Image-based Stereo Background Modeling for CAVE System

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ABSTRACT

In this paper, we make 3D stereo backgrounds for a CAVE system from real world for users to feel more realistic. We take panorama photographs with the 3D sweep panorama™ functions and generate equirectangular panorama format image by stitching them manually. Finally 3D stereo background of CAVE is constructed using this panorama format image. We propose a generation method of 3D equirectangular panorama format image and background modeling of CAVE using these images.

KEYWORDS: Panoramic Stereo Imaging, Omnistereo, Immersive Projection Display, CAVE, Virtual Reality.

INDEX TERMS: I.3.7 [Three-Dimensional Graphics and Realism]: Virtual reality; H.5.1 [Multimedia Information Systems]: Artificial, augmented, and virtual realities

1 INTRODUCTION

In computer graphics and computer vision, there are image based rendering and modeling methods. These methods can product more realistic results than synthesis ones in low costs. These methods can be applied to background generation of virtual reality environments like CAVE [1]. Using real image as background, the users of virtual environment can feel more realistic than synthesis one when the system is for telepresence. The real image background can be also useful for virtual education (e.g. traffic safety education for kids) and virtual therapy (e.g. acrophobia, agoraphobia therapy).

In this paper, the panorama image format [2] is used to contain whole directional scene of real environment. The CAVE is the system that consists of several screens with projectors for users to feel emersion. So we need whole directional image to render the background of it.

Several methods about stereo panorama have been researched [3][4][5]. It is called 'omnistereo' and the researches are about generations of stereo panorama image. But their results are not whole directional panorama and are only cylindrical landscape one. There is a study about omnistereo for panoramic virtual environment display systems, i.e. CAVE but it use synthesized graphics and only cylindrical landscape panorama, too. In this paper, we make an equirectangular panorama image by stitching the cylindrical omnistereo images.

We develop a method that generates whole directional stereo background of CAVE system as an application of omnistereo methods and telepresence of virtual reality. In next chapter, the panorama image format is explained and how we generate stereo panorama in chapter 3. We explain the modeling of background of CAVE and show some results in chapter 4, 5. Finally we conclude our sturdy and suggest our future directions.

2 PANORAMA IMAGE FORMAT

The panorama image format is the format of a panorama image and the image of this format contains more scene information than only one shot of image. There are two formats contain whole directional scene used mainly among all panorama formats. They are cubic and equirectangular format [2].

The cubic format consists of six faces that fill the whole sphere around us. When we use this format panorama as background of CAVE, there is no problem and even efficient if the rotation of background is fixed as shown in the left image of Figure 1. But when the rotation is changed, there happen distortions in the corners of background cube as shown in the middle image of Figure 1. Or it needs the extra cost to map into the CAVE's faces.

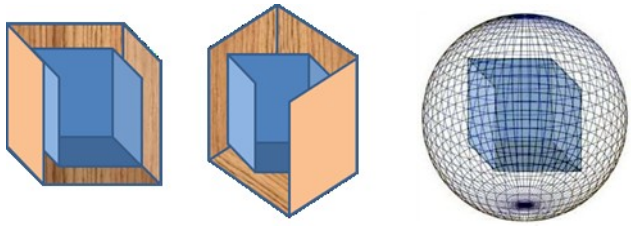

Figure 1. Cubic and equirectangular panorama formats

The equirectangular format uses a single image which's aspect ratio is 2:1. The width corresponds to 0 ~ 360° horizontally and the height to -90 ~ +90° vertically. We use this format image in the background modeling by making virtual sphere around the CAVE as shown in the right image of Figure 1. The advantage of this method is that there is no distortion or needs no remapping about the rotation of user's viewing direction. The background modeling of the CAVE is explained in detail in Chapter 4.

3 STEREO PANORAMA

We use omnistereo method to make 3D stereo panorama image. There are researches about omnistereo with two lenses [3] and a single lens [4]. We use Sony α NEX-5™ digital camera because it provides 3D sweep panorama™ function [6]. It can make a still stereo panorama from several photos taken sequentially with a single lens. It is only cylindrical subset of panorama and the angles of result image are also limited.

After shooting 3D panorama images, we stitch them manually. First we stitch the photos using 3D sweep panorama™ in the middle raw of the sphere of Figure 2. The arrows mean the direction of taking sequential photos that make stereo panoramas. For example, there are four stereo panorama images taken using 3D sweep panorama™ to stitched into one cylindrical panorama.

The upper part above this raw and lower part below this of whole equirectangular panorama are generated using photos taken with a panoramic tripod head using this method [7]. The minimum

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IEEE International Symposium on Virtual Reality Innovation 2011
19-20 March, Singapore
978-1-4577-0037-8/11/$26.00 ©2011 IEEE

numbers of taking pictures are calculated. They are not stereo panorama image.
Finally we combine the upper part and the lower part subset of whole panorama with middle stereo panorama images by stitching. There are two middle panoramas, made of left and right photos of 3D sweep panorama™. Finally two equirectangular panoramas are generated for left and right eyes.

