person to watch the image and the view angle less than 10°. Instead of Fresnel lens, the use of holographic screen will allow many persons to watch and consequently the view angle can exceed several 10 degrees[7].

An example of MIS which can display 8 view full color scenes built at KIST is shown in Fig. 1. This MIS is composed of 3 separate parts such as image generation, signal

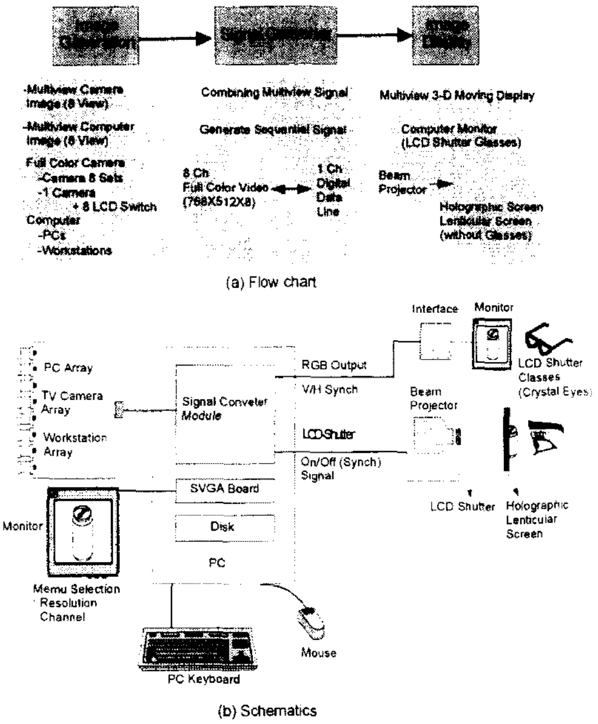

Fig. 1 A multiview 3-D imaging system.

converter and image display. The image generation part consists of 8 synchronized cameras in a box and a PC. The cameras in the box are 3.5cm apart from each other and have a common focal length of 3m as shown in Fig. 2. They produce 8 parallel VGA

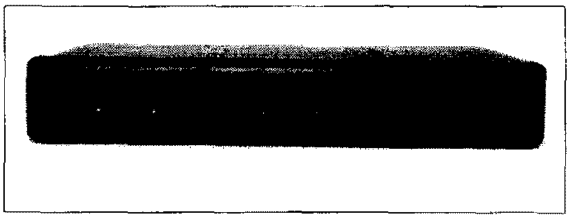

Fig. 2 8-view camera.

compatible images. The PC controls the MIS and generates animated images of 8 different views. This animated images can replace the camera images. The role of the signal converter is synchronizing all the system components and converts 8 parallel image signals from cameras or from the PC to a serial signal trains for each of 3 TV primary colors. The timing diagram of sampling image signals from the cameras is shown in Fig. 3. The sampling is done by field image rate because the image will be projected through CRT. The sampling sequence is that first, odd

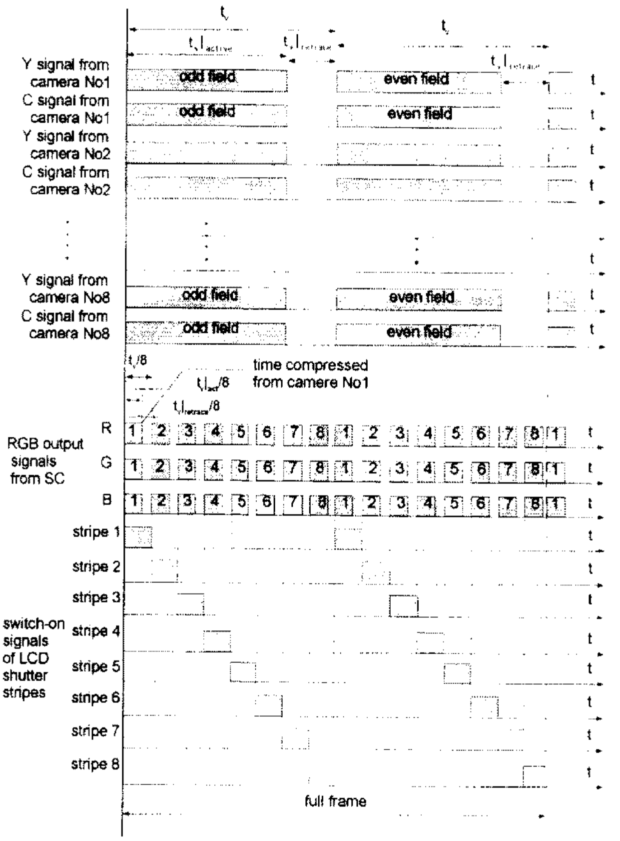

Fig. 3 Timing diagram of multiview 3-D imaging system.

