# Panoramic Stereo Representation for Immersive Projection Display System

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## ABSTRACT

In this paper, the panoramic stereo images are produced from the real environment using a digital camera and a panoramic tripod head. And they are applied to the CAVE system as panoramic stereo background to increase user's immersion. The images for left and right eye are taken and stitched separately for stereo imaging. Finally the stereo backgrounds are constructed using the virtual sphere surrounding CAVE.

**Keywords:** Panoramic Stereo Imaging, Omnistereo, Immersive Projection Display, CAVE, Virtual Reality

## 1. INTRODUCTION

The immersive projection display systems like CAVE™ [1] have developed for users to feel they are in a virtual world. The virtual world can be a newly synthesized world. This system can be used for the telepresence application that the users feel they are at a location other than their true location. In both cases, if we use real world images as background in this system, we can get reality without graphic designers' efforts.

To make a real world background, we use a panoramic image format because this format image contains 360° whole direction's information systematically. If a panoramic image representation which surrounds users by the real images is applied to the immersive projection display system, we can make more immersive environment. There are several researches about panoramic imaging [2].

There are several researches about stereo representation of panoramic image [4][5][6] and it is called omnistereo. They focused on the generation of stereo image and their panoramic images are only the horizontal ones. There is a study about omnistereo for panoramic virtual environment display systems [6] but they use synthesized graphics and only horizontal panoramic, too.

In this study, we developed a panoramic stereo image representation for the K-CAVE [7] to increase user's immersion. First we took pictures of real world using a digital camera with a tripod and a panoramic tripod head. Then we stitched them to make panoramic images of left and right eye's view for background. Finally we make a panoramic stereo image representation for the K-CAVE using these images.

## 2. PANORAMIC STEREO IMAGE REPRESENTATION

### 2.1 Panoramic Imaging

The panoramic image format which shows 360° field-of-views in the vertical and horizontal directions is used in our work. There are two main formats of panorama image; cubic and sphere (equirectangular) formats [3]. We use the sphere format to produce image representation because the background images are located and shown with 3-D coordinate in the K-CAVE, then the images of the cubic format are distorted in the boundaries of each image. We make a virtual sphere in 3-D coordinate which contains the cubic of K-CAVE screens like Figure 1. Then we projected the sphere format image to the inner faces of the virtual sphere. This projection is implemented using the texture mapping technique.

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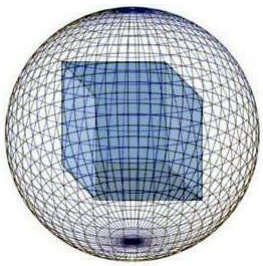

**Figure 1. Virtual Sphere containing K-CAVE**

## 2.2 Panoramic Stereo Image Photographing

We considered several factors of panoramic photographing in our previous work [8]. For stitching, a camera was rotated in the axis of a no-parallax point. A panoramic tripod head guided the rotation of the camera systemically. The exposure value, the f-number, the focal length and the shutter speed must be fixed through all images.

But if we want to get stereo image of left and right separately, the camera must be rotated with some parallax. It makes the binocular disparity for stereoscopic vision. The camera configuration for each eye's view is in Figure 2.

**Figure 2. Camera Configurations for Left/Right Eye's View**

In our previous work [8], the number $n_\theta$ of needed images with tilt degree $\theta$ is as follows.

$$n_\theta = \left\lceil \frac{360\cos\theta}{fv(1-l)} \right\rceil \qquad (1)$$

$fv(^\circ)$ is the field of view and the adjacent images overlap $l(\%)$. To make stereo panoramic images, we must take pictures of same tilt as possible as we can. The more pictures we take, the small distortion between the adjacent one are happened. We can calculate reversely using the formulations of our previous work. So the number of pictures and overlap percentage are fixed and the focal length can be calculated.

The images for each eye's view are stitched separately. They stitched manually and the distortion between the adjacent images is interpolated.

