Effective Contents Creation for Spatial AR Exhibition

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ABSTRACT

In this paper, we propose the exhibition system using the spatial augmented reality technology for the digital museum. This exhibition system can represent the atmosphere around the exhibits, for example, the bustle of town, a lifestyle of people, and the situation of excavation site. However, this method has some problems that must be solved to represent the atmosphere correctly. Then, we examined the effective color overlapping and the viewpoint control to create the effective contents by the experiment. As the result, it has been clarified that Value of the color and the movement of the animation in the virtual image had a great influence on the correct expression of the augmented reality scene. By considering these results, an example of the exhibition contents using the spatial augmented reality technology was created and the effectiveness of this method was evaluated.

Keywords

digital museum, spatial augmented reality, exhibition and atmosphere

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1. Introduction

This paper describes the application of spatial augmented reality technology to the next generation museum. Recently, the number of visitors who visit the museum is decreasing gradually. There are some reasons of this problem. First, people have come to acquire necessary information without going to the museum due to the development of the Internet and the increase of the chances to visit the first-class cultural assets with the social globalization. Next, the current museum exhibits only objects. At the moment, people who are indifferent to the museum are increasing, especially among young people. Though they are not interested in the contents, they might only be bored with watching the exhibits or reading the explanatory note. In order to realize the attractive exhibitions, it is necessary to provide the information that visitors can’t obtain by watching only the exhibits, for example, the bustle of town, a lifestyle of people, and the situation of the excavation site. In other words, that is atmosphere around the exhibits.

Atmosphere about the exhibit can be presented using the photographs or videos. Usually, these images are displayed near the exhibits or in the separate space from them. In this exhibition style, visitors have to integrate the information provided separately. As a result, visitors might obtain the wrong knowledge.

Then, we propose a new exhibition system using the spatial augmented reality technology for the next generation museum, called digital museum. It is the exhibition system in which the user cannot only watch the exhibit but also feel the atmosphere. We implemented the exhibition system that can express the atmosphere by mixing the computer graphics images with the real exhibition space using the spatial augmented reality technology [1]. This new exhibition system would help visitors to get new interests. However, the spatial augmented reality exhibition system has some problems that must be solved. Then, the purpose of this study is proposing the guideline to create the attractive contents for the spatial augmented reality exhibition in the future digital museum.

In this paper, we describe the system configuration of the spatial augmented reality exhibition system, the method of the representation of correct occlusion, the method to effective color overlapping, and the verification of the viewpoint control.

2. The Spatial AR Exhibition System

Various exhibition systems using the virtual reality or augmented reality technology have been developed and used. The exhibition of "The Golden Capital of SICAN" held in these days is an example using the virtual reality technology [2]. One of the popular contents of this exhibition is the three-dimensional theater that represents the situation of the ancient relics. In this theater, visitors can see the ancient objects represented using the three-dimensional computer graphics image while wearing the three-dimensional glasses. But it is not enough to represent the relationship between the real object and the virtual reality image, because the theater room is not in the exhibition space.

On the other hand, as for an exhibition system using the augmented reality technology, Virtual Showcase has been developed. This is a desktop type exhibition system using the half-mirror [3]. But it is too small to express the image of sufficient size for the representation of the atmosphere. Then, the next generation exhibition system should be able to integrate the full-scale image with the real world.

2.1 System configuration

In this study, spatial augmented reality display system named AR View was developed [4]. ARView is a display system that combines the virtual image projected by projectors with a real world. ARView is composed of the large semi-mirror film (3.0m x 4.5m), which is placed at an angle of 45 degrees to the floor, DLP projectors, and the screen placed on the floor. The principle of ARView is as follows. At first, the computer graphics image is projected from the DLP projectors (Inforcus DepthQ) placed at the ceiling to the floor screen. Then, the users can see the computer graphics image reflected with the semi-mirror film. Since this semi-mirror film has highly transmissivity (visible light transmission is 87.8%), the users can see the real object placed behind the semi-mirror film. One of another good point of ARView is representing immersive sensation, and the users can feel that they are in the augmented reality world, since the virtual image has sufficient size to represent the atmosphere. Figure 1 is the system configuration of ARView.

