Creation of Three Dimensional Dome Contents Using Layered Images

Tetsuro Ogi[*1] — Graduate School of SDM, Keio University

Yoshisuke Tateyama — Graduate School of SDM, Keio University

Hasup Lee — Graduate School of SDM, Keio University

Daisuke Furuyama — Graduate School of SDM, Keio University

Takeharu Seno — Graduate School of Design, Kyushu University

Takuro Kayahara — School of Project Design, Miyagi University

Abstract

In the dome display environment, it is known that three-dimensional scene can be represented utilizing the effects of geometrical perspective and motion parallax effectively without using the stereo glasses. However, the creation of contents for the dome display is not easy, because it needs omni-directional images. In this study, we propose the layer based method to create the dome contents easily. This method generates three-dimensional contents by placing two-dimensional image elements in the space and moving them or using the camera work effectively. In particular, in this paper, the depth sensation felt from the layered image was measured quantitatively and the necessary number of layers to represent the three-dimensional image was discussed based on the psychophysical experiments. Moreover, several dome contents were created using the proposed method and the effectiveness of this method was evaluated.

Keywords: Dome display, contents, depth sensation, motion parallax, depth resolution.

Index Terms: H.5.1 [Information Interfaces and Presentation]: Multimedia Information Systems - Artificial, augmented, and virtual realities

1 Introduction

In recent years, various display technologies such as the three-dimensional display and the high definition display have been developed [1][2]. As a next step, the importance of the contents has been pointed out. However, creation of the contents that utilize the characteristics of the display system effectively has become difficult according to the advancement of the display technologies, and it causes the current low productivity of the contents.

In the field of the dome display, super high definition display using 4K projectors has been developed [3], as well as the digitalized planetarium facilities has been used [4][5] as the dome display environments that project not only the constellation but also various image contents [6][7].

In the dome display environments, it is known that the audiences can feel the three-dimensional scene from the effects of the geometrical information and the motion parallax of the displayed image, even if they do not use the special devices like stereo glasses [8]. However, the contents for the dome displays cannot be created easily, because they need to correct the distortion due to the screen shape and the projection system as well as to create omni-directional images. In particular, when the three-dimensional computer graphics is used to create the contents, the entire model of the 360 degree world always must be constructed, because the audiences might see any directions. This problem has been one of the bottlenecks of the contents creation problem.

In this study, in order to solve this problem, the layer based dome contents creation method was proposed. Particularly, in this paper, the required number of the layers to represent the three-dimensional images in the dome display environment was discussed, and this method was evaluated by actually creating several dome contents.

2 Concept of Layer Based Dome Contents

This chapter explains the principle of the three-dimensional effect that the audiences feel in the dome display environment. When the monaural images were projected onto the dome display, the users cannot utilize the effects of the binocular parallax and the convergence. But, it is known that they can experience the three-dimensional world by utilizing the special effect of the dome environment in which the frameless image with wide field of view is displayed [9].

The principle of perceiving the depth sensation in the dome environment can be explained as follows. For example, when the square image is simply projected onto the curved screen, it is seen as a distorted quadrangle on the screen surface, as shown in figure 1 left. However, when the distorted image based on the screen shape is corrected and the lighting condition is darkened enough so that the user cannot see the screen shape, the projected image can be recognized as a correct square image that is floating above the screen surface. In addition, when this square image is moved right and left on the virtual plane, the depth sensation felt for the square image becomes stronger because the user can perceive the movement plane, as shown in figure 1 right.

In the dome display environment, the physical distance to the screen surface on which the image is projected is not constant between the center area and the surrounding area. Therefore, the user can easily perceive the virtual distance sensation to the projected image that is different from the physical distance to the screen surface, by recognizing the virtual movement plane.

