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重心感覚を考慮した実写ベースのドーム映像表現
Representation of Video Based Dome Image Considering Sense of Gravity

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Abstract: In this study, in order to create dome image contents easily, the video based dome contents creation method was developed. In this method, surrounding image is shot by 360 degrees camera, and the wide viewing angle image that is cut out from the panorama image is projected onto the dome screen by using the fish-eye projector. Particularly, the condition of the camera work that is permitted to represent the dome image without generating the uncomfortable feeling about the sense of gravity was experimentally evaluated. From the result, we can understand that the difference between the shooting direction and the viewing direction should be less than 30 degrees, and especially the scene that is shot looking down by the camera should be avoided. In addition, the questionnaire survey was conducted in demonstration, and we confirmed that the user experienced the immersive sensation in the dome environment.

Keywords: Dome display, video based dome content, 360 degrees camera, sense of gravity

1. Introduction

Recently, in a lot of planetarium systems, optical mechanical analog projector has been replaced with digital projector, and not only constellations but also various image contents have been shown [1]. Moreover, various kinds of dome display systems have been used as immersive virtual reality environment [2]. In such dome environments, the user can experience immersive virtual world, by utilizing the feature of frameless and wide viewing field image effectively [3].

Although current most dome contents are created based on 2D cell animation or 3D computer graphics image. In these methods, the whole image of the user's surrounding world must be drawn to represent a scene, and it needs a lot of cost. Therefore, this study aims at constructing the dome contents creation method based on the video image. By constructing the methods of shooting omni-directional image and projecting distortion-corrected image onto the dome display, it is expected that the video based dome contents can easily be created. Although the video based dome contents have been created using the special camera and special projection system such as IMAX DOME, this study aims at establishing the general method that can be used in various dome environments [4].

This paper describes the method of shooting the omni-directional image using the 360 degrees camera and projecting the wide field of view image onto the dome screen. Particularly, the image projection method in which the user can experience the natural image without feeling the uncomfortable feeling about the sense of gravity based on the camera work in the immersive virtual environment was discussed.

2. Method of creating video based dome contents

In general, fish-eye camera is often used to shoot the omni-directional image for the dome display. Since the shape of most dome displays is hemisphere, the image projected onto screen can be shot by using the fish-eye camera which has 180 degrees viewing angle. However, since the various dome displays have the difference in the size of screen, angle of hemisphere dome, arrangement of projectors etc., the difference in such dome environments affects the conditions of the camera system or the camera work. In order to create general purpose dome contents, it is necessary to construct the camera system that is independent of the projection system. Therefore, in this study, the dome contents creation method in which a panorama image was used as a middle data of dome content image, was constructed.

Figure 1 shows the process of shooting and projecting dome image that was constructed in this study. In this method, Freedom 360 camera system is used to shoot the omni-directional image [5]. This camera system is constructed by placing six digital video cameras GoPro Hero3 on the cubic mount. The viewing angle of each camera is 122.6 degrees by 95.5 degrees, and the whole system can shoot the full spherical immersive video.

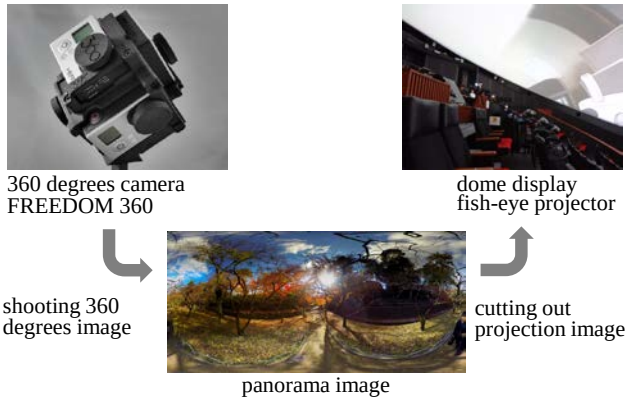

Figure 1: Process of shooting and projecting dome image

By stitching the images that were shot by six video cameras synchronously using the software of Kolor AutoPano Video

Pro and Autopano Giga, a panorama image is generated. The resolution of each video image is 1,920 by 1,440 pixels, and the panorama image that was generated by stitching has total image resolution of 4,000 by 2,000 pixels. This panorama image is used as the common data that is independent of the projection system. Then, the projection image is cut out from the panorama image according to the specified viewing direction and viewing angle using Viewer software of Global System, Inc. and it is sent to the fish-eye projector. As a projector, NEC NP2000J (XGA, 4000 lumens) equipped with the fish-eye lense Raynox DCR-CF185Pro was used.

