Live 3-D Video in Volumetric Display

Jung-Young Son, Sergey A. Shestak, Vladmir P. Huschyn, Vitaliy A. Ulizko and Dong-Hoon Kang

Korea Institute of Science and Technolog , Seoul, Korea

ABSTRACT

A live volumetric image is created from a plane image taken by a CCD camera with the aid of depth-wise segmented images from a high-speed B/W camera. The segmented images are obtained by a rotating screen in the image volume of an objective with a large aperture objective. By processing the output signal from th e B/W camera, the boundary of each segmented image from the camera is extracted. This boundary information is used to control the frame size of CCD camera image, which is projected through CRT projector to another rotating screen to generate volumetric image. The rotating screen displays image with frame speed of 30Hz. Each volumetric image is consisted of 8 layers. The rotating screen has a form of rotating cylinder with 8 slanted leaves along its circumference with an equal distance.

Keywords : Depth-wise profile image, Image Volume, Volumetric Image, Rotating Screen, Gating Signal

1. INTRODUCTION

Among many 3 dimensional(3-D) image displaying methods[1], the most frequently used method is representing many different view images created by animation or ma ny equal cameras aligned in horizontal direction with an equal distance between them, with use of a special optical plate. This method can be easily implemented compared with other known 2-D imaging methods due to its compatibility to the current plane ima ge systems. However, this method reveals several problems to be solved because it requires many cameras equal in number to the different view images to be displayed and having equal optical and electrical characteristics, and results eye fatigue due to it only dependence on both binocular and motion parallaxes for providing sense of depth[2]. As the number of cameras increases, they become bulkier and consequently, carrying them will cause more difficulties to the photographer. And also, there are difficulties in finding many cameras with the same characteristics, and further, making them have zoom capability will be extremely difficult.

Instead of using many cameras, input aperture of a camera objective can be divided with either use of a scanner in the image volume of the objective or LCD shutter in the aperture[3]. These methods can provide many different view images, however, they require that the objective needs to have a large field of view and aperture size to obtain necessary parallax amount. These requirements make the objective heavy and further provide no solution to the eye fatigue problems.

Since the image formed by the camera objective has a volume, the plane images sampled along the axis of the objective will represent the depth-wise profile image of the object. The depth-wise image will be clearer as the objective's depth of focus smaller,

In this paper, the depth-wise profile images of an object, focused at the image volume of a camera objective are sampled with a rotating screen. These images are used to segment a plane image of the object, taken with a CC camera. The segmented plane images are projected sequentially in accordance with the order of the profile image sequence, on another rotating screen synchronized with the first, to create volumetric image of the object.

2. FORMATION OF CAMERA IMAGE

The image volume of a camera is located behind the back focal plane of the objective and its profile is like that of a bel whose top is at the back focal point, because the magnification of the camera becomes smaller as nearer to the focal point. The plane image obtained with the present camera is the squeezed image of the volumetric image formed in th image volume. However, as the aperture size of the objective increases, the cross-sectional image in the image volume along the optics axis of the camera becomes more localized. Hence if a diffuser plate is moved along the axis of the

Stereoscopic Displays and Virtual Reality Systems IX, Andrew J. Woods, John O. Merritt,
Stephen A. Benton, Mark T. Bolas, Editors, Proceedings of SPIE Vol. 4660 (2002)

camera objective, the image formed on the plate will be a clearly focused image of the object corresponding t the plate position, along with defocused image corresponding to the other positions along the axis. The focused image on the plate will be photographed by a high -speed camera and processed to obtain the profile of the volumetric image along the axis. A ra ster pattern can be projected on the object to enhance the accuracy of the profile information by providing extra clue of sharpness. It is possible to obtain the image profile with moving the diffuser plate if the objective with variable focuses is used. Lens formula tells that when object image position is fixed, focal length is a function of objec position[4]. And also the object image position is not a linear function of object position, this factor should be compensated in the designing the rotating screen in either side of camera or display to minimize distortions in the depth direction of the displayed image.

