レイヤ分割法を用いたドーム映像の生成

Dome Image Contents based on Layered Image Representation

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本研究では、プラネタリウムを始めとするドーム型ディスプレイに、立体感の高い空間映像コンテンツを提示するための手法を構築することを目的としている。フレームの無い広視野のディスプレイ空間では、運動視差の効果を効果的に利用することで、視差映像を用いなくても立体感の高い映像体験ができることが知られている。本論文では、曲面スクリーン環境における単眼映像に対する奥行き知覚に関する心理実験を行い、その結果を映像コンテンツ制作に応用する方法を試みた。この方法では、空間映像を 2 次元レイヤで表現される映像要素に分割し、各レイヤを空間的に配置することで 3 次元世界を構築する。この際、各レイヤの移動やカメラワークを効果的に使用し、観客に空間的な運動面を知覚させることで、立体感を演出する。

This study aims at developing the contents creation technique that can project a high presence image onto the dome display. In the dome display, the user can feel the three-dimensional sensation from the image by using the effect of motion parallax, even if the monocular image is projected on it. In this paper, the psychological experiment concerning the user's depth perception that can be felt in the curved screen environment was conducted, and the result was applied to the contents production method. In this method, the image space was divided into the two-dimensional image elements, and each image element was placed at the three-dimensional position to construct the virtual world. In this case, the user can feel the three-dimensional sensation by controlling the movement of the layered image or the camera work effectively.

1. Introduction

Recently, large screen displays that can present high presence images to a large number of audiences have been used in various kinds of exhibitions [1][2]. In particular, the dome displays such as the Earth Vision exhibited in Aichi Expo have been attracted attention as immersive environments that can present three-dimensional image space to the users [3][4]. Since the dome display covers the user's wide field of view with the frameless image, the user can feel the three-dimensional sensation from the image by using the motion parallax effectively even if it is a non-stereo image.

On the other hand, recent planetarium facilities have been replaced from the analog projection system to the high luminance digital projection system to project the constellation [5][6]. Since these digital planetariums can project various kinds of images such as the computer graphics image and the video image, they can be used as convenient dome display environments. Moreover, in the planetarium industry, it is expected that these usages would contribute to the improvement of the utilization rate of the planetarium facilities.

As for the contents production, though the effective method of representing the dome image from which the user can feel the three-dimensional sensation has been partially known from the experience, it cannot be used as the image production technique. For example, it is known that the user can feel the three-dimensional sensation when the geometrically corrected image is displayed on the curved surface screen using the effect of movement parallax. However, the depth sensation that the user perceives from the displayed image have not been quantitatively investigated.

Moreover, in order to use the dome display, it is necessary to create the image contents that can be seen in all directions. In the case of producing the ordinary image contents, only the image within the rectangular frame is created, but when the dome image contents is produced, constructing the entire image space and thinking about the story in all directions are necessary. Therefore, the workload of producing the entire image space by using the ordinary three-dimensional computer graphics technique is very high. Then, it is required that the novel technique to create the dome image contents would be established.

The purpose of this study is developing technique that can be used to produce dome image contents as an industry level. Concretely, we aim at systematizing the effective image representation method that can be used to generate the dome image, from which the user can feel the three-dimensional sensation, based on the psychological experiment. In addition, we also aim at developing the contents creation method based on the layered image representation that constructs the three-dimensional virtual world by placing two-dimensional image elements without using the three-dimensional computer graphics models. This paper describes the basic principle of the proposed layered image representation method, the psychological experiment on the user's depth sensation in the curved display environment, and the examples of creating the dome image contents.

2. Three-dimensional Sensation in Dome Display

In order to project the high presence image in the multi-persons dome display, the feature of the wide field of view display should be effectively utilized, because the projection of the stereo image according to the users' view positions is difficult. The proposed image production technique for the dome display using the layered images is based on several findings in the psychological visual perception. For example, though the projected image on the curved screen is perceived as a distorted image where the screen shape is seen by the viewer, the shape of the projected image would be perceived accurately by correcting the distortion based on the screen shape and obscuring the screen shape. From the preparation experiment, it has been known that the viewer could perceive the correct shape of the displayed object when he cannot recognize the screen shape under the dark condition, according to the top down knowledge that the image must be projected onto the flat screen. In addition, when the displayed object is moved on the virtual plane surface, the viewer can feel the three-dimensional depth sensation using the effect of motion parallax [7].

