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Telepresence System with an Omnidirectional HD Camera

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Abstract

We proposed the telepresence method that enables us to instantly look around a visualized space of a dynamic real world. However, it was a problem with the conventional omnidirectional camera with a NTSC camera and a hyperboloidal mirror that the resolution was poor. This paper describes a new telepresence system with an omnidirectional HD camera, which used a HD camera and a hyperboloidal mirror. This system has the resolution of more than four times more than a conventional system with a NTSC camera.

1. Introduction

Recently, in the remote control of the mobile robot, the telecommunication conferencing that many people participate in, and so on, there are many requirements of looking around the distance with rich presence. The virtual reality technique that gives users the sensation, which he is similar in the distance, is called telepresence. In most conventional telepresence systems, active cameras such as panning and tilting cameras are utilized to immersively present to a user view-dependent images of a scene in the distance (Figure 1). This often suffers from the time delay from the change of viewing direction to the change of displayed image. The time delay is mainly caused by both the communication between an observation site and an observed world and the control of cameras to follow the user's viewing direction. Especially the former factor depends on the actual distance between the observation and observed sites.

Thereagainst, we proposed a new telepresence system with an omnidirectional video camera. This system requires video-rate omnidirectional imaging of dynamic real scenes and view-dependent image display, which simulates camera motions such as panning and tilting. This provides a novel approach to real-time telepresence and is applicable to the situation where the real world to be seen is far from an observation site, because the time delay from the change of viewing direction to the change of displayed image does not depend on the actual distance between both sites. Moreover, this technique enables not only real-time telepresence, but also store-and-playback telepresence. However, because the conventional omnidirectional camera acquires omnidirectional images by NTSC camera, there was a problem in the resolution of the conventional system.

Thereagainst, we use omnidirectional camera with HD camera and develop high-resolution telepresence system. This paper describes this high-resolution telepresence system.

This paper is structured as follows. First, we describe the omnidirectional HD camera with the conventional omnidirectional NTSC camera. Second, we describe the high-resolution telepresence system compare with the conventional telepresence system using omnidirectional NTSC camera. Finally, we describe conclusions.

2. Omnidirectional HD camera

Recently wide-angle or omnidirectional camera has attracted much attention in several different fields. A variety of sensors has been developed to acquire

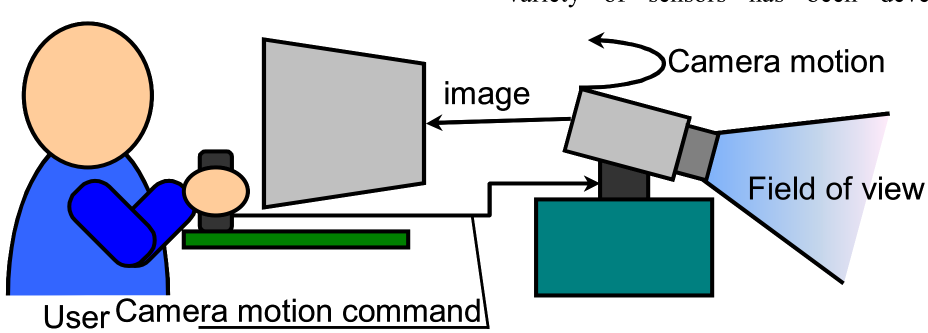

Figure 1: Conventional telepresence system using panning and tilting

omnidirectional visual information on a 3D environment[[1]-[8]]. Our Omnidirectional camera is HyperOmni Vision using a hyperboloidal mirror[[7],[8]]. HyperOmni Vision satisfies following two requirements in the telepresence.

1. video-rate imaging of a dynamic environment;
2. satisfaction of perspective optics.