*1: 4-1-1 Hiyoshi, Kohoku-ku, Yokohama 223-8526, Japan
ogi@sdm.keio.ac.jp

IEEE International Symposium on Virtual Reality Innovation 2011
19-20 March, Singapore
978-1-4577-0037-8/11/$26.00 ©2011 IEEE

Especially, it is known that the image projected onto the center area of the dome screen can be perceived as a floating image above the screen surface based on the effect of dome environment.

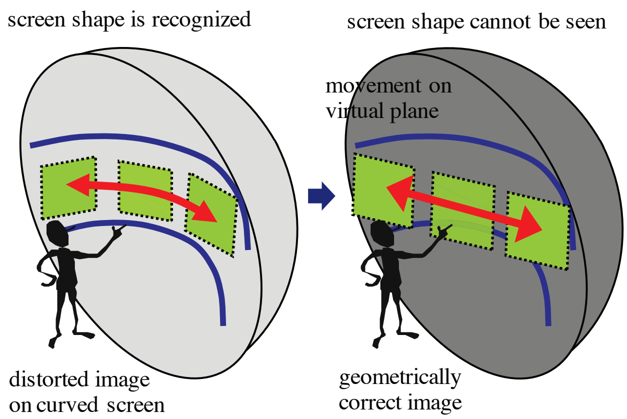

Figure 1. Principle of depth perception in dome environment

This study proposes the layered image method to create the spatial image contents using the above mentioned effect in the dome display environment [10]. In this method, the virtual world is constructed by arranging two-dimensional images such as the images captured by camera and the computer graphics images in the three-dimensional space. In this case, by moving the layered images or using the camera work, the difference of the distances to each layer is recognized and the three-dimensional spatial image is represented [11]. Figure 2 shows the concept of the layer based contents creation method.

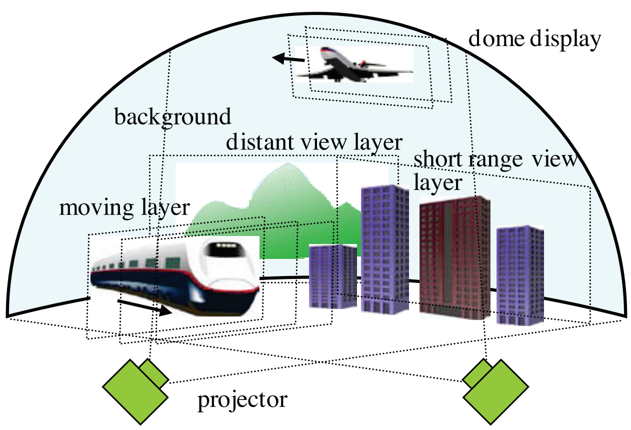

Figure 2. Concept of layer based contents creation method

This method can be considered as an efficient contents creation method, because it can represent the omni-directional image by simply placing the layered images for each viewing direction without making three-dimensional models of the whole space. Moreover, this method can be considered as an expansion of the celluloid picture method that is used in the field of animation production to the omni-directional image. Therefore, it is expected that a lot of current creators can accept this method. The following chapters explain the experimental environment used in this study, discuss the psychophysical experiments that were conducted to examine the sensations of the depth value and the depth resolution, and evaluate the proposed method by actually creating several dome contents.

3 Experimental Environment

In this study, the psychophysical experiments were conducted to examine the three-dimensional sensation felt in the dome display environment quantitatively.

In general, as dome display environments, the inclined type dome and the horizontal type dome are used. In this study, as experimental environments, the inclined type planetarium of Hokutopia (diameter: 18m, inclined angle: 20 degrees) [12] and the horizontal type planetarium (diameter: 8m) in Keio Senior High School were used. Figure 3 shows Hokutopia, and figure 4 show the planetarium in Keio Senior High School.

In order to generate the spatial image and project it onto the dome display, one graphics PC (CPU: Pentium4 3.0GHz, Graphics card: NVIDIA Quadro FX1300) and one LCD projector (NEC NP2000J, 4000 lumens) with fish eye lens (RAYNOX DCR-CF185PRO) were used respectively.