3. SYSTEM OPERATION

In Fig. 1, the schematic diagram of the current volumetric image system is shown. The object image is formed in the region where the rotating screen is positioned. The axis of the rotating screen is aligned in parallel with the optics axi of the objective to make the optic axis be in the center of the screen. The screen has a shape like two-layered cylinder with 17cm length. The gap between inner and outer cylinders has a size of 15 ㎝. This gap is divided into eight equal regions along its circumference and then a diffuser plate is mounted diagonally in each of the eight regions. The diffuse plate in each region has th same parameters as others and has a size of 20(Horizontal) X 15(Vertical) ㎠. The rotating speed of the screen is 3.75Hz and the images appearing in each diffuser plate are sampled 16times/rotation by the high-speed camera. Hence the rotation angle covered by each diffuser plate is 45degrees and each frame image of the high-speed camera covers depth range equivalent to 2.8degrees rotation angle.

The images appearing on the screen are photographed by a high-speed camera. This high-speed camera is operating with the frame rate of 480Hz and provides only black and whit e(B/W) image. The same object image is taken by a CC camera through a half-mirror in front of the objective. The CCD camera is necessary to display full color image because there are no full color camera with 480Hz frame rate. The half mirror can be place d behind the objective. In this case,

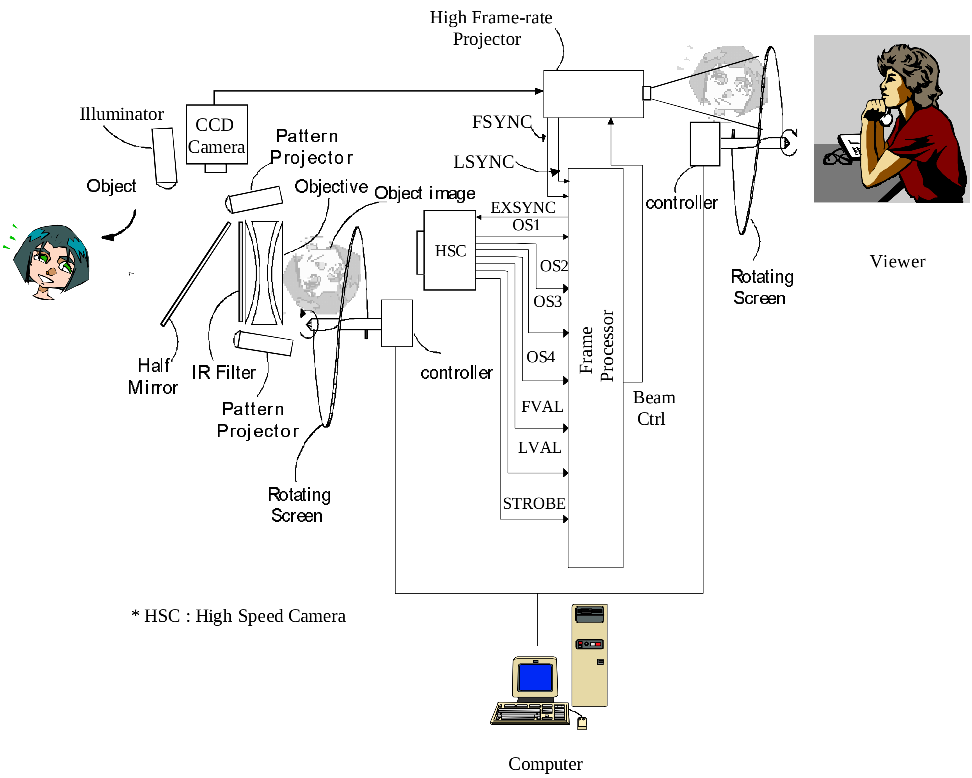

Fig.1 The Schematic of Designed Volumetric Syste m

the system will be easy to assemble, but extra distortions in the displayed image will be introduced. A raster pattern is projected on the object surface with use of an IR(Infrared) light source to enhance the contrast of the pattern under any illumination condition of the object. It is necessary to put an IR blocking filter in front of the CCD camera and put a visible-light blocking filter in front of either the objective or the Dalsa camera. The frame processor is fin ding edges of the focused B/W images from the high-speed camera and generating a gating signal that specifies the width between the edges. This signal is used as a gate for projecting the CCD camera image through the high -speed CRT projector, which is operating with field rate 480Hz. The rotating screen in the display side is the same shape as and rotates synchronously with the one in the camera side. Hence the high-speed projector projects one frame image eight times(8 odd + 8 even fields) to each diffuser plate. Since each diffuser plate covers 45 degrees, the image displayed on the diffuser plate will be changed accordingly by the frame processor signal output.

