

# 몰입형 프로젝터 디스플레이 시스템을 위한 이미지 기반 파노라마 표현 Image Based Panorama Representation for Immersive Projection Display System

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**Abstract:** The immersion is the key feature of the CAVE system of virtual reality. If we surround users by the real images - panoramic imaging - in CAVE, we can make more realistic environment. We make the panoramic images from the real environment using a digital camera and a panoramic tripod head and apply them to the K-CAVE system to increase user's immersion. We formulate panoramic image photographing for efficiency and use the SCTP data connection for reliability in the K-CAVE system.

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

## 1. Introduction

In virtual reality research field, the CAVE [Cruz-Neira92] is a widely used display system for user's immersion. The projectors and the screens of the CAVE are used for users to feel high immersion. They surround users with artificial objects, avatars, background and etc. The CAVE can use a real images or image-based rendering objects to feel more realistic. A real image-based background can be used just as users see in real world and a panoramic image can be viewed like this because it can surround user in the 360° whole direction.

If a panoramic image representation which surrounds users by the real images is applied to the CAVE, we can make more immersive environment. There are several researches about panoramic imaging like QuickTime VR [Chen95] and they are well surveyed in [Gledhill03].

In this paper, we develop a panoramic image representation for the CAVE to increase user's immersion. First we shot background photos of real world using a panoramic tripod head, a digital camera and a tripod. Then we stitch them to produce a panoramic image for background. Finally we make a panoramic image representation for the CAVE using these images. Also we use SCTP [Stewart07] data transfer for reliable data connection in runtime.

## 2. Panorama image representation

### 2.1. Panorama image format

There are two main formats of panorama image [PanoTools] which show 360° field-of-views in the vertical and horizontal directions. One is the equirectangular format (Figure 1) and the other is cubic (Figure 2). The equirectangular format is also called the spherical format. It contains a single image of the equirectangular projection

and its ratio is 2:1. The cubic format is made of six face images of cube that surrounds user.

Figure 1 and 2 are example of equirectangular and cubic panorama image format. The earth map image of Figure 1 is from NASA and Figure 2 is made from Figure 1. In Figure 2, we can see Antarctica and the Arctic Ocean without distortion.

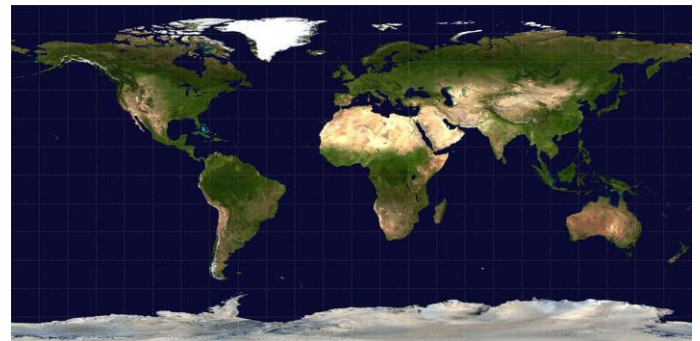


Figure 1: Equirectangular panorama image format. (Courtesy of NASA)

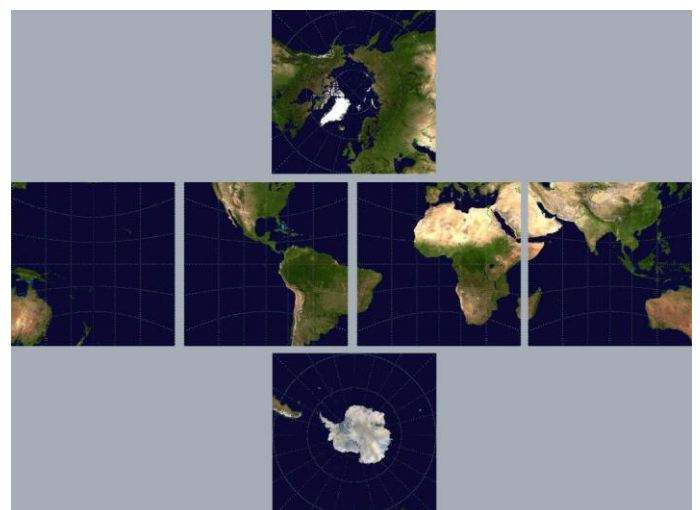


Figure 2: Cubic panorama image format version of Figure 1.

## 2.2. Panorama image representation in CAVE

We use the equirectangular format to produce image representation. Because the background images are located and shown with 3 dimensions in the CAVE, the images of the cubic format are distorted in the boundaries of each image. We make a virtual sphere which contains the whole hexahedron of CAVE screens. Then we project the equirectangular format image to the inner face of the virtual sphere. This projection is implemented using the texture mapping technique.