Figure 3. Inclined type dome display Hokutopia

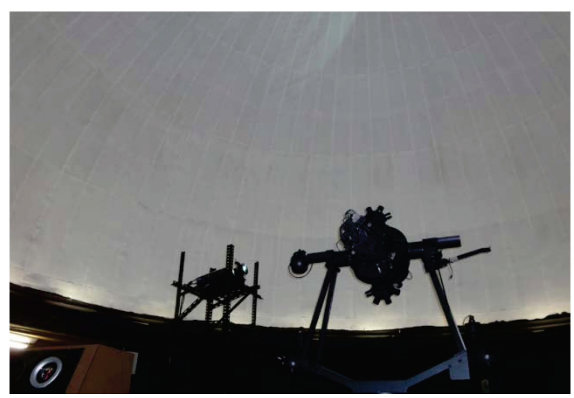

Figure 4. Horizontal type planetarium in Keio Senior High School

The image projected onto the dome screen contains distortions based on the fish-eye lens and the screen shape. Therefore, in this study, camera calibration was introduced to correct the distorted image [13]. In this method, the image of the chessboard pattern is projected onto the screen, and it is captured by the camera to calculate the correction matrix. However, in the case of the dome display, since the projection angle of the projector is larger than the capture angle of the camera, the calibration image cannot be captured as one image. Therefore, eighteen partial images were captured by the camera from the same view position, and one panoramic image was generated from them by using the image stitching method [14].

In the panoramic image, all corner coordinates of the chessboard pattern are detected, and the conversion matrix that arranges the corner points at even intervals is calculated. By applying this conversion matrix to the original image before projection, the distortion of the image projected onto the dome screen from the fish-eye projector is corrected. Figure 5 shows the corrected image of the chessboard pattern projected onto the dome screen.

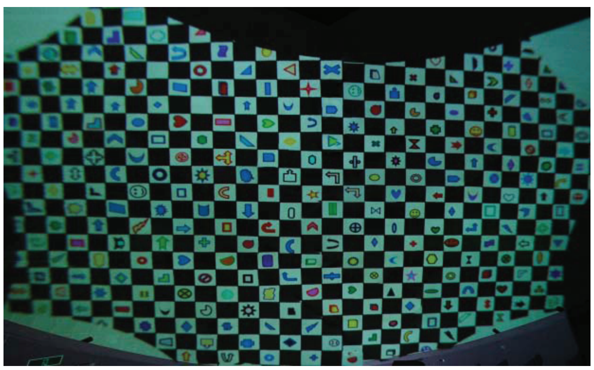

Figure 5. Corrected image of chessboard pattern

4 Experiment on Depth Sensation

First, in this study, the depth sensation that is felt by the user in the dome display environment was quantitatively measured [15].

In this experiment, in order to measure the vague sensation of distance felt from the projected image quantitatively, the magnitude estimation method was applied. In this method, the distance sensation to the real object was used as standard stimulus. The subjects were asked to see the real pole that is standing 11m ahead from them, and to memorize the distance sensation of it as standard stimulus of the value of 100. Next, the images of the comparison stimuli were displayed, and the subjects were asked to answer the numerical values of the depth sensations felt from the displayed images.

As the images of the comparison stimuli, video image of the person walking from left to right on the floor was used, as shown in figure 6. The height of the person was changed among 3m, 6m, and 9m on the virtual plane placed at 11m ahead from the subjects, and these images were displayed 6 times in random order for each subject. The subjects can feel the depth sensation for the virtual plane on which the image of the person moves, by utilizing the effect of motion parallax. If the subjects felt the displayed image nearer than the pole, they would answer the numerical value less than 100, and if the subjects felt the displayed image farther than the pole, they would answer the numerical value larger than 100.

This experiment was conducted using Hokutopia. The subjects were university students, and the number of the subjects was eleven.