This effect is caused by the characteristic that the human recognizes the three-dimensional world by using the several visual cues non-equivalently. As for the physiological cues, the accommodation, the binocular parallax, convergence and the motion parallax are used to perceive the depth information. In addition, as the experiential cues, the occlusive perspective, the linear perspective, the texture gradient, the aerial perspective and the shadow affect the user's depth perception. However, in the current virtual reality systems, all of these cues are not necessarily utilized. For example, stereo vision system using the stereo glasses utilizes the feature that the effects of the binocular parallax and the convergence function superior to the accommodation. Compared to this, the image production method proposed in this study utilizes the feature that the effects of the motion parallax and the experiential geometric cues function superior to the binocular parallax under the condition of wide field of view.

Though the qualitative feature of the phenomenon that the human can perceive the depth sensation in the dome display has been known, the quantitative characteristic has not fully been investigated. Therefore, this principle could not be applied to the production technique to create the dome contents in which the user can perceive the three-dimensional sensation. The purpose of this study is constructing the effective image production technique by systematizing the know-how of representing the three-dimensional image in the dome display environment based on the psychological perception experiment. Particularly, in this paper, the psychological experiment about the user's depth perception that was felt from the moving image was conducted to evaluate the quantitative characteristic and it was applied to the image production method.

3. Layered Image Representation

In order to create the dome image contents, it is necessary to construct the three-dimensional image space and make a story in all directions, because the audiences might see various directions. This process needs a large amount of workloads, compared with producing the ordinary image contents that are represented within the window frame. Since the construction of the entire image space using the three-dimensional computer graphics model needs much cost and time, it is expected to develop an efficient image production technique. In this research, as a basic principle of constructing the dome image, the layered image representation method was used [8], in which the image space was divided into two dimensional image elements and they were placed as layers in the three-dimensional space.

Figure 1 shows the concept of generating the three-dimensional image space using the layered images. In this method, the image elements such as the buildings and the train that compose the image space are represented using the two-dimensional layered images. By placing these images in the three-dimensional space according to the depth information, the virtual world can be constructed. In this case, the geometrical distortion of the projected image is corrected and the positions, the directions and the movements of the layers are controlled so that the psychological effect can be utilized effectively. Therefore, it is expected that image space in which the user can feel the three-dimensional sensation can be constructed using the layered image method.

As image elements used for the layers, various kinds of image sources, such as the computer graphics image, the photograph, the animation, and the video can be used. Though the entire image space is composed by the two-dimensional layers, each image element can be constructed using the three-dimensional model. In general, when the three-dimensional computer graphics image is projected onto the curved screen, two pass rendering is used to represent the corrected image, because user's viewpoint is different from the projector's viewpoint. In this case, by considering the projection plane used in the first pass rendering as a layer, the rendered image of the three-dimensional model can also be treated in the same manner as the two-dimensional image.

This layer based technique of generating the image space can be thought to be an extension of the ordinary animation production method using the celluloid picture to the three-dimensional dome image. Therefore, it is possible for the usual creators to produce the dome image without any special programming such as the modeling or rendering of the three-dimensional object.

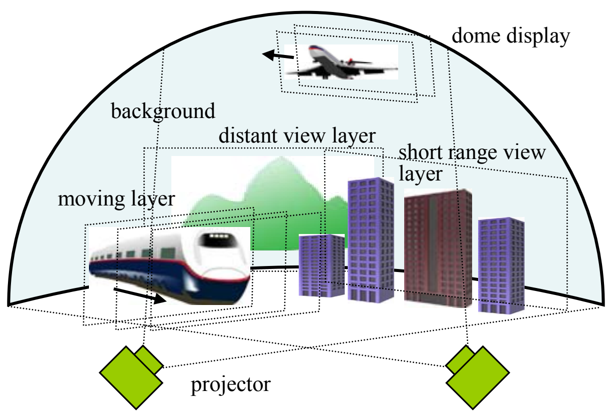


Fig. 1. Concept of Dome Image Using Layered Image Method

4. Psychological Perception Experiment

This study aims at constructing the image production technique for the dome display by storing the data of the psychological experiment and systematizing an effective image representation method. As a basic experiment, we conducted a psychological perception experiment concerning the depth perception that the user felt from the image projected on the curved surface screen. In this experiment, various kinds of images were projected, and the depth sensation that the user felt from the monocular image was measured quantitatively.