## 2.3. Data transfer over SCTP in CAVE

In our K-CAVE system [Tateyama08], we use 4 screens and 8 projectors – left and right image projectors for each screen. There are 4 rendering PC servers which controlled by one master server. We develop data transfer between master and rendering servers using SCTP protocol [Stewart07]. We had already implemented a SCTP test bed in UNIX system.

A host is multihomed if it can be addressed by multiple IP addresses as is the case when the host has multiple network interfaces [Stewart07, Iyengar04]. The current transport protocols - TCP and UDP - are ignorant of multihoming; TCP allows binding to only one network address at each end of a connection. When TCP was designed, the network interfaces were expensive components, and hence multihoming was beyond the scope of research. Increasing economical feasibility and a desire for networked applications to be fault tolerant at an end-to-end level have brought multihoming within the purview of the transport layer.

SCTP is a new transport protocol in the Internet [Stewart07, Iyengar04]. It is a connection-oriented protocol and provides reliable data communication between applications. One of the important features of SCTP is multihoming function. SCTP establishes a logical connection called the association prior to data communication. The end points of an association may have multiple addresses, i.e., there can be multiple data paths in an association. One of the paths is called the primary path and the others are called the secondary paths. Data is transmitted on the primary path. If the primary path becomes unavailable due to some errors, one of the secondary paths is selected as the primary. For a reliable data connection in future, we use SCTP protocol for data transfer. The update rate is not so important yet because we send only one panoramic image in this step.

## 3. Panorama image photographing

### 3.1. Panorama photographing

We use a digital camera and a panoramic tripod head for photographing because a digital camera is widely spread and a panoramic tripod head is very cheaper than a panoramic photographing system.

When we take a panoramic image, it must be considered to stitch together later. We can rotate the camera in the axis of a no-parallax point, which is also called a nodal point, to

eliminate parallax between images. A panoramic tripod head which is shown in Figure 3 is used to rotate the camera on the no-parallax point.

While we take a picture, there are some conditions which were kept in mind. The exposure value, the f-number, the focal length and the shutter speed must be fixed through all images. If these values are not fixed, the resulting images are mottled. We can take pictures in this condition using manual mode. Large f-value is preferred to get generally clear image.



Figure 3: Photographing using panoramic tripod head.

To get the images, we must move a tripod which is not so light to carry and take dozens of pictures. If we pre-calculate how many and what directions images we must take, we can do photographing more efficiently.

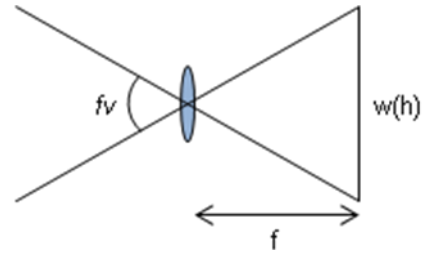


Figure 4: Camera diagram.

As shown in Figure 4, for the width  $w(\text{mm})$  (or the height  $h(\text{mm})$ ) of CCD in the camera and focal length  $f(\text{mm})$  of camera lens, the field of view  $fv(\text{degree})$  in horizontal direction is as follows.

$$\tan(fv/2) = \frac{w/2}{f} \quad (1)$$

If we want to overlap  $l(\%)$  between the adjacent images, we need  $n$  images to fill in horizontal direction as follows.

$$n = \left\lceil \frac{360}{fv(1-l)} \right\rceil \quad (2)$$

Using similar calculation with the height  $h(\text{mm})$  of CCD, we can get the number  $k$  of images to fill in vertical direction. The unit tilt degree difference  $d$  between the adjacent images in vertical direction is as follows.

$$d = \frac{360}{m} \quad \begin{array}{l} m \text{ is the smallest number that} \\ \text{is a multiple of 2 and } m \geq k \end{array} \quad (3)$$

$m$  is a multiple of 2 because + and - degree parts are symmetry. We take photos of tilt degree  $d$ ,  $\pm 2d$ ,  $\pm 3d$ , and so on until  $\pm 90^\circ$ . The number  $n_\theta$  of needed images with tilt degree  $\theta$  is as follows.

$$n_\theta = \left\lceil \frac{360 \cos \theta}{fv(1-l)} \right\rceil \quad (4)$$

$\theta$  is one of a multiple of  $\pm d$ . But when we photograph in the wide area with same texture like Figure 6, 7, we must the smaller degree than  $d$  for - degree part below horizon for stitching.

## 4. Results

Our photographing system is shown as Figure 3. We take images using Nikon™ D70 digital camera with Nikon™ 18~70mm DX lens. As the panoramic tripod head, Fanotec™ NN3-II is used. We take 12 images in  $0^\circ$ , 8 in  $-30^\circ$ ,  $+45^\circ$  and 1 in  $\pm 90^\circ$  as shown in Figure 6. We take pictures in  $-30^\circ$  instead of them of  $-45^\circ$  which contains no anchor to stitching. We stitch these images to a panoramic image using Autodesk© Stitcher™ Unlimited 2009 software. The final panoramic image is shown in Figure 7. Its resolution is 3600 X 1800.