HyperOmni Vision is mainly composed of a hyperboloidal mirror and a single standard camera as illustrated in Figure 2. The hyperboloidal mirror has two focal points (O_M and O_C). Note that the camera center is fixed at one of the focal points (O_C) of the mirror. The hyperboloidal mirror yields a 360-degree circular omnidirectional image of a 3D environment around sensor. Given a world coordinate (X,Y,Z) and an image coordinate (x,y) as shown in Figure 2, the shape of hyperboloidal mirror is implicitly represented as

$$\frac{X^2+Y^2}{a^2}-\frac{Z^2}{b^2}=-1 \quad (Z>0) \qquad (1)$$

The inner focal point O_M of mirror is at (0,0,c) and the outer focal point (camera center) O_C is at (0,0,-c) in the world coordinate, where $c=\sqrt{a^2+b^2}$. Omnidirectional HD camera used a HD camera as a video camera of HyperOmni Vision. We want to have reference [[7],[8]] referred to for the detail about HyperOmni Vision. The specifications of configuration hardware and hyperboloidal mirror are shown in the table 1. Moreover, the appearance of the omnidirectional HD camera is shown in the Figure 3. Because a HD camera was used as the video camera of omnidirectional camera, it could get the resolution of more than four times in the area more than a conventional omnidirectional NTSC camera. The input image of the omnidirectional HD camera is shown in the Figure 4, and the common perspective image, which converted a part of the Figure 4, is shown in the Figure 5. Moreover, the input image of the usual omnidirectional NTSC camera is shown in the Figure 6, and the common perspective image, which converted a part of the Figure 6, is shown in the Figure 7. Therefore, the omnidirectional HD camera can acquire the image which details are understood more than a conventional omnidirectional NTSC camera. The solid angular resolution of the omnidirectional HD camera and the conventional omnidirectional NTSC camera is shown in the Figure 8.

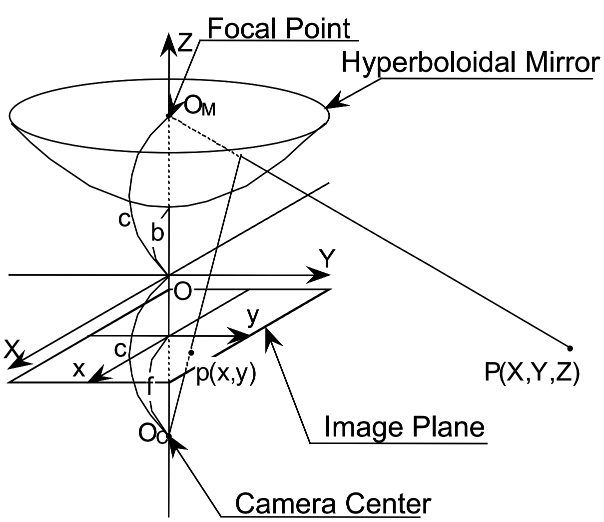

Figure 2: Geometry of the Omnidirectional camera (HyperOmni Vision)

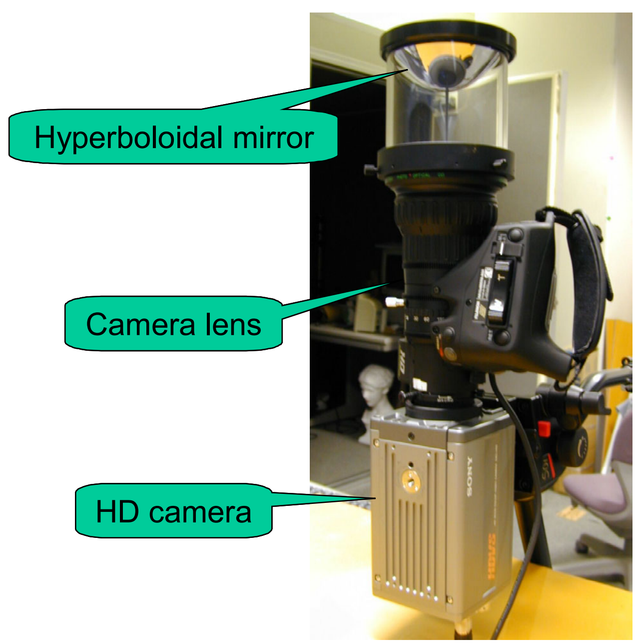

Figure 3: Appearance of the omnidirectional HD camera.

