Digital Conservation of Cultural Assets

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Abstract. Research goal of archiving is not simply digitalization of assets ,but archiving based on clarification of the original structures of the assets. For example, the information on old and deteriorated documents may be difficult to decipher. We aims to make such material widely available after using advanced analytic techniques to revive script and illustrations, thus restoring the document to its original form. First Cases: The Nishi Hongwanji holds a large collection of paintings and artifacts. To preserve the cultural property we are investigating preservation, conservation and conservation documentation methods. Second Cases: we report the virtual reconstruction and conservation of a lost cave shrine. The purpose of this research is to search for the possibility of the digital restoration that maintained the resolution for the realistic representation and the interactive media for digital archives of ruins in the future.

Keywords: Digital Archives, Photo Realistic Representation, Mixed-Reality, Image-Based Rendering (IBR), Model-Based Rendering (MBR).

1 Introduction

Nowadays, large numbers of cultural properties are found that have deteriorated through exposure to sunlight and dust over a long period of time, and that require conservation, repair or restoration. Recent years have seen active use of digital archiving technology to preserve or restore paintings, artifacts and other cultural properties that contain highly valuable historical information. In the study presented here, First Cases: The Nishi Hongwanji holds a large collection from the Momoyama era, paintings and artifacts, as well as the Momoyama style architecture. To preserve the cultural property we are investigating preservation, conservation and conservation documentation methods.

In the Nishi Hongwanji digital archive project, pigments data and measuring data from digital images are gathered and the database is developed.

In this paper, pigments on ‘shouhekiga’, pictures on (room) partition, or ‘ranma’, Japanese traditional transom are analyzed, and 3D computer graphics is constructed using the analysis data of pigments and gold foil.

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Second Cases: we describe a digital conservation method for Bezeklik Cave No.4 in Turfan. We digitized wall paintings of Cave No.4 scattered all over the world. Then, we integrated these paintings, made up the lack parts of paintings by using similar paintings, and corrected the color tone of paintings. Finally, we generated 3D-model of Cave No.4 with restored wall paintings.