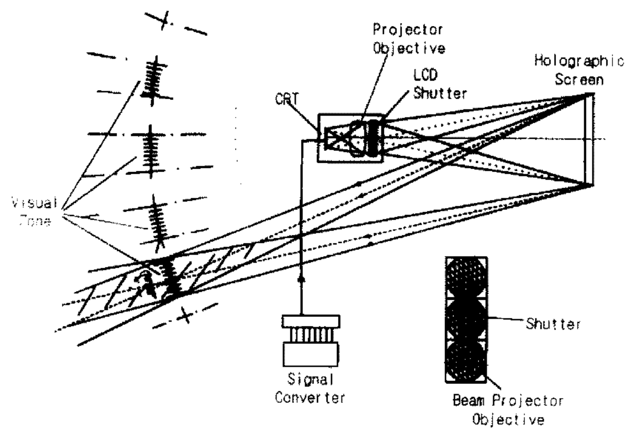

Fig. 4 Visual zone creation by hologaphic screen.

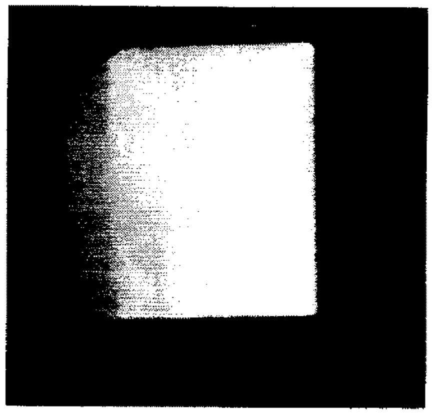

Fig. 5 LCD shutter CRT with a gray level pattern.

field image of first frame image of each camera is sequently sampled from camera 1 to 8, then repeats with the same order for even field images, next repeats with the second frame image the same sequence and order as the first frame and so on. Since each camera is working for 30 frames/sec, total 480 field images are sampled for each second. The sampling time of each field of a frame of each camera is about 2ms. The display part consists of a beam projector with 3 TV primary color (red, green, and blue) beam projection lenses, a 8-strips LCD shutter for each projection lens and a full color holographic screen. The beam projector projects image on the holographic screen. The holographic screen makes the image of the projector's output aperture in front of the screen as shown in Fig. 4. This image works as a viewing zone. Each objective lens of the beam projector is covered by a 8-strips LCD shutter as shown in Fig. 5. Each strip in the LCD shutter works synchronously with the camera sampling sequence by the synchronization signal from the signal converter. So it opens for 2ms and repeats 60times/sec. Since the objective is covered by the LCD shutter, the viewing zone is actually formed by the images of the LCD strips. This means that the viewing zone are divided into 8 sub-zones corresponding to the strip numbers in the LCD shutter and each sub-zone will be appeared when the corresponding strip is on and disappeared when the strip is off. The holographic screen for our system has the properties of 6 spherical mirrors oriented in different directions. The screen creates 6 viewing zones. More detail on the holographic screen will be described in section 6. The multiview 3-D imaging system and the image of a PC generated parallelepiped appeared on the holographic screen is shown in Fig. 6.

3. The Multiview 3-D Imaging System with a Moving Aperture

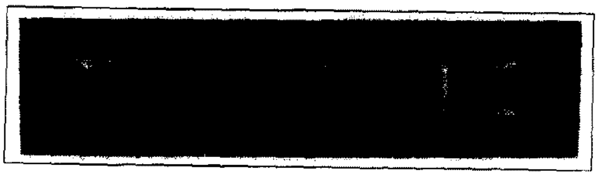

Fig. 6 Computer generated a parallelopiped image on holographic screen.