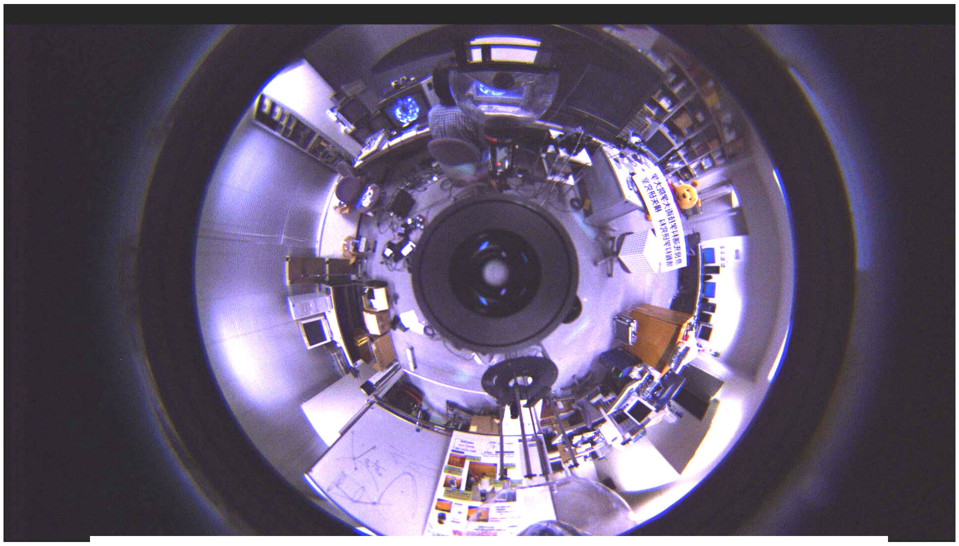

Figure 4: Input image of the omnidirectional HD camera

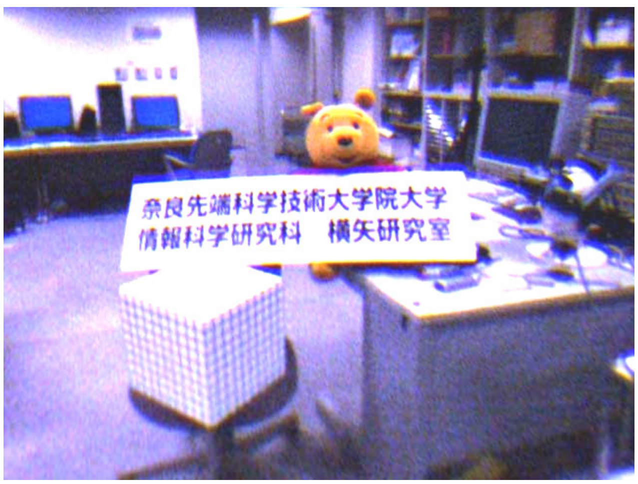

Figure 5: Computed perspective image from Figure 4

Figure 7: Computed perspective image from Figure 6

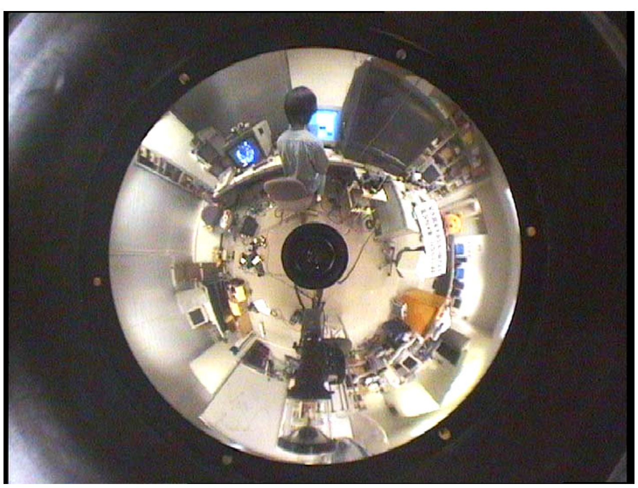

Figure 6: Input image of the conventional omnidirectional NTSC camera

Table 1: The specifications of the omnidirectional HD camera.