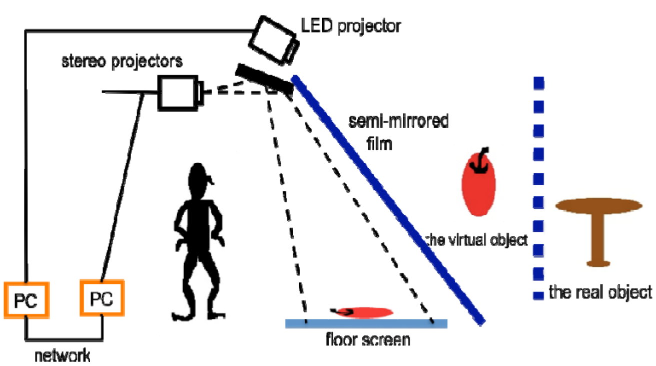

Figure 1: System configuration of ARView


Figure 2: Appearance of ARView

In this study, a small size prototype system of AR View was developed for the experiments using the spatial augmented reality exhibition technology. The height and the width of the experiment system are 65cm and 80cm respectively. And the real objects can be placed up to 40cm away behind the virtual image plane. We conducted the experiment using this prototype system in this study.


Figure 3: Prototype of the spatial AR exhibition system

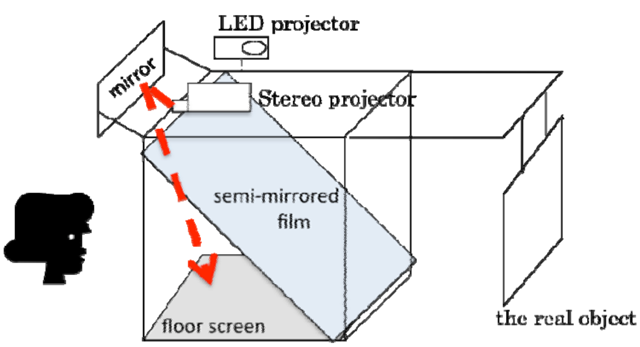

Figure 4: System configuration of the prototype

2.2 Representation of the Correct Occlusion

In this system, the exhibits are placed in the dark space behind the semi-mirror film. When the exhibit is displayed in this system, it is very important to represent the correct occlusion so that the computer graphics image does not disturb the exhibit.

In this study, the method to represent the correct occlusion using the lighting projector has been introduced [5]. In this method, it becomes possible to represent the positional relationship between the real object and the virtual image by using the LED projector for the lighting. The principle of the representation of correct occlusion is as follows. When the virtual object occludes the real object, the virtual image is projected from the DLP projector and the LED projector is turned off. On the other hand, when the real object occludes the virtual object, the LED projector illuminates the real object and the virtual image is blackened. By controlling the LED projector as the lighting, we can represent the correct occlusion. Consequently, we can mix the virtual scene with the real world correctly in the three-dimensional space.

2.3 Requirements for Spatial AR Exhibition

In the museum, visitors have to be able to appreciate the exhibits freely. In this case, two or more persons have to be able to see them simultaneously. However, in the spatial augmented reality exhibition system, this function is not sufficient, because the sweet spot where the users can see the correct scene was restricted strictly. Therefore, the audience can feel the atmosphere, when he is in the sweet spot and see the correct scene. However, the audience who sees the exhibits from different view direction can't feel the correct atmosphere.