4.1 Experimental Environment

As for the display environment with wide field of view, the curved surface display named CC Room was used [9]. The CC Room constructs the immersive environment by projecting a wide field of view image through the fish-eye lens onto the curved surface screen where the corner part in the room was compensated with the styrene foam as shown in Figure 2. Though the purpose of this experiment is to investigate the user's perception for the monocular image, this system itself can project a stereo image using two projectors. The diagonal screen size of the CC Room is 414x246cm.

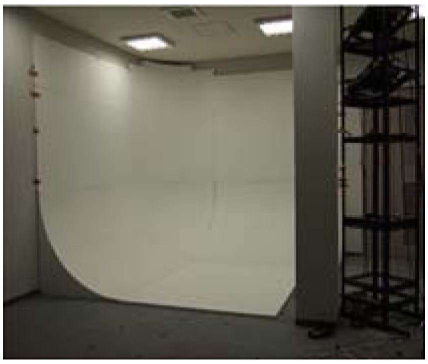


Fig. 2. CC Room Display

4.2 Experimental Method

As a simple example that the viewer can feel the three-dimensional sensation from the wide field of view image projected on the curved screen, we focused on the effect of the motion parallax caused by the moving image. In this experiment, the depth sensation that the viewer felt from the projected image when it was moved along the horizontal direction in the dark condition was quantified. In order to measure the user's depth sensation quantitatively, the reference stereo image using the binocular parallax was used. The experiment was conducted using the simple up-down method as follows.

(1) The subjects sat on the chair and saw the test image projected on the curved screen. The projected test image was monocular though the subjects wore the stereo glasses. Figure 3 shows the appearance of this experiment.

(2) After the test image was displayed, the referential stereo image using the binocular parallax was displayed. And the subjects were asked to answer the question whether the reference image was felt closer than the test image or farther than it.

(3) When the subject answered "closer", the reference image was moved 10cm farther, and when the subject answered "farther", it was moved 10cm closer.

(4) By repeating the processes from (1) to (3), the reference image that has been felt farther than the test image would be seen closer than it. And the reference image that has been felt closer than the test image would be seen farther than it. Then, the turning position of the reference image where the perceived depth sensations was changed from "farther" to "closer" or from "closer" to "farther" was recorded

(5) This process was repeated seven times for each subject and in each experimental condition, and the perceived depth position was evaluated using the average value of the seven turning position data.

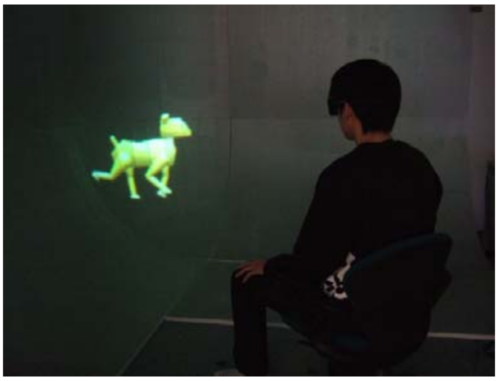
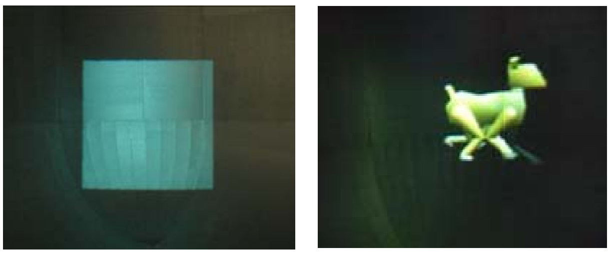