The K-CAVE [Tateyama08] 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 [Tateyama08]. We implement a panoramic image representation in K-CAVE as shown in Figure 5.



Figure 5: Panoramic image representation for K-CAVE.

## 5. Conclusions

We make the panoramic images from the real environment using a digital camera and a panoramic tripod head and apply them to the K-CAVE system with SCTP data transfer to increase user's immersion.

Our contributions are as follows. We take photos for panoramic image representation efficiently by formulating

the calculation of panoramic image photographing. And we construct panoramic representation for the CAVE to improve user's immersion and use SCTP data transfer for reliable data communication.

## 6. Future Works

We plan to expand the panoramic image representation to stereo. For  $360^\circ$  field of view in horizontal only, there are several researches but we expand them to in whole direction - vertical and horizontal direction.

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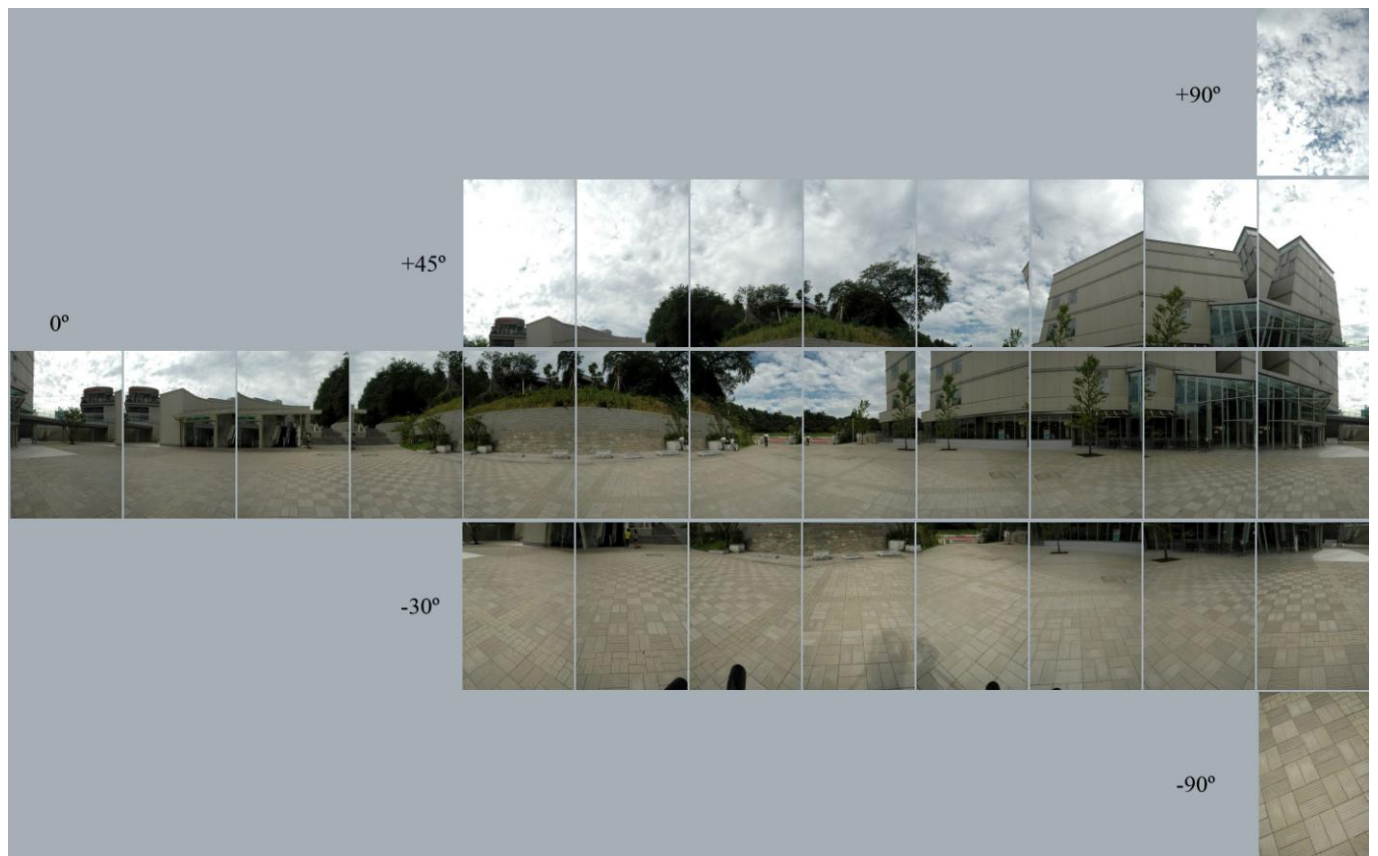


Figure 6: Raw images of each tilt degree.



Figure 7: Stitched panoramic image.