There are two methods to solve this problem. The first method is expanding the sweet spot by using the effect of color overlapping. The second method is leading the viewpoint of the user intentionally to the sweet spot. By using these methods, all the audiences can enjoy the exhibition with the same quality. But the studies about the user's view in the augmented reality exhibition system have not been conducted enough. Therefore, we conducted the basic experiment about the effective color overlapping and the viewpoint control to obtain the guideline for the effective contents creation.

3. Experiment on Effective Color Overlapping

First, the experiment on color overlapping was conducted. The purpose of this experiment is to examine the influence of the color combination between the real object and the virtual image. The color is defined by specifying three elements such as Hue, Value, and Chroma. For example, the Munsell Color System is often used to specify the color elements, and a three-dimensional color space is defined [6]. To examine the influence of the color overlapping, it is necessary to discuss the influence of each element of the color.

In this paper, we attempt to clarify which color element in the real object and the virtual image is most influential with the user's view. First, we focused on the relationship between Value parameter and the user's view, and we conducted an evaluation experiment. After that, we conducted the experiment considering the Hue and Chroma parameters as well as Value parameter of the color.

3.1 Method

In this experiment, we asked subjects to see the virtual image reflected with the semi-mirror film. Then, the subjects evaluated whether they recognized the real object through the virtual image.

3.1.1 Real objects

As real objects, we chose four cards which have different Value parameters, and placed them at the position 40cm away behind the semi-mirror film. The Value of the four cards is shown in Table 1.

Table 1: The Value of the real cards

	Value parameter
card1	1.5
card2	4
card3	7
card4	9.5

The positions of the four cards were changed randomly for each subject. Figure 5 shows the example of the placement of the four cards.

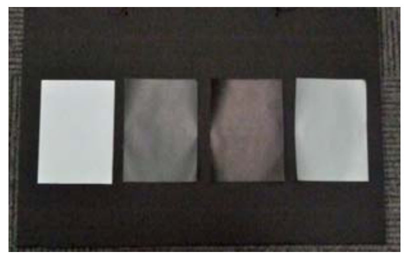

Figure 5: Placement of the cards in color overlapping experiment

3.1.2 Virtual images

As a virtual image, the image plane painted with one color was used. As for the color, achromatic color and chromatic color were used. When the achromatic color was used, the Value parameter of the gray image was changed by specifying the RGB parameters as shown in Table 2.

Table 2: The RGB parameters for achromatic color

	R	G	B	Munsell color system
White	1.0	1.0	1.0	N10
Gray1	0.8	0.8	0.8	N8
Gray2	0.6	0.6	0.6	N6
Gray3	0.4	0.4	0.4	N4
Gray4	0.2	0.2	0.2	N2

And when the chromatic color was used, the color was changed among red, yellow, green, blue, and purple that are specified based on Japan Industrial Standards. RGB parameters and Hue, Value, and Chroma parameters of these colors are shown in Table 3.

Table 3: The RGB parameters for chromatic color

	R	G	B	Munsell color system
Red	0.93	0.10	0.24	4R 3.5/11
Yellow	1.00	0.83	0.00	5Y 8/14
Green	0.00	0.50	0.00	2.5G 6.5/10

Blue	0.00	0.60	0.84	10B 4/14
Purple	0.65	0.34	0.66	0.3RP 4.8/12.2

3.1.3 Subject evaluation

In the experiment, the real cards were placed behind the semi-mirror film by turning off the lighting projector, and the virtual image was displayed. As the virtual image, 5 colors were changed at every 20 second in random order in the set of one experiment. The number of subjects was 10, and three sets of experiments were conducted for one subject.

First, we conducted an experiment to examine the influence of the Value parameter using the achromatic color for the virtual image. After that, we conducted the experiment in the condition where Hue, Value, and Chroma parameters were changed using the chromatic color for the virtual image.

In each experiment, the subjects were asked to evaluate whether they can recognize each card based on the valuation basis shown in Table 4.

Table 4: A valuation basis for user's view

Point	A valuation basis
-2	You can see the card completely.
-1	You can see the card a little.
0	You can't the judge.
1	You hardly can see the card.
2	You can't see the card completely.