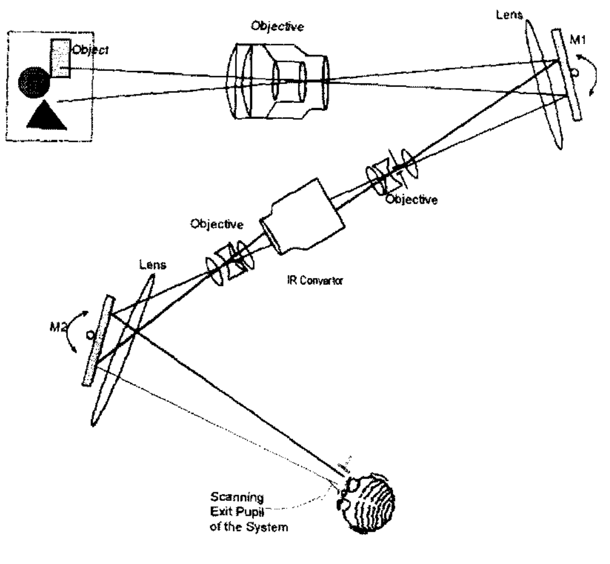

Fig. 7 Principle diagram of sliding aperture multiview system.

The moving aperture MIS is in a real sense, a kind of volume image generation and display systems, however, in a sense that the aperture of the camera objective is virtually divided into many small size apertures by a moving aperture, it is a multiview 3-D system. The moving aperture MIS requires an objective lens having a large output aperture and field of view angle to obtain bright image with wide field of view. In Fig. 7, a schematic diagram of the moving aperture MIS developed at KIST is shown. In this MIS, one large aperture objective lens which is used to image outside scenes is a camera. The aperture size of the objective lens is about 14cm and the field of view angle of the lens is 30°. The multiview images are prepared by a scanning spherical mirror located in the image volume of the objective lens. As the spherical mirror scans the image volume, the different parts of the image volume are continuously reflected from the mirror and are focused by a small lens to CCD or a fiber bundle for transmission. Since the mirror is scanned, the image of the small lens formed by the mirror, which appears on the objective lens aperture, scans across the objective lens like a moving aperture. The maximum resolvable number of multiview images obtainable with this moving aperture is given by the ratio of the objective aperture size to the image size of the small lens. This number can be made to very big by the proper selection of the aperture size of the objective lens and the image size. The brightness of each view image will be the decisive factors for determining the number. The moving aperture MIS can be a multiview 3-D system. At the receiving side of the system, the original volume image is reconstructed by a scanning mirror moving synchronously with that in the image volume of the objective lens. This system has a problem in magnifying image because of no available scanners to hold large size mirrors. The images created in the image volume of the objective lens is distorted in depth direction due to the magnification difference between transverse and longitudinal directions in lens. To compensate this distortion, it is necessary to magnify the image as much as the demagnification done by the objective lens. To do that, it is necessary to have a scanner with a large size mirror. Otherwise, it is necessary to arrange scanners with a long slit type mirror in parallel without gap between them. In this case, all scanners should be moved synchronously. Some of the image distortion can be compensated by increasing the scan angle of the scanner in the display side more than that in the camera side. The larger scan angle can effectively increase the parallax between images[8]. The scan rate of the scanner should be 30Hz for symmetrical fashion and 60Hz unsymmetrical fashion to compatible with the usual TV image. The scanners performs both functions of the LCD shutter and the signal converter in the previous MIS.

4. A Pulse Holographic Video System

The holographic video system was first developed at MIT to display holograms by electronic means. This system consisted of a CW laser as a source, an AOM (acousto-optic modulator) for holographic fringe display as (an) acoustic wave stream(s), and a polygon mirror or a scanner array to compensate reconstructed image moving due to the acoustic wave flow in the AOM and a graphic workstation for the preparation of computer generated hologram(CGH) as an input data[9].

The holographic video system developed at KIST uses a pulse laser as a light source instead of the CW laser, a multichannel AOM which is consisted of 6 trapezoidal shape AOM cells and a PC for the preparation of CGH data[10]. In this system, no polygon mirror or scanner array is utilized for the purpose of stopping the image moving because the AOM is sampled once for every time period of acoustic wave transit to the AOM, i.e., every time aperture of the AOM by a laser pulse. No image loss by this sampling is observed. However, there will be some blurs in the reconstructed image due to the image moving during the laser pulse duration. This image blur can be minimized by properly selecting the laser pulse duration. The multichannel AOM is designed such that every component AOM cell works independently but the acoustic wave inside of each cell is continuous with that in its neighbour cells. The multichannel AOM can effectively increase aperture length to the sum of component AOM cell's aperture length. Since the multichannel AOM has 6 AOM cells, the input data loading time is reduced to 1/6 of that for a single AOM. Fig. 8 shows the structure of the multichannel AOM. The current AOM cell structure allows to join the cells without limit.