Fig. 3. Appearance of Depth Perception Experiment

Figure 3 shows the appearance of this experiment. As the test images, two kinds of images such as the simple square and the computer graphics model of the dog were used as shown in Figure 4. Since the square image has only the shape information, the subject doesn't have the knowledge concerning the size. However, as for the dog image, the subject has a knowledge concerning the general size as well as the shape of dog. In the experiment, the difference of the depth sensation that the subjects felt from these two kinds of test images was investigated.



square image dog image

Fig. 4. Test Image Projected on the Curved Screen

In the experiment, three kinds of sizes of 0.3x0.3m, 1.0x1.0m, and 1.5x1.5m were prepared for both the square image and the dog image. Each image was displayed moving along the horizontal direction as shown in Figure 5. In the case of the dog image, the animation data concerning quadruped walking was prepared and it was displayed synchronized with the moving speed of the image. As for the reference image, stereo image of the cylinder of 10cm diameter and 60cm height was displayed. The cylinder was placed upright on the ground and was moved back and forth at intervals of 10cm.

Five subjects were selected from the university students who were accustomed to the binocular vision. The viewing position was changed in three positions indicated in Figure 5, and the difference of the user's depth sensation according to the distance between the viewing position and the screen was investigated.

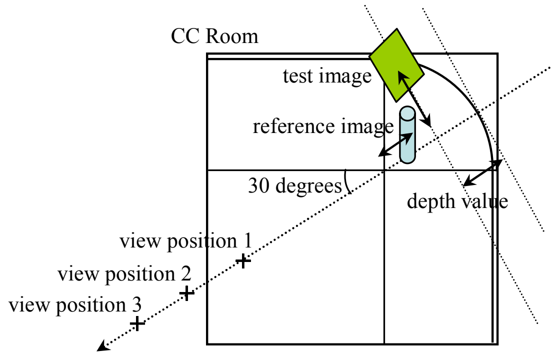


Fig. 5. Experimental Condition

4.3 Experimental Results

Figure 6 and 7 show the results of this experiment. In this graph, the average values and the standard deviations of the perceived depth sensation were shown. The depth sensation was expressed by the distance value from the center of the curved screen.

From the graph, when the square image was projected, the perceived depth value was almost constant, regardless of the displayed image size and the viewing position. On the other hand, when the dog image was projected on the curved screen, the depth sensation of the subjects changed according to the image size. A multiple comparison test was applied among the image sizes of the dog, and the significant difference at 5% level was found between the sizes of 0.3x0.3m and 1.0x1.0m. We can understand that this result was caused by the fact that the subjects had preliminary knowledge about the general size of the dog, but they did not have knowledge about the square size. Namely, the subjects recognized that the dog that looked small was walking at a distance, and the dog that looked large was walking near them.

When the distortion of the projected image based on the screen shape was corrected and it was moved along the horizontal direction, the user felt that the image was placed at the three-dimensional position by perceiving the motion plane based on the motion parallax. This effect was emphasized in the dome display environment, because the screen surface and the moving plane were different. In this case, when the user did not have information about the image size, it was difficult for the user to identify the quantitative depth position of the displayed image. However, when the user has information about the size of the displayed object, he can perceive the quantitative depth position from the appearance size.

In this experiment, the stereo image of the cylinder was used as the reference image. However, it was difficult to perceive the accurate position of the reference image, when it was located far away behind the screen, because the effect of the binocular parallax was very small. Therefore, in order to measure the user's depth sensation more accurately, more precise reference image is necessary. Moreover, this experiment measured only the user's depth sensation that was felt from the image element moving along the horizontal direction. In the next step, we are planning to investigate the depth sensation that the user felt from the image moving along various directions and in various speeds.