Hyperboloidal Mirror	
a	39.2931mm
b	55.4982mm
Diameter	90mm

Lens FUJINON HA15x8BERM	
Focal length	8-120mm
Angle of view	61º52'x37º14'

HD Camera SONY DXC-H10	
CCD	2/3-inch 3-chip
picture elements	1920x1035

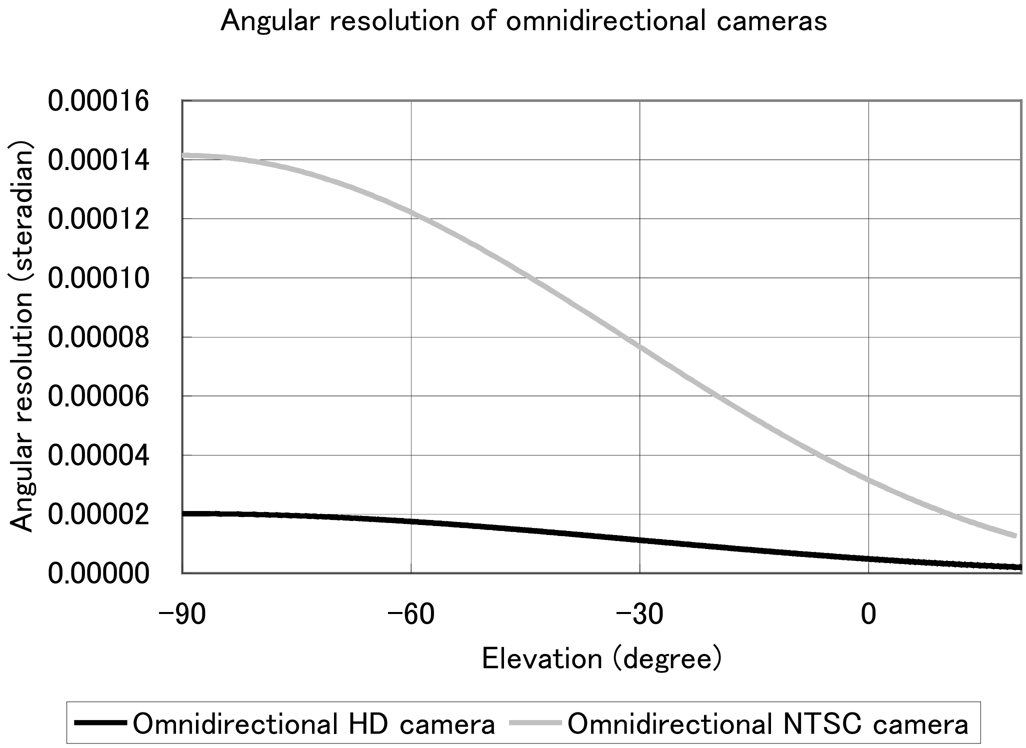

Figure 8: Angular resolution of omnidirectional cameras

3. Telepresence system with omnidirectional HD camera

A telepresence system was construct by using the omnidirectional HD camera in the previous section. We want to have reference [[9]] referred to for the detail about the telepresence system with omnidirectional camera. The configuration of the system constructed is shown in the Figure 9. This system generates common perspective images by clipping a part of omnidirectional images and displays those on the head mounted display in real-time. Therefore, the system gives the user the sensation, which he is similar in the distance. The specifications of configuration hardware are shown in the table 2. The input images of the telepresence system are 1920x1035 pixels. The output images of the telepresence system are 640x486 pixels. We made experiments with the store-and-playback telepresence system. We have acquired two kinds of video streams. One is a video stream of the suspension bridge when a person shouldered the hardware on the back. The other is a video stream with driving the car, which the hardware being carried on. The images of the acquired video streams and the output images generated looking-around are shown in Figure 10 and 11. The number of grids in the output image in the Figure 10 and 11 is 32x24. Output video stream could be generated with 40x30 grids in video-rate because of the experiment. It can be seen more clearly to the details than the conventional telepresence system.