Figure 7 shows the experimental result in which the averages and standard deviations of the depth values felt by the subjects for each size of the image are plotted. From the results, it is shown that the smaller image was felt being located farther, and the larger image was felt being located nearer. Namely, we can understand that the change of the size of the displayed image was recognized as the change of the distance to the object, by using the knowledge of the person's size, the geometrical perspective, and the effect of the motion parallax. However, in this experiment, the person's image reflected onto the retina of the subject was felt as a little bigger size, compared with the real person's size.

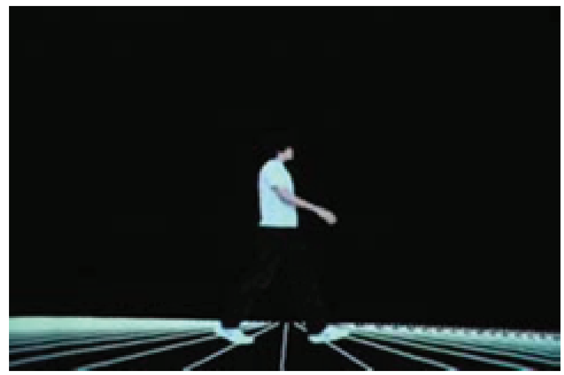

Figure 6. Image of walking person used as comparison stimulus

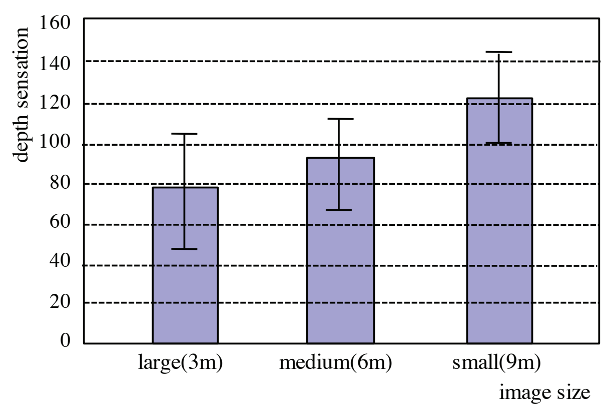

Figure 7. Result of experiment on depth sensation

Next, the experiment to examine the effect of the camera work under the same condition was conducted. In this experiment, the camera was moved along the walking person instead of moving the person's image. Figure 8 shows the method of this experiment. In this experiment, the person's image was always located at the center position of the dome screen, and the floor image was moved from right to left in the opposite direction.

Figure 9 shows the result of the experiment in which the camera was moved along the person. From this graph, we can see that the depth sensation changed according to the change of the image size, also when the camera work was used. The t-test was applied, and there was no significant difference between the results when the person's image was moved and when the camera was moved. Thus, it was shown that the camera work has an equivalent effect to the movement of the layered image.