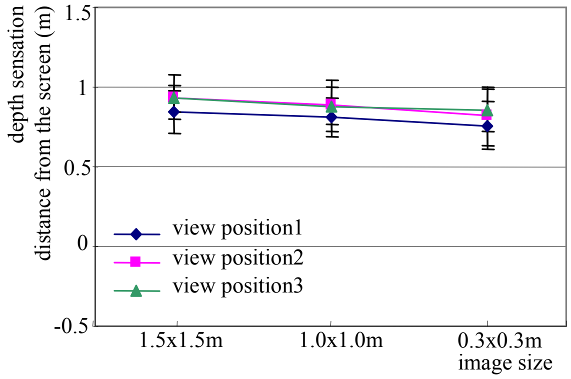


Fig. 6. Experimental Result for Square Image

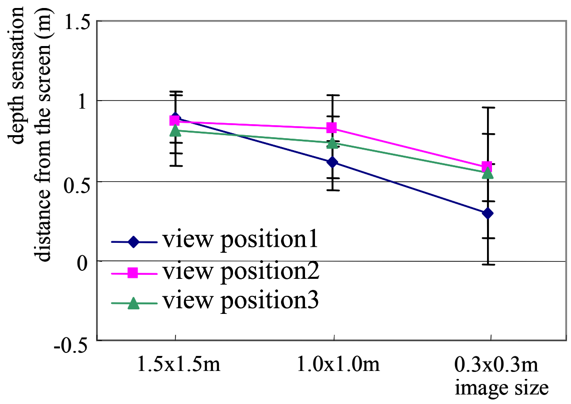


Fig. 7. Experimental Result for Dog Image

5. Applications of Dome Image

This study aims at systematizing the method to represent the dome image from which the user can feel the three-dimensional sensation, by storing the data based on the psychological experiments. For example, the experimental result concerning the effect of motion parallax gives the knowledge about the effective camera work for the creation of the dome image contents. Though it is difficult for the user to feel the depth sensation from the image space composed of the static layered images, the three-dimensional sensation that can be felt from the image space would be improved by using the effective camera work that raises the effect of motion parallax. In this paper, the virtual space of the university campus was constructed as an example of the layer based image space.

Figure 8 shows the example of the constructed virtual space. In this example, the virtual world was divided into the image elements, and each image element was constructed using the two-dimensional layer of the photograph image or the video. For example, the images of the ground, the building, the signboard and the fence use the photograph image, and the image of the human uses the video image to represent the human's behavior. These image elements are represented by clipping out only the objects' images from the background. Figure 9 shows the top view of the virtual world. From the figure, it can be understood that the virtual world is constructed using the two-dimensional layered images.