3.2 Result

The following figures show the results of this experiment. In these graphs, the averages and the standard deviations of the evaluation for each condition are shown.

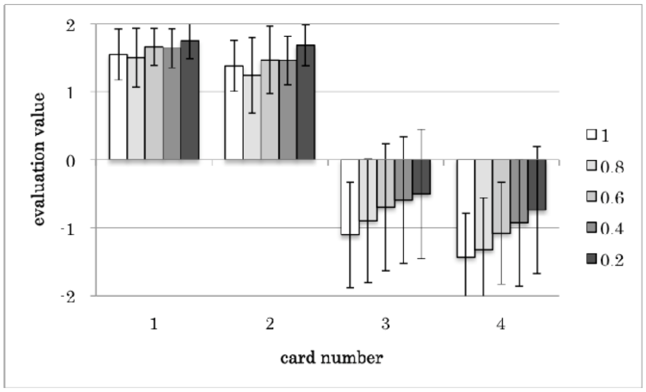

Figure 6: Result of evaluation when gray virtual image was used

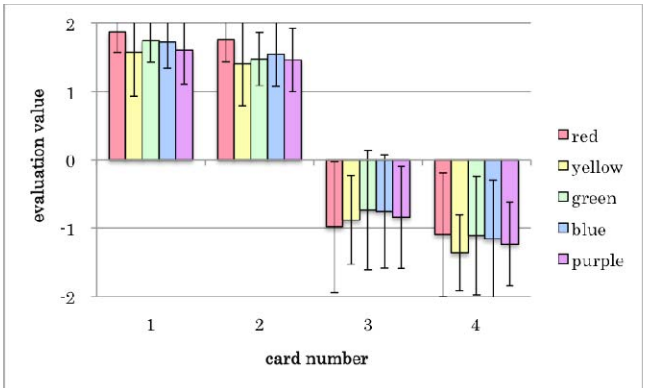

Figure 7 : Result of evaluation when color virtual image was used

The results were analyed using two-way ANOVA. From the result, Value of the color of the real object had an influence on the user's view significantly. When Value of the real object was low (card 1 and 2), the real object culd hardly be recognized by the user. On the other hand, when Value of the real object was high (card 3 and 4), the real bject could be recognized. And the change of the color of the virtual image did not have a significant influence on the user's view. However, as for the cards 3, there was significant difference between the white card and the Gray4 card, when the gray image was used. And as for the card 4, there was significant difference between the Gray1 card and Gray4 card for the gray image.

3.3 Discussions

From the experiment, the card with low Value was hardly recognized. Therefore, we can understand that when the exhibits with dark colors were placed in the dark condition, the virtual image could be expressed correctly without being disturbed by the exhibits.

As for the difference of the evaluation due to Value parameter of the virtual image in card 3 and 4, it is thought that the card was reflected by the light of the virtual image. When the real object is placed in the dark space, the virtual image occludes the real object. However, in the cases of card 3 and 4, it is thought that when the virtual image of bright color was displayed, the real object was illuminated by the reflected light from the virtual image, and the subjects recognized the real object.

To examine the influence of the reflected light, we measured the illumination at the point where the cards were placed. Table 5 shows the result of the measured illumination when the achromatic color was used. These data show the average values when the illumination was measured three times at the same position.

Table 5: illumination based on the achromatic color (lx)

	The value of illumination
White	72.4
Gray1	36.3
Gray2	16.6
Gray3	5.5
Gray4	1.1

When the chromatic color was used for the virtual image, the change of the color did not affect the user's view. This is because there was little difference in Value of the virtual image, though RGB parameters were changed. Table 6 shows the result of the measured illumination when the chromatic color was used.