Fig. 2 shows the principle of generating the gating signal by the image captured by the high s peed camera. In each pixel line of the captured image, if the difference between gray levels of two consecutive pixels exceeds a preset value, a short pulse is generated. The time interval between the short pulses is measured and it is within the preset va lue, a gating pulse is generated. If the interval is exceeding the value, the short pulse is either used as the gating pulse or grouped with next short pulses. The preset time interval is determined by the projected raster period. Fig. 3 shows the timing diagram of image sequence. One CCD frame is divided into odd and even field images and then multiplexed in time into a serial signal, which consists the eight consecutive odd field images followed by the eight even field images within the one frame time, i. e., 33.3msec. Each frame of the high -speed camera starts the same moment with that of each field image. However, The frame image ends earlier than the field image. In the frame buffer, the short pulse and its corresponding pixel position is recorded to gen erate the gating signal.

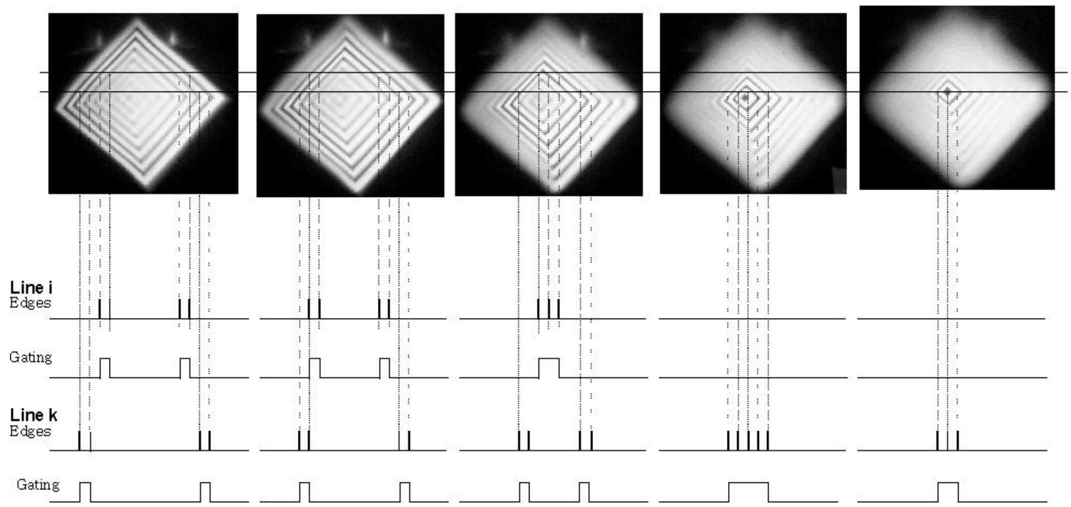

Fig.2. Generating Gating signal for Image Displa

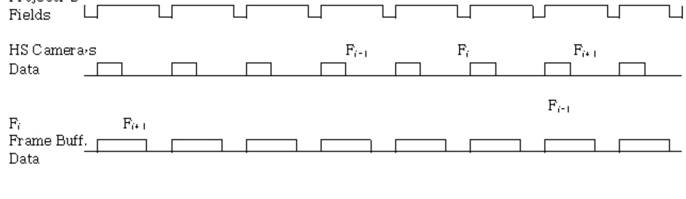

Fig.3. Timing Diagram of Image Sequence

Fig.4. Experimental System

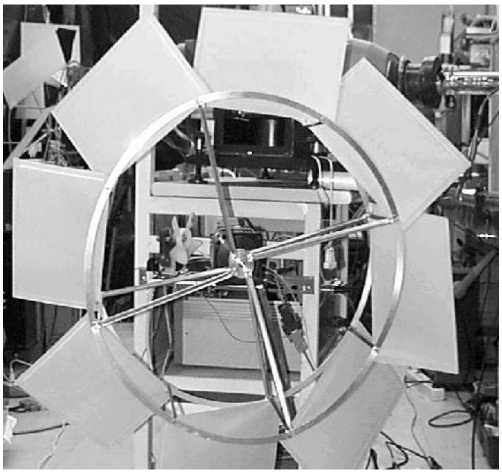

Fig.5. Frontal View of the Rotating Screen

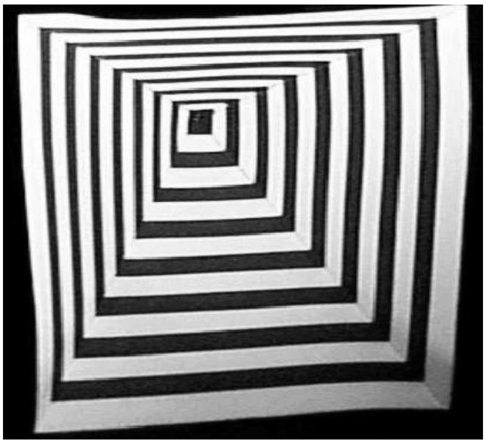

Fig.6. A Pyramidal Cone Shape Object

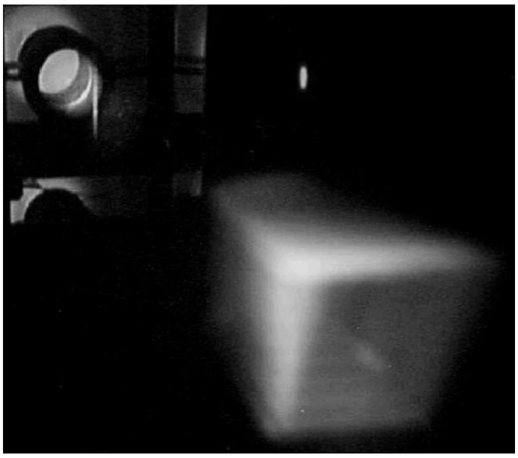

Fig.7. Pyramidal Cone Shape Image Formed by the Volumetric Rotating Scree

4. EXPERIMENTAL RESULTS