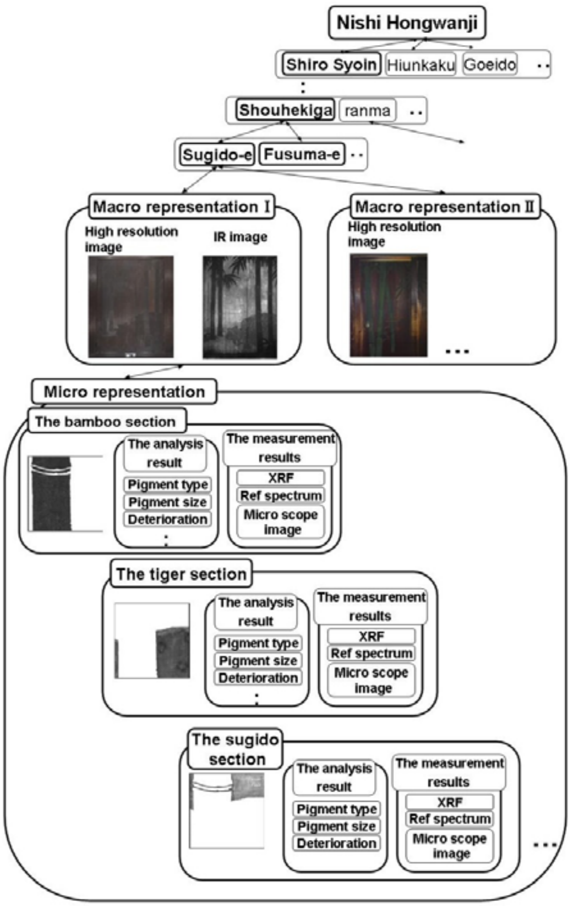


Fig. 1. Nishi Hongwanji Digital Archives structure

2 Nishi Hongwanji Digital Archives

Conventionally, digital archives of paintings store such data as the artist's name, year of production, pigments used and reflection spectra. Nishi Hongwanji Digital Archives store similar data on *shouhekiga*, though a different arrangement of data is required. This is because Nishi Hongwanji's *shouhekiga,* which are still in use as part of the temple buildings, are in varying degrees of discoloration, deterioration, pigment exfoliation and so on, depending on their location, building structure, exposure to the elements and other factors. For example, all the paintings on the northern side of Tora-no-ma have blackened, whereas those on the southern side of the same room retain their original colors. In consideration of this fact, therefore, instead of archiving each *shouhekiga* simply as one picture, a multi-scale structure—as illustrated Fig.1.—has been developed for Nishi Hongwanji Digital Archives, to take into account the factors affecting the conditions of the respective paintings.

2.1 Analysis of Pigments

Shouhekiga and *ranma* are painted with pigments called *suihi enogu* and *iwa enogu*. *Suihi enogu* is made from mud or earth found mostly in mountains, which is washed with water to remove impurities and then dried in plate form. *Iwa enogu*, granular pigments made of various crushed minerals and semi-precious stones, are used with *nikawa* (glue) as a binder. They come in only a few basic colors, but this single raw material can yield a variety of hues, depending on the granule diameter. This characteristic is used to achieve various nuances and a three-dimensional effect. Granule diameters are indicated by numbers: the higher the number, the finer the granule. The finest granule is called *byaku* (see Fig.2. and Table 1).

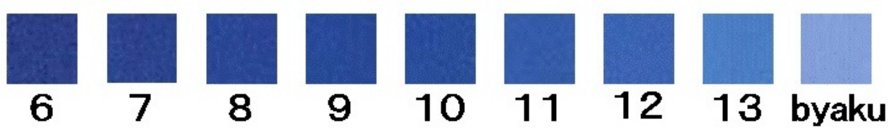


Fig. 2. Iwa enogu numbers and gradations

Table 1. Table 1 *Iwa enogu* numbers and granule diameters

Number	6	7	8	9	10	11	12	13
Av. diam(μm)	120	100	70	50	30	15	10	7

- X-ray fluorescence (XRF) analysis
- Granular diameters
- Reflection spectra

The results of these measurements revealed that the pigment *rokusho* (green) No. 8 is used in the bamboo sections of well-preserved *shouhekiga*. At the same time, the results led to the assumption that the same pigment is used in the bamboo sections of deteriorated paintings and that the pigment *oudo* (yellow ocher) is used in the tiger sections.

2.2 Reflection Models

Using the color-restored *shouhekiga* images, we attempted to create a representation of *shouhekiga* that also expresses the characteristics of the pigments used. As stated above, pigments have different granule diameters, which, as they become larger, render the surface of a painting coarser, due to the diminishing intensity of reflected light. We tried to recreate this effect using a surface scattering model that takes pigment characteristics into account. In the study we used the microfacet distribution function (Beckman distribution function, Formula (1).

$$D(x, k_2, k_1) = \frac{1}{S^2 \cos^4 d} \exp\left(-\left(\frac{\tan d}{S} \right)^2 \right) \quad (1)$$

$$[d = n \cdot h]$$

here x = denotes a sample point, k_1 = the incident vector

k_2 = the reflecting vector, n = the normal vector

h = the half-angle vector, S = the coarseness parameter

Fig. 3. Representation of *shouhekiga* using pigment reflection model

2.3 Gold Foil Reflection Model

Since Nishi Hongwanji has large numbers of gilded art objects, realistic representation of the surfaces of such objects constitutes an important aspect of the digital archiving. Gold foil, thinly spread gold obtained by striking the metal wrapped in deerskin or a similar material, is cut into squares for application. A gilded surface is minutely uneven and reflects light diffusely. As well, gold foil being a metal, it is known to cause anisotropic reflection. In this study, therefore, we combined the Ashikhmin[1] and Beckman models to form a gold foil reflection model that reproduces images of gilded complex surfaces. The Ashikhmin model can be obtained from the sum of specular reflection $\rho_s(k_1,k_2)$ and diffuse reflection $\rho_d(k_1,k_2)$, which can be obtained from formulas (2) and (3), respectively:

$$\rho_s(k_1,k_2)=\frac{\sqrt{(n_u+1)(n_v+1)}}{8\pi}\frac{(n\cdot h)^{(n_u(hu)^2+n_v(hv)^2)}}{(h\cdot k)\max((n\cdot k_1),(n\cdot k_2))}F((k\cdot h)) \tag{2}$$

$$\rho_d(k_1,k_2)=\frac{28R_d}{23\pi}(1-R_s)\left(1-\left(1-\frac{(n\cdot k_1)}{2}\right)^5\right)\left(1-\left(1-\frac{(n\cdot k_2)}{2}\right)^5\right) \tag{3}$$

where u, v = orthogonal vectors to the normal direction

R_d = denoting the intensity of diffuse reflection

R_S = denoting the intensity of specular reflection

$F((k\cdot h))$ = Fresnel coefficient

Surface coarseness can be expressed by applying Formula (1) to the highlighted part of Formula (2).

Since the minute surfaces of *shouhekiga* and *ranma* are uneven, the mutual interference of microfacets must also be taken into consideration. This can be expressed by the following formulas:

$$G_{out}(n,k_2,h)=2\frac{(n,h)(n,k_2)}{(k_2,h)} \tag{4}$$

$$G_{in}(n,k_2,h,k_1)=2\frac{(n,h)(n,k_1)}{(k_2,h)} \tag{5}$$

$$G(n,k_2,h,k_1)=\min(G_{in},G_{out},1) \tag{6}$$

Ranma portion representations realized using the gold foil reflection model are also shown further below. Here, only a texture reproduced using the gold foil reflection model is applied. In the future, we intend to reproduce more realistic *ranma* surface images using the gold foil reflection and pigment reflection models.

3 3D Spatial Representation of Nishi Hongwanji

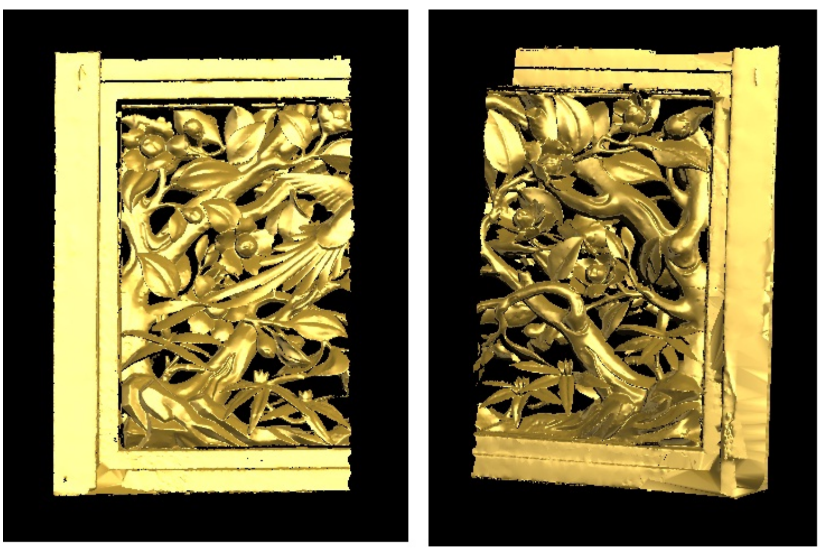
We produced a three-dimensional representation of Nishi Hongwanji's Tora-no-ma using a three-dimensional geometric model based on temple structure data. Model-Based Rendering (MBR), collective term for methods for synthesizing and expressing input data on structures, involves creating a three-dimensional geometric model in a virtual world using input data on structures or a light reflection model or other physical models. Texture mapping, one MBR method, is particularly effective for realistic three-dimensional geometric model production.