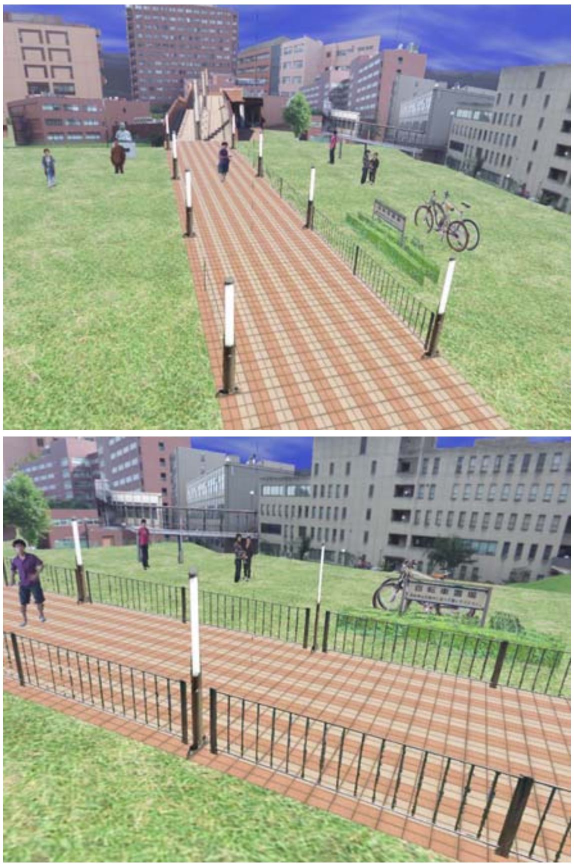


Fig. 8. Virtual World Composed of Layered Images

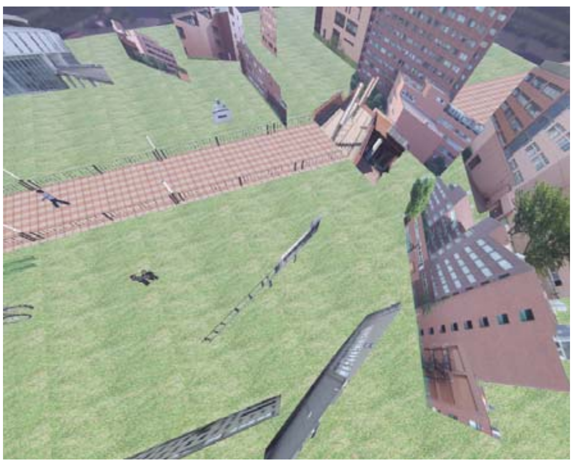


Fig. 9. Top View of the Virtual World based on Layered Images

In order to present the layer based virtual world with three-dimensional sensation, it is necessary to utilize the effect of the motion parallax. In this example, the position of the human's image was moved according to the walking gesture so that it can represent the natural human's walking behavior. When the image of the static object was represented, the camera work that represents the movement of the user's viewpoint in the image space was intentionally used. In this case, it is known from the experience that the camera work of moving up and down as well as moving along right and left or back and forth directions causes the user's three-dimensional sensation effectively. Moreover, the non-daily movement of the camera work such as crawling on the ground or hitting against the object can be effectively used to advance the three-dimensional sensation.

The constructed virtual world was projected onto the small-scale dome display as shown in Figure 10. The size of this dome screen is 3.0m in diameter and image is projected using one projector. In order to create a dome image with three-dimensional sensation, not only the placement of the layers but also the representation of the image in each layer should be three-dimensional. In the case of the distant view image, it can be represented by preparing one image, because the change in the scene due to the user's viewpoint is small. However, as for the short range view image element, the viewer might recognize the two-dimensional structure of it from the camera work, because the change in the scene due to the user's viewpoint is large. Therefore, it is necessary to restrict the movement of the camera work or to prepare the images seen from various viewpoints, so that the user cannot recognize the structure of the layers. In this example, the human's image was represented, by preparing the photograph images captured from multiple directions at the intervals of 10 degrees and switching the selected image according to the camera work [10].

In the layered image method, the dome image contents are created by placing the image elements in the three-dimensional space and moving them according to the time line. Therefore, the creator can make a scenario independently of the programming and modeling. Then, the development of the scenario description language and the authoring tool are necessary to create the contents easily.

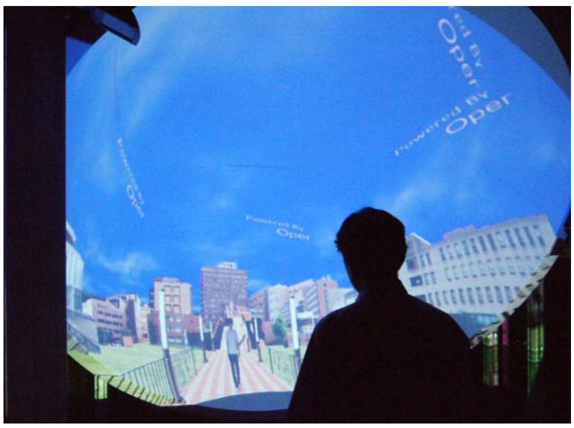


Fig. 10. Image Contents Projected on Dome Display

6. Conclusions

In this study, the layered image method based on the psychological experiment was developed. This method can create the image space contents in the dome display environment such as the planetarium, in which

the user can feel the three-dimensional sensation without using the stereo image. As an example, the psychological experiment concerning the depth sensation that the viewer perceived from the non-stereo image moving along the horizontal direction by using the effect of the motion parallax in the curved display was investigated. And the result of the experiment was applied to the camera work to represent the image space in the dome display. In practice, it is necessary to restrict the movement of the camera work because it might cause the feeling not only of the depth sensation in the virtual world but also of the two-dimensional structure of the layer.
In the future work, the image production technique for the dome display will be systematized, by storing more data obtained in the psychological experiments. In addition, the scenario description language and the authoring tool will be developed so that the contents creators can easily produce the dome contents.

7. Acknowledgement

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