The experimental system is shown in Fig. 4. The objective lens has focal length of 18 ㎝ and input pupil size of 12㎝. The rotating screen has a diameter of 47㎝. The front view of the screen is shown in Fig. 5. As an object, a pyramidal shape cone placed with bottom area near to the objective is used. This is shown in Fig. 6. In the inner surface of the cone, dark parallel stripes are drawn to enhance the contrast between the focused and unfocused images on the diffuse plate. The images taken by the high-speed camera, which has 260 X 260 pixel resolution is shown in Fig. 2. These images clearly show that the focused region moves from bottom to top regions. The green color pyramidal image formed by the rotating screen in Fig. 5 is shown in Fig. 7. The image is close to the original object. The main obstacle in this experiment is the low sensitivity of the DALSA camera. Due to its low sensitivity, only small size and simple shape object can be used. In the current experimental configuration, if the high-speed camera can output full color image, the CCD camera can be removed because the output image of the high -speed camera can be directly used to form the volumetric image.

CONCLUSIONS

It is shown that a volumetric image can be formed from a plane image if the plane image is segmented properly by depth information and then projected in proper order to a layered screen. Due to the low sensitivity of the high-speed camera, only simple object is used. If illumination method is improved, more complicate object can be used.

REFERENCES

1. Jung-Young Son, Vladimir I. Bobrinev, Autostereoscopic Imaging Systems Based on Holographic Screen", Three Dimensional Video and Display: Devices and Systems, Eds. B. Javidi and F. Okano, SPIE Press, Vol. CR76, 2001.
2. Fundamentals of 3D Images, Edited by Izumi Takehiro, NHK Broadcasting Technology Research Center, Ohm Sa, Tokyo, Japan, 1995.
3. Sergei A. Shestak, Jung-Young Son, Hyung-Wook Jeon, and Victor G. Komar, "Sliding Aperture Multiview 3-D Camera-projector System and Its Application for 3-D Image Transmission and IR to Visible Conversion", SPIE, V3012, pp96-106, 1997.
4. F. A. Jenkins and H. E. White, Fundamentals of Optics, McGra -Hill, New York, 1976.