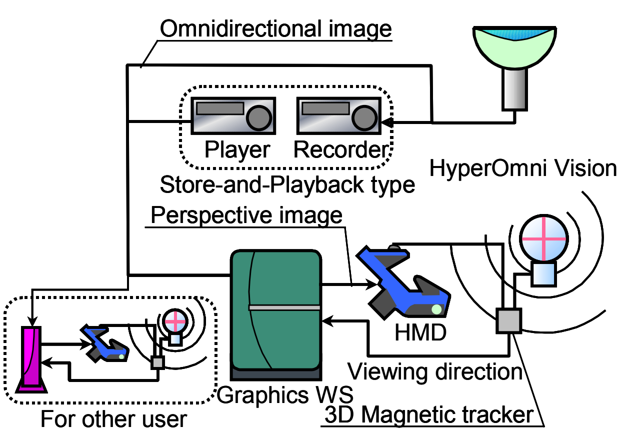

Figure 9: Hardware configuration of telepresence system

Table 2: Specifications of the telepresence system

Camera	Omnidirectional HD camera
Recorder and Player	SONY HDW-250
Graphics WS	SGI Onyx2 (R10000 195MHz 16CPU (Using only 1CPU))
HMD	OLYMPUS Mediamask (512,880pixels)
3D Magnetic Tracker	POLHEMUS 3SPACE FASTRAK (120Hz)

4. Conclusions

In order to increase the resolution more than the conventional telepresence system with omnidirectional NTSC camera, this paper describes the telepresence system with omnidirectional HD camera. The common perspective image outputted was greatly improved because the HD camera has the resolution of more than four times of the NTSC camera. It thinks from the experiment that the system can get the resolution that can be used for entertainments, remote monitoring, telecommunication conferencing, and so on. The future work includes more high resolution and view-dependent audio generated.

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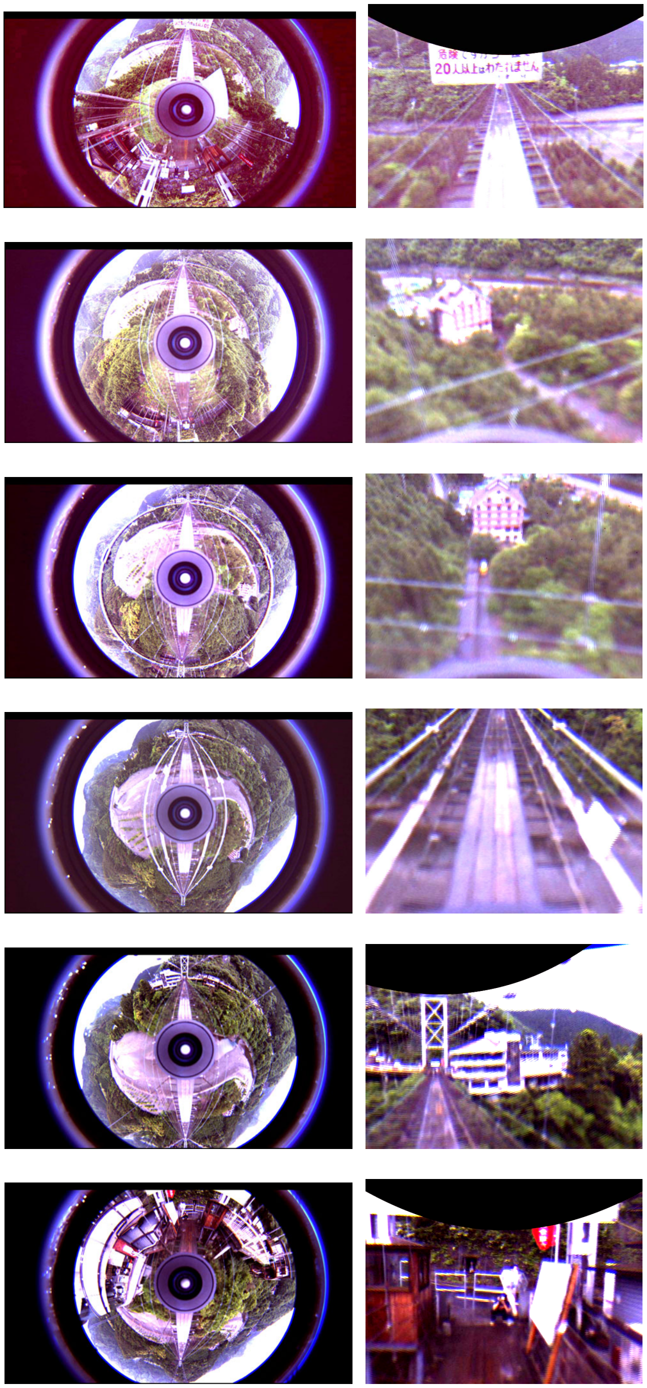