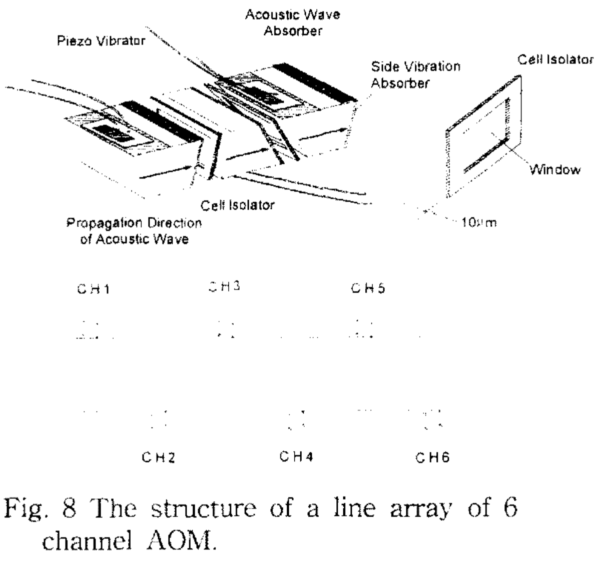

Fig. 8 The structure of a line array of 6 channel AOM.

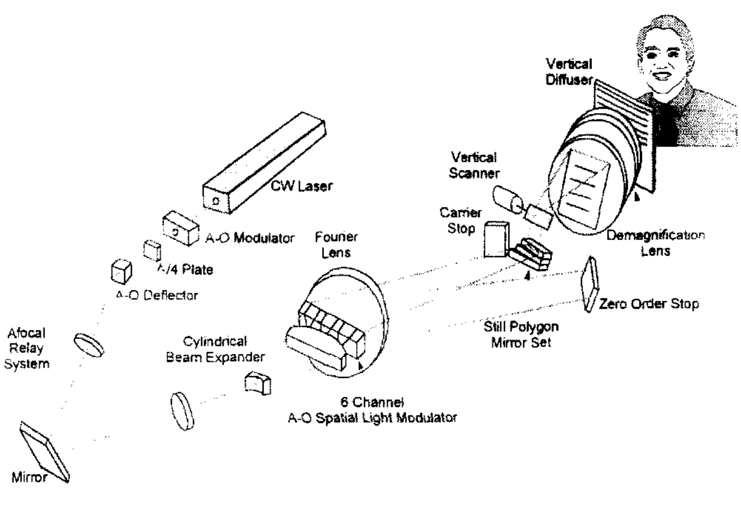

Fig. 9 Optical diagram of a pulse laser holographic video system.

The optical diagram of the pulse laser holographic video system is depicted in Fig. 9. The multichannel AOM is sampled 50,000 times/sec with a 200ns laser pulse. The source laser is an Ar laser (λ= 514.5nm). The CGH data has binary format. The total CGH data points for this system are 36,864 (Horizontal) $\times$ 128 (Vertical). The horizontal data point are segmented to 6 parts for each AOM cell. This system can display images having 7.4 $\times$ 5cm^2 with viewing angle 12°. The CGH images generated by KIST system is shown in Fig. 10.

Fig. 10 The left view and the right view of an edge cube image displayed by the holographic video system.

5. Holographic Screens

The holographic screen is a holographically made optical element which can be used to project both plane and 3-D images. The holographic screen has two types such as reflection and transmission and strong color dispersion property as the usual hologram.

KIST made full color holographic screens of both types. The transmission type screen[10] is

(a) Transmission type

(b) Reflection type
Fig. 11 Full color holographic screen.

recorded with a long slit type diffuser as an object to make red, green, and blue lights from different screen areas can be overlapped in (a) space(s) which is(are) a certain distance away from the screen. The full color reflection type screen is recorded on photopolymer film. Currently, it is possible to make full color transmission type holographic screens of size 30 × 40cm^2 and reflection type 20 × 30cm^2. In Fig. 11, full color holographic screens of transmission (Fig. 11(a)) and reflection (Fig. 11(b)) are shown.

6. Conclusion

Korea developed several multiview 3-D imaging system including pulse holographic video system. These systems are not fully developed yet but their performances are impressive. For the case of the 8 views 3 dimensional imaging system, the displayable full color views is exceeding the Cambridge Univ. version (5 Views). It is hoped that these systems can find their application to 3 dimensional computer/game/communication terminals, 3 dimensional movie system, and 3 dimensional TV in near future.

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