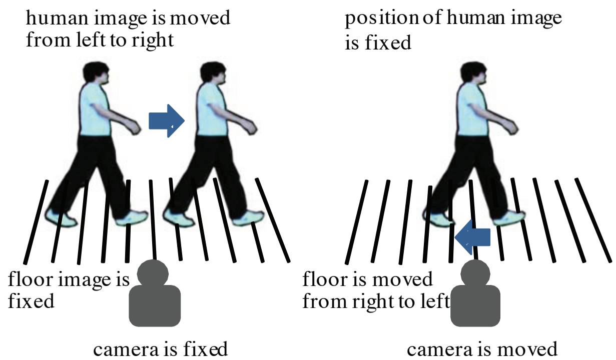

Figure 8. Displayed image by camera work

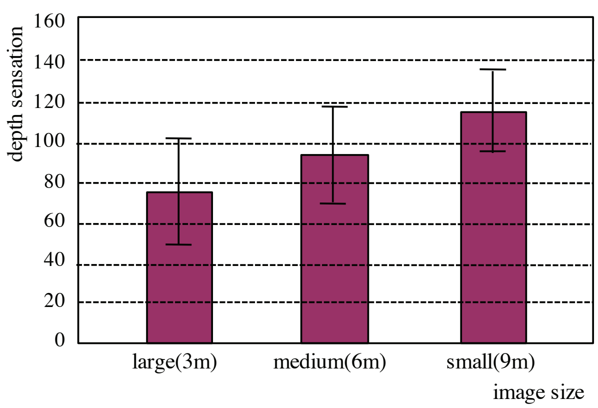

Figure 9. Result of experiment for the images using camera work

5 EXPERIMENT ON SENSATION OF DEPTH RESOLUTION

Next, the psychophysical experiment concerning the perception of the depth resolution for the layer based virtual world was conducted using the magnitude estimation method. The layered images can represent the three-dimensional image by utilizing the difference of the depth sensations for each layer. However, if a lot of layers were needed to express the detailed three-dimensional world, there would be no difference between this method and the conventional three-dimensional modeling method. Therefore, it is important to discuss the optimum number of the layers also from the view point of the efficiency and the cost of the contents creation.

The experiment was conducted using the planetarium in Keio Senior High School. In this experiment, the image in which a lot of squares were distributed in the three-dimensional space was moved from left to right at the speed of 1.0m/s. In this case, the image of 2 layers was used as standard stimulus, and the images of the comparison stimuli were displayed by changing the number of layers among 3, 4, 5, 6, 7, 8, 9, 10, 12, 14, 16, and 18. In these images, each square was rendered on the layer at the nearest depth position. In the experiment, the image of the comparison stimulus was displayed for 5 seconds after displaying the black color for 5 seconds, and the standard stimulus was displayed for 5 seconds every six times of displaying the comparison stimulus. The number of layers of the comparison stimulus was changed in random order, and each image was displayed five times repeatedly for each subject. Figure 10 shows the example of the displayed image.

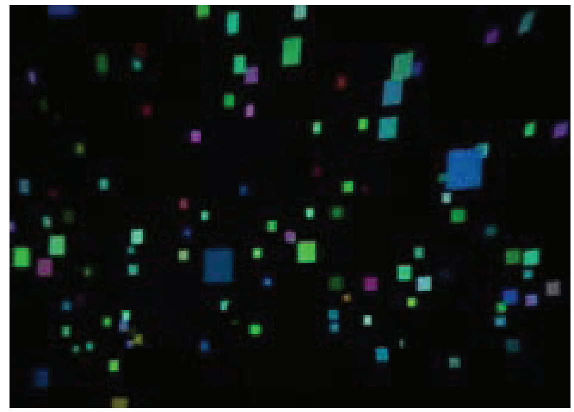

Figure 10. Example of the displayed image of distributed squares

The subjects were asked to evaluate the perceived depth resolution of the displayed image using the clues of the geometrical perspective and motion parallax. The sensation of the depth resolution was answered using the numerical value, by comparing with the sensation of value of 10 for the standard stimulus. The subjects were university students, and the number of the subjects was thirteen.

For the experimental result, two way analysis of variance (ANOVA) was used to investigate the effects of the individual difference and the number of layers, and both of them had significant effects at 1% level. Namely, it was shown that the number of layers influenced the perception of the depth resolution, though the individual difference was large. Figure 11 shows the average values and the standard deviations of the answers of the perceived depth resolutions. From the result, we can see that the sensation of the depth resolution increased according to the increase of the number of layers when it was less than 6 layers. Particularly, when the number of layers was more than 4, the perceived depth resolution increased and decreased gradually, and it was saturated.