Table 6: illumination based on the chromatic color (lx)

	The illumination value
Red	8.5
Yellow	31.7
Green	6.7
Blue	16.6
Purple	11.5

If Value of the color in the virtual image is high, the illumination based on the virtual image is high. Therefore, the card with high Value reflects the light from the virtual image. Consequentially, this situation makes the same function as using the lighting projector, even if the lighting projector is turned off.

In order to solve this problem, it is necessary to separate the distance between the real object and the floor screen. In this experiment system, since the floor screen is placed at the same height as the stage behind the semi-mirror film, the virtual image has a great influence on the real object. However, this phenomenon can be prevented by separating the real object from the floor screen. In the case of ARView, the floor screen is located 60cm lower than the stage where the real object is exhibited. Therefore, the virtual image had little influence on the real object.

4. Experiment on Effect of Viewpoint Control

Next, we conducted the experiment on the viewpoint control. The purpose of this experiment is to verify the influence of viewpoint control. We expected that the animation of the virtual image could lead the user's view direction intentionally to the sweet spot.

Then, we experimented on the effect of viewpoint control to the sweet spot using the animation image.

4.1 Method

In this experiment, the cards of the real object were placed behind the semi-mirror film, and animation of the virtual image was displayed. Then, we asked subjects to see the virtual image and evaluate how they can see the virtual image.

4.1.1 Real object

As a real object, we chose the four cards that were used in the previous experiment, and placed them behind the semi-mirror film. The Value of the four cards is indicated in Table 2. The positions of the four cards were changed randomly for each subject. Figure 8 shows the example of the placement of the four cards.

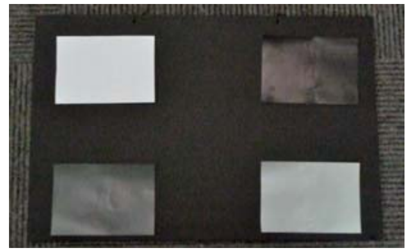

Figure 8: Placement of the cards in viewpoint control experiment

4.1.2 Virtual image

As a virtual image, the image in which spheres of various sizes were drawn was used. Figure 9 shows an example of the virtual image used in this experiment. The color of the background of the image was changes among five colors such as red, yellow, green, blue, and purple. And the spheres in the image were moved as animation in the following conditions.

1) Spheres are static.
2) Spheres rotate around the origin.
3) Spheres become large or small, and the positions of the spheres change at random.

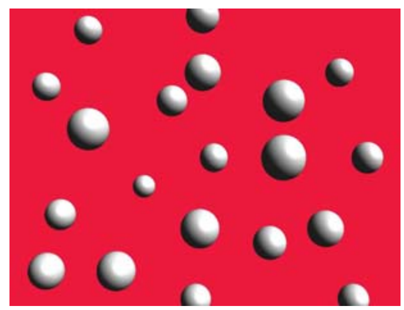

Figure 9: Example of the virtual image

4.1.3 Subject evaluation

In the experiment, the color of the background and the movement of the animation were changed at every 15 second in random order in the set of one experiment. The subjects were asked to see the virtual image and evaluate how they can see the virtual image using a ten-grade system (0-10) shown in Table 7. The number of subjects was 10, and three sets of experiments were conducted for one subject.

Table 7: A valuation basis for user's view

Point	A valuation basis
0 (min)	The card doesn't disturb when you see the image.
10 (max)	The card disturb when you see the image.

4.2 Result

The results of this experiment were analyed using three-way ANOVA. From the result, factor of card was significant at 1% level, and factor of animation was significant at 5% level. Figure 10 shows the average values and standard deviations of the evaluation for each animation condition are shown. From the result of this experiment, we can see that the animation has influence on leading the user's viewpoint significantly.