## 3. IMPLEMENTATION

The K-CAVE [7] is a CAVE-clone display system at the Keio University. It consists of 4 screens, 8 projectors, 8 Linux based PCs, a magnetic position sensor and a joystick. Stereo feature is achieved by circular polarization filters and all experiments are developed using OpenCABIN library [7].

To produce stereo image background in K-CAVE, two panoramic stereo format images are used. The system architecture is shown as Figure 3. The server module read left and right panoramic image JPG file and send them to four renderer modules via TCP. The modules are implemented using OpenCABIN library which displays graphical contents on the screens and handles user's inputs like position, direction, joystick values, etc.

The stereo polarization filtered glasses is equipped in our K-CAVE system. We use two panoramic images for left and right eye to produce stereo background image. We can make the user see the texture using left panoramic image through left eye and vice versa.

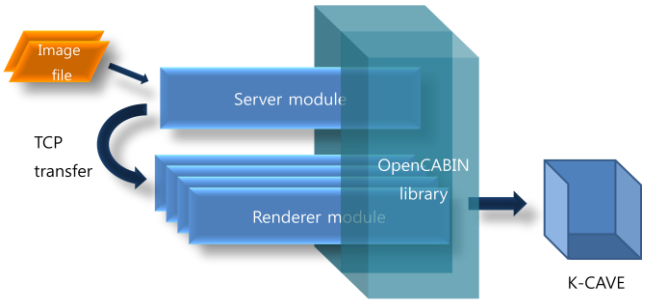


**Figure 3. System Architecture**

## 4. RESULTS

Nikon™ D70 digital camera with Nikon™ 18~70mm DX lens are used in our work. As the panoramic tripod head, Fanotec™ NN3-II is used. We take 24 images in 0°, 20 in +/-30°, 12 in +/- 60° and 4 in +/-90° to produce one panoramic image. The focal length is 40.9mm and the parallax distance is 328mm. We stitch these images to a panoramic image using Autodesk© Stitcher™ Unlimited 2009 software. The final panoramic image for left eye's view is shown in Figure 5 and for right is Figure 6. Their resolutions are 1948 X 974. The demonstration in K-CAVE is shown as Figure 4.

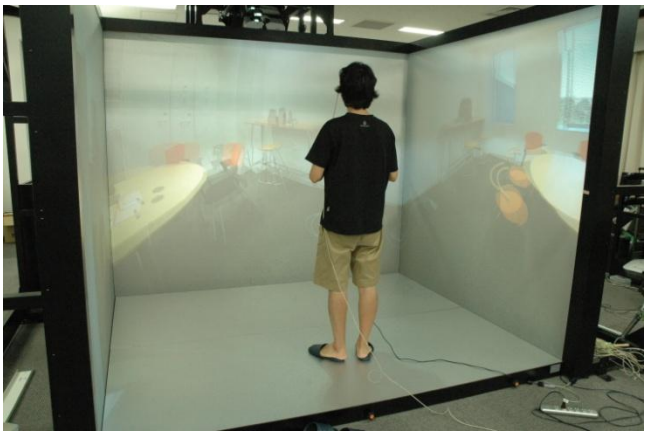

**Figure 4. Panoramic Stereo Representation in K-CAVE**

## 5. CONCLUSION AND DISCUSSION

In this study, the panoramic stereo images are produced from the real environment using a digital camera and a panoramic tripod head. Then they are applied to the K-CAVE system as panoramic stereo background to increase user's immersion. The images for left and right eye are taken and stitched separately for stereo imaging. We make the stereo backgrounds using the virtual sphere surrounding CAVE.

The contribution of our study is to try to extend panoramic stereo to 360° whole direction vertically. But there are distortions that can't be ignore between images of different tilt degree. It must be solved in the future study. And the parallax distance between left and right view are also to be considered.

## 6. FUTURE WORKS

The distortions between different tilt images in the panoramic image must be solved in our future works. And we plan to apply stereo reconstruction algorithm to our works for interaction.

## 7. ACKNOWLEDGMENTS

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**Figure 5. Panoramic Image for Left Eye's View**

**Figure 6. Panoramic Image for Right Eye's View**