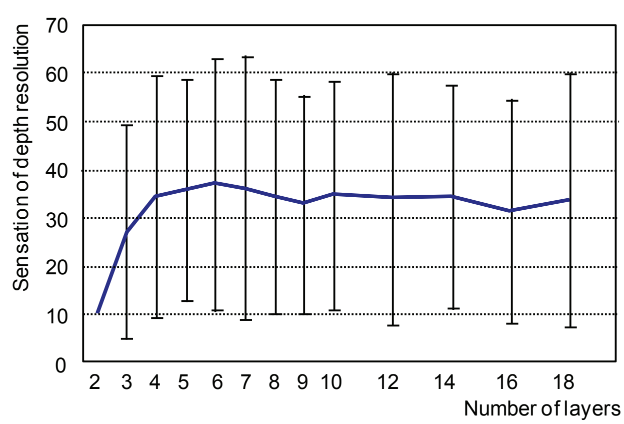

Figure 11. Result of experiment on depth resolution

Namely, we can understand that the optimum number of layers was about 4 to 6, and the difference of the depth resolution cannot be perceived by the audience even if the number of layers was more than 6. This means that the dome contents can easily be represented using a few layered images. Therefore, in the dome contents creation, it is expected that the representation of the spatial image can be realized by dividing the three-dimensional world into several layers, such as the short range view layer, the middle distant view layer, the long distant view layer, and the background. Thus, the contents creation method using the layered images is expected to be an effective method from the view points of the efficiency and the cost.

6 EXAMPLES OF DOME CONTENTS

From the above mentioned experiments, it was shown that when the dome contents are created using the layered images, the three-dimensional world can be represented by arranging several layered images without detailed models. In this study, the dome contents were actually created using the layered images and the evaluation experiment was conducted to verify the effectiveness of this method.

Two kinds of dome contents, such as "Walk in University Campus", and "Guide to Tsukuba City" were created. Figure 12 shows the examples of the scenes of the created contents that are projected in the dome display environment. The length of each contents was about 1 minute. In these contents, about ten layered images were used to represent the spatial images in which the continuous object such as the building is expressed using one image and the separated objects are expressed using separate layers.

In the evaluation experiment, these contents were displayed in the dome display of Hokutopia, and fifteen subjects of the university students were asked to answer the questionnaire after seeing them. Table 1 shows the question items and the results of answers. Each question was evaluated using the five grade system (1-5), and the average values of the answers are shown in this table.

From this table, we can see that the evaluation for "I did not recognized the screen shape." was high, and this result means that the conditions of distortion correction and lighting were satisfied. Moreover, the evaluation for "I felt presence.", "I felt interesting.", and "I felt powerful." were about 4. Then, the representation ability of the contents is thought to be satisfactory. In addition, we can understand that the representation of the depth sensation using several layers was realized, since the evaluation for "I felt depth resolution" was high.

On the other hand, the evaluations for “I felt pleasant.”, “I did not feel tired.”, “I did not recognize layer”, "I did not feel something was wrong." and "I felt natural movement." were a little low. It is thought that this result was caused by the exaggerated movements of the image elements and camera works to represent the three-dimensional sensation. The representation of the natural scene that does not give unpleasantness and tiredness to the audiences would be a future task.

From these results, we can understand that effectiveness of constructing the three-dimensional spatial image using several layered images was shown, though there are some problems in creating the contents that represent three-dimensional sensation without giving unpleasantness to the audiences.

Table 1. Results of questionnaire for contents evaluation

Question	Answer
I did not recognize the screen shape. (1-5)	4.20
I felt presence. (1-5)	4.13
I felt interesting. (1-5)	4.13
I felt powerful. (1-5)	3.73
I felt depth resolution. (1-5)	3.67
I felt pleasant. (1-5)	2.80
I did not feel tired. (1-5)	2.73
I did not recognize layer. (1-5)	2.67
I did not feel something was wrong. (1-5)	2.20
I felt natural movement. (1-5)	2.07

7 CONCLUSIONS

In this study, as a contents creation method that utilizes the effect of three-dimensional sensation felt in the dome display environment, the layer based dome creation method was proposed. This method represents the spatial image by utilizing the difference of the depth sensation for each layer that is felt based on the effects of geometrical perspective and motion parallax. Particularly, in this study, the optimum number of the layers that is required to represent the three-dimensional image in the dome display environment was discussed based on the psychophysical experiment, and it was confirmed that the perceived depth resolution is saturated with 4 to 6 layers. This means that this method does not need the detailed model or detailed division of the scene and it is an effective method from the viewpoints of the efficiency and the cost.