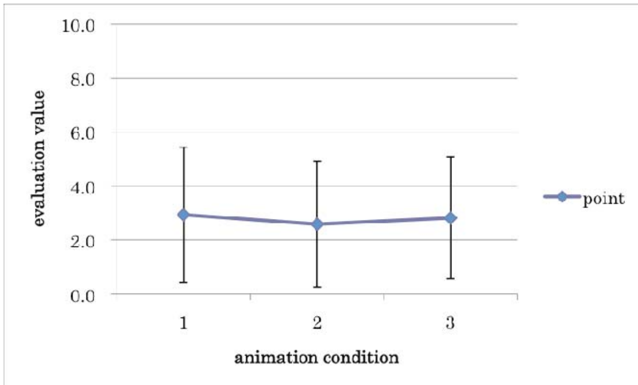

Figure 10 : Result of evaluation for animation image

4.3 Discussions

In this experiment, the condition of animation 2 was the most effective to control the user's viewpoint so that the user can hardly recognize the real object behind the virtual image, and the condition of animation 3 was the second. This is because the subjects' viewpoints were led to seeing the moving spheres by the effect of the animation.

Though the control of the user's viewpoint by the animation image is thought to be effective, it often has opposite effect. For example, in the condition of animation 3, when the spheres moved, the distance among the spheres might be spread, and consequently the card behind the virtual image can be noticeable.

On the other hand, in the condition of animation 2, the spheres passed over the positions of the cards many times. But, in this case, the users' viewpoints were led to the moving spheres and they hardly see the real object behind the virtual image, because the distances to the real object and the virtual image were different. That is why the image of animation 2 led the user's viewpoint effectively. Thus, we can conclude that the animation in which the virtual objects pass over the exhibits would be very effective, in order to lead the user's viewpoint effectively.

5. Exhibition of the Golden Mask

Considering the result of effective color overlapping and viewpoint control, we created an example of the exhibition contents of "Golden Mask", which is one of the typical relics in Sican culture. This exhibition contents was created in digital museum project funded by the Ministry of Education, culture, Sports, Science and Technology, Japan. Since this contents was a demonstration to show the effect of the exhibition methodology, a replica of the Golden Mask was used for the exhibit.

This exhibition contents consists of two scenes. In the first scene, we represented the virtual image of the excavation site. First, the audience sees the photograph of a current Huaca Loro. Next, this photograph changed to the three-dimensional computer graphics image (Figure 10). Then, the viewpoint moved into the tomb where the Golden Mask was excavated.

In the second scene, we represented the virtual image of the inside of East tomb. The audience looks around the scene of the buried bodies and burials. Then, he sees the virtual mask at the position where the genuine mask was located. At last, the virtual mask disappears and the audience can see the real mask (Figure 11). In this exhibition, the audience would understand the relationship between the exhibit of the mask and the excavation site.

Figure 11: Scene of excavation site in Huaca Loro

Figure 12: Scene of representing the atmosphere around the exhibit of Golden Mask

The color of the Golden Mask is dark red, and it includes metal partially. In this case, it is generally difficult to represent the correct occlusion, because the metal reflects the light of the virtual image. As a result, the audiences often recognize the real mask, when they see the virtual image. In order to solve this problem, we created the virtual image mainly using the colors of brown and yellow ocher with low Value, and introduced the walk-through and the camera work functions in which the viewpoint moved constantly.

In this exhibition contents, we could represent the atmosphere around the Gold Mask using the spatial augmented reality technology. And the quality of the contents for the augmented reality exhibition system was improved by using the appropriate effect of the color overlapping and viewpoint control.

6. Conclusion

In this study, we proposed the new exhibition system using the spatial augmented reality technology for the next generation digital museum. And we conducted the experiments on the effective color overlapping and on the viewpoint control for the effective contents creation. As the result, we understood that Value of the colors used in the exhibits and the virtual image has influence on the correct expression of the augmented reality scene. And, effect of the viewpoint control using the animation image could be shown.

In the future work, we are planning to examine the effects of the viewpoint guidance in the scene that includes multiple objects and the influence of the positional relationship between the exhibit and the virtual image in more detail.

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