Figure 10: Experimental result with the scene at the suspension bridge. Left ones are omnidirectional images. Right ones are generated looking-around images.

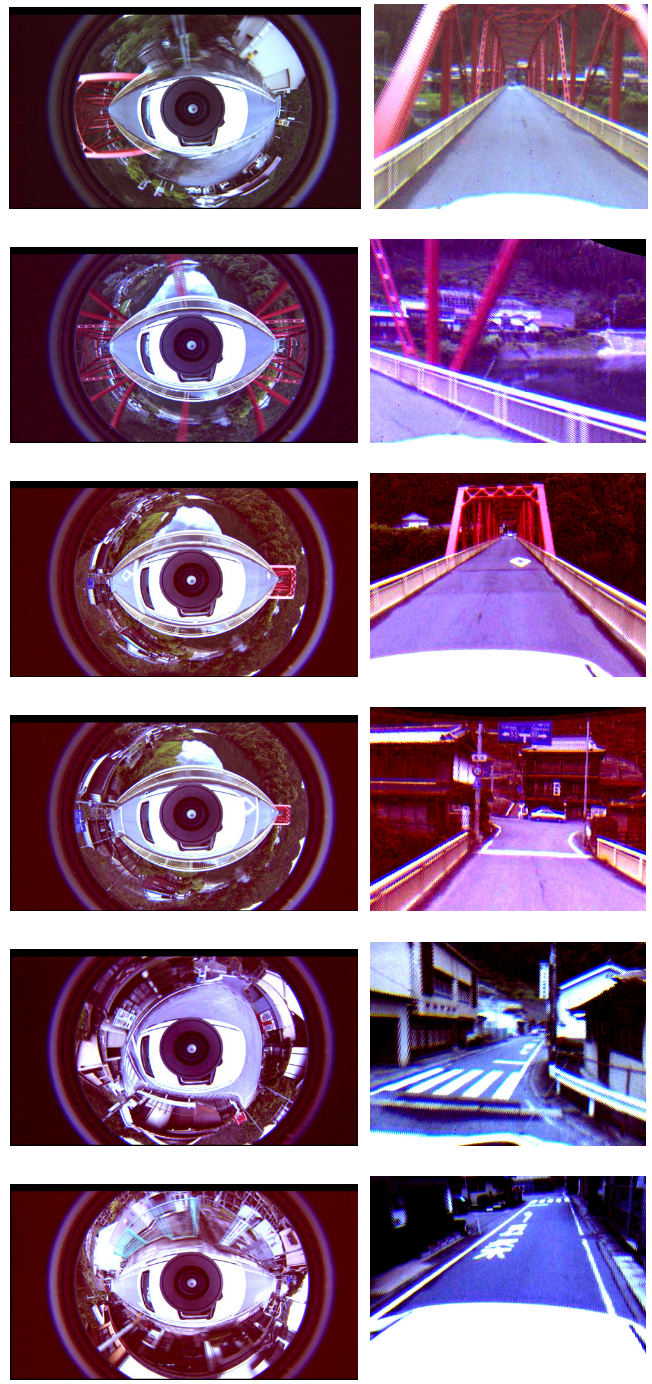

Figure 11: Experimental result with the scene on the car. Left ones are omnidirectional images. Right ones are generated looking-around images.