Since there was a gap between the fish-eye lense and the projector, the horizontal and vertical viewing angles of the projected image were about 130 degrees and 100 degrees respectively. Moreover, in the dome environment, the projection angle of the displayed image and the viewing angle of the user are not necessarily consistent due to the positional relationship between the projector and the user, and this causes the distortion of the perceived image. In the proposed method, since the images shot by the 360 degrees camera are once converted to the panorama image, the distortion of the projected image can easily be corrected by adjusting the viewing direction and the viewing angle of the image that is cut out from the panorama image. Therefore, this method can be a general projection method independent of the structure of the dome display system. Figure 2 and Figure 3 show that the same images are projected onto the different dome screens with a diameter of 3m and 18m, respectively by using the same panorama data.

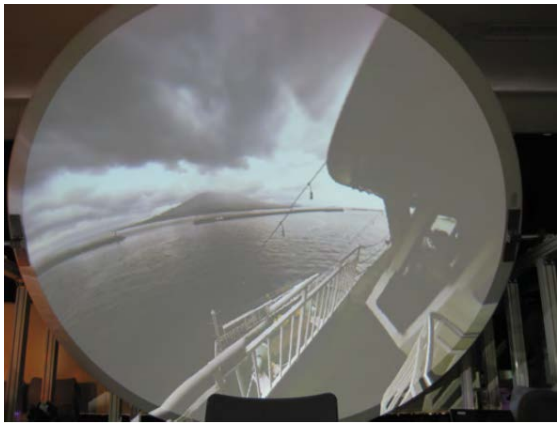

Figure 2: Dome image projected onto the 3m dome screen

Figure 3: Dome image projected onto the 18m dome screen

3. Uncomfortable feeling about sense of gravity in dome environment

Although the video-based omni-directional image can be projected onto the dome screen using the above mentioned method, it is important to consider the problem of the restriction of camera work.

When the 360 degrees sphere display is used, the image can be projected correctly in the same direction with the shooting direction. However, when the hemisphere display such as the horizontal dome or the inclined dome is used, the image is often projected in the different direction with the shooting direction. For example, if the image must be projected in the same direction with the shooting direction, the scene looked down from upper direction cannot be represented in the hemisphere dome display. Then, the image shot from the upper direction is often projected onto the upper screen in the hemisphere dome system.

When the user looks at the displayed image from the viewing direction that is different from the shooting direction using a small display such as a television, the user does not feel uncomfortable feeling. However, when a large screen is used to display the image that was shot from the different direction from the viewing direction, the user feels uncomfortable feeling as shown in figure 4 [6]. We can consider that this uncomfortable feeling is caused by the difference between the direction of gravity that is represented in the displayed image and the direction of sense of gravity that the user feels in the real environment.

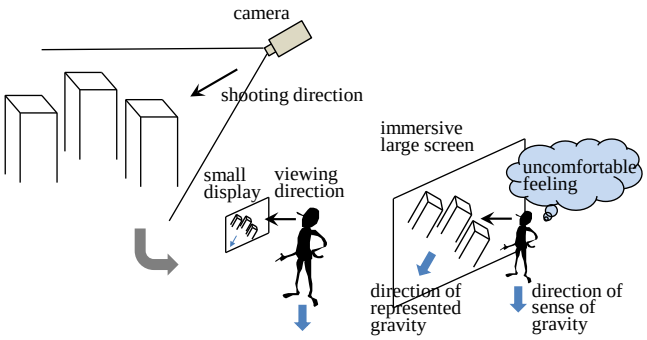

Figure 4: Uncomfortable feeling felt from the large screen image

In this study, the direction of projected image permitted in the dome environment was experimentally investigated by measuring the sense of uncomfortable feeling that was felt from the projected image. This means investigating the acceptable value of the camera work in the dome content creation.

In the experiment, the image of the horizontal line was cut out from the panorama image by changing the center of viewing direction and it was projected onto the dome screen. As dome screens, inclined type large size dome display (18m diameter and 30 degrees inclined angle) and inclined type small size dome display (3m diameter and 36 degrees inclined angle) were used. In addition, the 12-inch liquid crystal flat monitor was also used to compare the uncomfortable feeling felt from the displayed image.