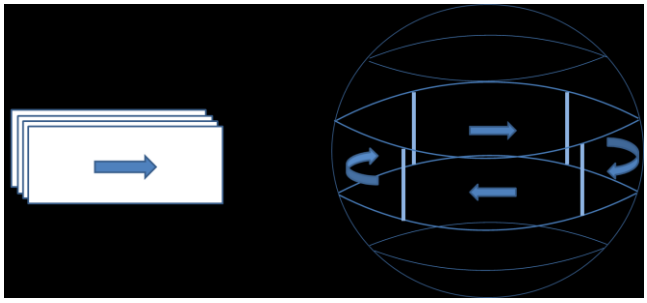

Figure 2. Stereo panorama stitching

The stereo effect of upper part and lower part is not so easy problem. When we look near horizon, the baselines of left and right eyes are almost same in our view regardless of the rotation. When we look up and down, the baselines change rapidly in our view. The center of our view and slightly left or right part do not have the same baseline.
We stitch the upper and lower part of panorama into the middle raw. The upper and lower parts are slightly rotated when they are stitched into left and right panorama raw separately. But there is unnatural transform in these borders.

4 Background Modeling for CAVE

The modeling of background of the CAVE uses virtual sphere and texture mapping. The virtual sphere surrounds the CAVE is defined as shown as the right image of the Figure 1. We use the equirectangular panoramas from Chapter 3 as the textures in rendering system of the CAVE. These textures are mapped into the inner faces of the virtual sphere.
The texture mapping is as shown in the Figure 3. If u and v are the coordinate of some point on the panorama image and x, y and z are correspond point in CAVE's coordinate, the relation between them are as follows.

$$x = \cos\theta\cos\pi$$
$$y = \sin\theta \qquad (1)$$
$$z = \cos\theta\sin\pi$$

$$u = \pi$$
$$v = \theta + 90° \qquad (2)$$

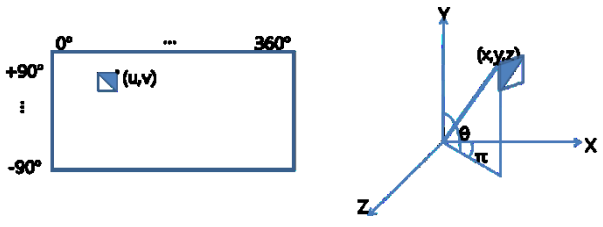

Figure 3. Modeling of background of CAVE

Under these relational conditions, we can produce texture mapping with changing θ and π by the unit values.

The stereo view is obtained using the separate texturing. The mapping is the same way for both eyes but the textures of panorama image are different. The separate texturing is implemented using the stereoscopic glasses and the stereo projectors of the CAVE.

5 Results

Our CAVE system consists of 4 screens, 8 projectors (4 for left eye and 4 for right eye), 5 Linux based PCs (one for master and 4 for renderer), a magnetic position sensor and a joystick. Stereo feature is obtained by circular polarization filters and experiments are developed using OpenCABIN library [8].
We use Sony α NEX-5™ digital camera with focal length 16mm lens for photographing the environment. It provides 3D sweep panorama™ function that produces stereo cylindrical panorama still image from sequential photo shooting [6]. We use Fanotec™ NN3-II as panoramic tripod head. It doesn't support compact camera like NEX-5 so we modify it a little. The configuration of photographing and calibration of tripod head are shown in the Figure 4.

Figure 4. Configuration of photographing and calibration

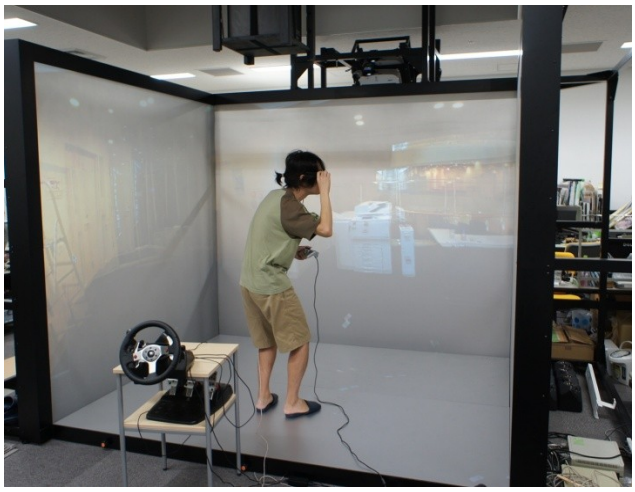

Figure 5. Stereo background modeling implementation in CAVE

We take 7 photos using 3D sweep panorama™ function. The example of this photo is shown in the Figure 6. 12 photos are taken in +/- 30° and 6 photos in +/- 60°. We take 4 pictures each +90° and -90°. After photographing, images of left and right eye view are aligned and separated using StereoPhoto Maker v4.31. We stitch and edit images with PTGui Pro 8.3.3 and generate the equirectangular panoramas. The results for left and right eye view are shown in the Figure 7 and 8. The border between the middle

raw and the upper or lower part is morphed by manual stitching. The implement in the CAVE is shown in the Figure 5.

6 Conclusion

We develop a method that generates whole directional stereo background of CAVE system as an application of omnistereo methods and telepresence of virtual reality. We take panorama photographs with the 3D sweep panorama™ function and generate equirectangular panorama format image by stitching them manually. Finally 3D stereo background of CAVE is constructed using this panorama format image.
We propose a generation method of 3D equirectangular panorama format image and stereo background modeling of CAVE using these images.

7 Future works

The stereo effect of the upper and lower part is thought to be the challenging problem. We plan to extend our study to a stereo street view.

Acknowledgement

This work was supported by G-COE (Center of Education and Research of Symbiotic, Safe and Secure System Design) program at Keio University.

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Figure 6. Photo for left and right eye view

Figure 7. Panorama image for left eye view

Figure 8. Panorama image for right eye view