Moreover, though a lot of contents in the current virtual reality system are displayed using the original program, the layer based contents creation method can separate the contents scenario from the image elements. Future work will include developing a scenario description language [15] and an authoring tool as well as spreading this method as an effective contents creation method for the dome environment.

ACKNOWLEDGEMENT

This study was funded partly by Ministry of Internal Affairs and Communications (SCOPE, No.061303034) and supported by Keio University Global COE program (Center for Education and Research of Symbiotic, Safe and Secure System Design). And we would like to thank Naoki Matsumoto (Keio Senior High School) and Tetsuro Fujise (Mitsubishi Research Institute) for their supports.

REFERENCES

[1] E. Lantz: Large-Scale Immersive Displays in Entertainment and Education, *2nd Annual Immersive Projection Technology Workshop*, 1998.

[2] M. Roussou: Incorporating Immersive Projection based Virtual Reality in Public Spaces, *Proc. of International Immersive Projection Technology Workshop*, pp.33-39, 1999.

[3] Takeshi Chikakiyo, Tetsuro Ogi: Evaluation of Super High Definition Stereo Dome Environment in Science Museum, *ASIAGRAPH 2009 in Tokyo Proceedings*, Vol.3, No.1, pp67-70, Tokyo, 2009.

[4] http://www.goto.co.jp/company/company.html

[5] Shibano N, Hareesh P.V, Hoshino H, Kawamura R, Yamamoto A, Kashiwagi M and Sawada K: CyberDome: PC Clustered Hemi Spherical Immersive Projection Display, *Proc. of 2003 International Conference on Artificial Reality and Telexistence (ICAT2003)*, pp.1-7, 2003.

[6] E. Lantz: The Digital Planetarium, *Proc. of 2002 International Planetarium Society Conference*, 2002.

[7] K.C. Yu: Digital Full-Domes: The Future of Virtual Astronomy Education, *The Planetarium*, pp.6-11, 2005.

[8] S. Otsuka: Depth from Motion Parallax in the Peripheral Visual Field, *IEIC Technical Report*, Vol.100, No.109, pp.37-39, 2000.

[9] Takeharu Seno, Masahiro Hayashi, Tetsuro Ogi, Takao Sato: Virtual Depth Effects for Non-Stereoscopic Dome Images -The Estimation of the Depth Effects of the Dome Image by Psychophysics, *2008 ASIAGRAPH Proceedings*, Vol.2, No.1, pp.121-126, Shanghai, 2008.

[10] Tetsuro Ogi, Masahiro Hayashi: Dome Image Contents based on Layered Image Representation, *ASHIGRAPH 2007 in Tokyo Proceedings*, Vol.1, No.2, pp.113-118, Tokyo, 2007.

[11] J. Wang, E. Adelson: Layered Representation for Motion Analysis, *Proc. of the IEEE Computer Society Conference on Computer Vision and Pattern Recognition 1993*, pp. 361-366, 1993.

[12] Hokutopia, http://www.kitabunka.or.jp/

[13] Z. Zhang: A Flexible New Technique for Camera Calibration, *IEEE Transactions on Pattern Analysis and Machine Intelligence*, Vol.22, No.11, pp.1330-1334, 2000.

[14] hugin, http://hugin.sourceforge.net/

[15] Tetsuro Ogi, Daisuke Furuyama, Tetsuro Fujise: Layer-based Dome Contents Creation Using Scenario Description Language, *2009 International Conference on Advanced Information Networking and Applications Workshops (INVITE'2009)*, pp.544-549, Bradford, 2009.

(a) Walk in University Campus

(b) Guide to Tsukuba City

Figure 12. Examples of dome contents