In each display, the viewing direction of the displayed image that was cut out from the panorama image was changed among 30 degrees, 15 degrees, 0 degrees, -15 degree, and -30 degrees. When the viewing direction is 0 degrees, the horizontal line is correctly represented horizontally. When the viewing direction is greater than 0 degrees, an upward image is cut out from the panorama image and the user looks down the displayed horizontal line. On the other hand, when the viewing direction is less than 0 degrees, a downward image is cut out and the user look up the displayed horizontal line. Figure 5 shows the method of this experiment when the inclined type small size dome display was used.

The subjects were asked to see each image for 10 seconds and to evaluate the uncomfortable feeling in the sense of gravity according to the five grade system. Answer of "+2" means "not feel uncomfortable feeling", "0" means "neither", and "-2" means "feel uncomfortable feeling".

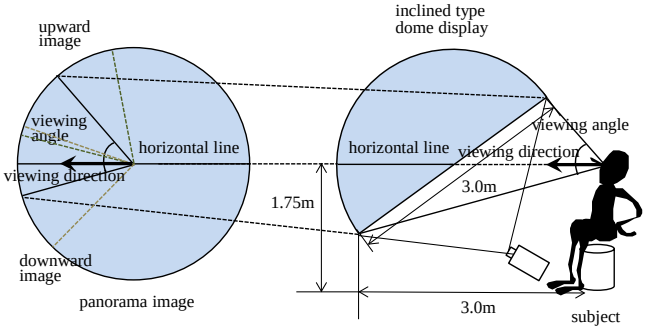

Figure 5: Experiment on evaluation of uncomfortable feeling in sense of gravity using 3m dome

Figure 6, figure 7, and figure 8 show the result of the evaluation for 18m large size dome, 3m small size dome, and 12inch LCD monitor. Number of subjects for each display were 10, 11, and 10, respectively, and the average, standard deviation, and the result of multiple comparison are shown in each graph. These results show that the difference of viewing direction greater than 30 degrees makes uncomfortable feeling, though the difference of viewing direction less than 15 degrees does not make uncomfortable feeling so much. From the comparison between the results of +15 degrees and -15 degrees, we can see that the viewing direction of -15 degrees makes more uncomfortable feeling than +15 degrees. When the viewing direction of the image that was cut out from the panorama image is greater than 0 degrees, the horizontal line is shown downward and this situation does not make uncomfortable feeling in the sense of gravity so much. However, when the viewing direction is less than 0 degrees, the horizontal line is shown upward and this situation makes uncomfortable feeling in the sense of gravity.

Namely, we can understand that the difference of the viewing direction should be less than 30 degrees, and especially the scene that was shot looking down by the camera should be avoided in the dome contents. Moreover, from the comparison among each display, we can see that such influence depends on the effect of large field of view of the dome display, and the difference of the influence according to the dome size was small.

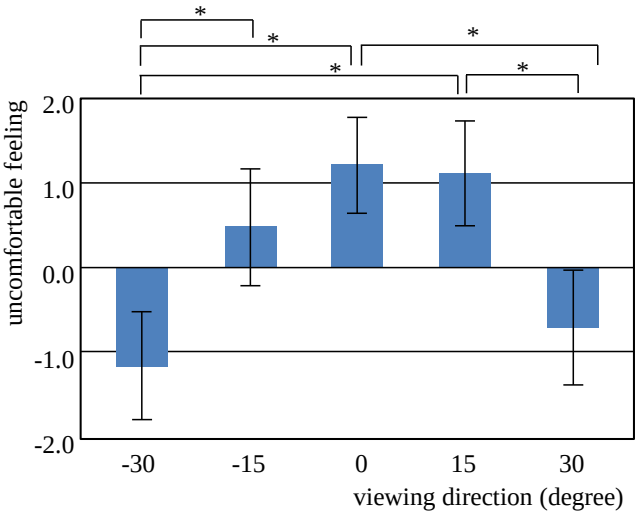

Figure 6: Result of evaluation for 18m large size dome

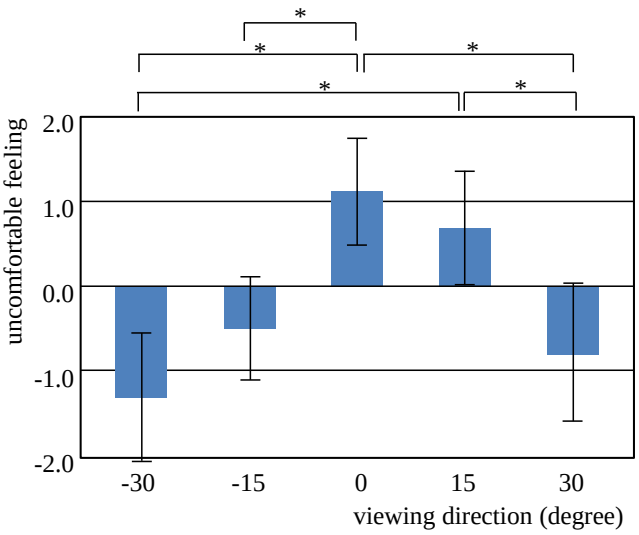

Figure 7: Result of evaluation for 3m small size dome

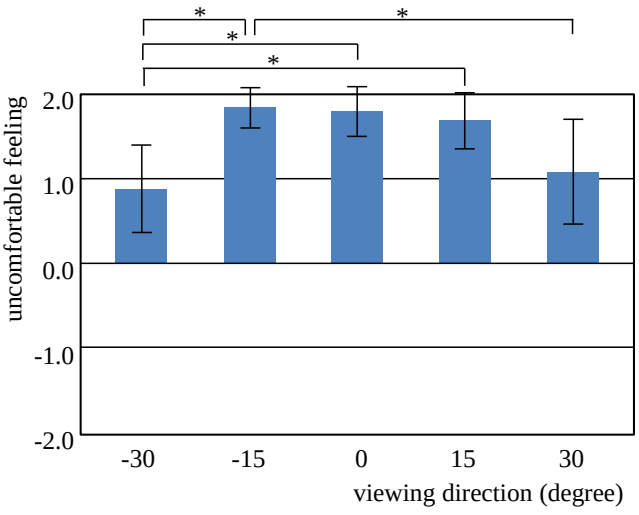

Figure 8: Result of evaluation for 12inch LCD monitor

4. Examples of dome contents

In this study, the above mentioned method was applied to create several video based dome contents. Since the user can feel immersive sensation in the wide viewing angle image that is projected in the dome environment, the dome contents can be used effectively in various application fields. In this study, several contents, such as “university introduction” and “sightseeing guidance” were created. In the content of university introduction, the 360 degrees camera was placed in the campus where a lot of students gather, and the images of campus life of the students were recorded. In the content of sight-seeing guidance, the 360 degrees images of sightseeing areas in Kagoshima were shot so that the user can experience the virtual tour.

These contents were shown using the dome display with a diameter of 3m in the open house of Saitama Prefectural Education Center, and the questionnaire survey was carried out. Figure 9 shows the demonstration of the dome contents and table 1 shows the results of the questionnaire for 18 subjects who experienced these contents. The subjects include junior high school students, high school students, and their parents. The subjects were asked to answer the question using five point scale.

Figure 9: Demonstration of dome contents in Saitama Prefectural Education Center

Table 1: Result of questionnaire

question	average	standard deviation
Did you feel three-dimensional sensation?	1.29	0.96
Did you feel sense of immersion	1.33	0.70
Did you concentrate your attention?	0.76	0.89
Were you excites?	0.86	1.15
Did you feel fatigue?	-0.24	1.04
Did you feel visually induced motion sickness?	-0.33	1.35

(2:strongly agree, 1:agree, 0:neither agree nor disagee, -1:disagree, -2:strongly disagree)

From the result, we can see that most users felt three-dimensional sensation, sense of immersion, concentrated their attention, and were excited, when they experienced the video-based dome contents. Moreover, they felt little fatigue and visually induced motion sickness. We can understand the video based dome image can be applied to various kinds of contents effectively.

5. Conclusion

In this research, in order to create the video based dome image contents easily, the method of shooting 360 degrees image and projecting wide viewing angle image from the data of panorama image was constructed. Particularly, the condition of the camera work that is permitted to represent the dome image without generating the uncomfortable feeling in the sense of gravity was experimentally evaluated. From the questionnaire survey conducted in the demonstration in the open house, we confirmed the effect of immersive sensation when the video based dome image contents was shown. Future work will include investigating the effective representation of the dome image by creating various kinds of video based dome contents.

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