3.1 Three-Dimensional Spatial Representation

In the study, we attempted a three-dimensional spatial representation of Nishi Hongwanji's Tora-no-ma in the following manner. First, we fixed the three-dimensional coordinates of the room on the basis of its structural data. We then conducted polygonal approximation with triangular patches, to generate a three-dimensional geometric model of a scene. We then texture-mapped the actual images onto the three-dimensional geometric model. For actual images, we used three types of image: digitalized high-resolution images, infrared photographic images and color-restored images.

3.2 Digital Color Restoration and Three-Dimensional Spatial Representation

We performed digital color restoration of Nishi Hongwanji's cultural properties using data stored in digital archives, such as pigment types, granule diameters, reflection spectra and infrared photographic images. Using color-restored images thus obtained, we generated digital representations of *shouhekiga* in Tora-no-ma using the reflection model, taking into consideration pigment characteristics and gilded surfaces using the gold foil reflection model. Finally, we created a three-dimensional spatial representation of Tora-no-ma, using *shouhekiga* images already in the digital archives and images color-restored in this study.



(a) Part of *ranma* (front) (b) Part of *ranma* (back)

Fig. 4. Representation of *ranma* using gold foil reflection model

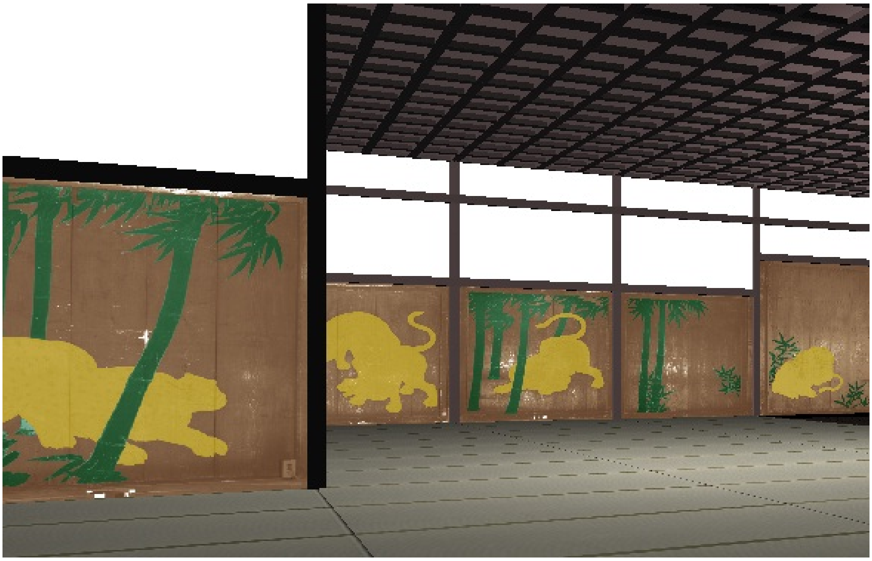


Fig. 5. Three-dimensional spatial representation of Tora-no-ma

Such is the scope of our study conducted thus far. In the future, we intend to go further by applying a reflection model that considers gold foil reflection to three-dimensional spatial representation, so as to include large numbers of Nishi Hongwanji's gilded art objects, such as *ranma* and *shouhekiga* in the archives. For this purpose, we intend to examine techniques for adding pigment and gold foil textures to images of objects having a shape similar to that of *ranma*.

4 Bezeklik Wall-Paintings

Fig. 6. shows Bezeklik temple shown in Turfan area in Dunhuang the northwest. Bezeklik means "Place with the decoration" in Uigur. This cave shrine was built from the 6th century to about the 14th century by Uigur, and there are about 83 cave shrines.

Several wall painting of the cave shrine were taken out by the expedition teams in the foreign countries, such that A. von Le Coq (Germany), Aurel Stein (England), SF. Oldenburg (Russia) and Otani expedition (Japan). Only few wall paintings remain in the original cave shrine. It is possible to see the fragments of the collected wall paintings in Chotscho[2] which published by A. von Le Coq, at National Museum of India (NewDelhi), at The State Hermitage Museum (St Petersburg) and at Tokyo National Museum. Fig.7. shows Bezeklik No.4 Cave. The ceiling of the cave shrine is

Fig. 6. Bezeklik temple

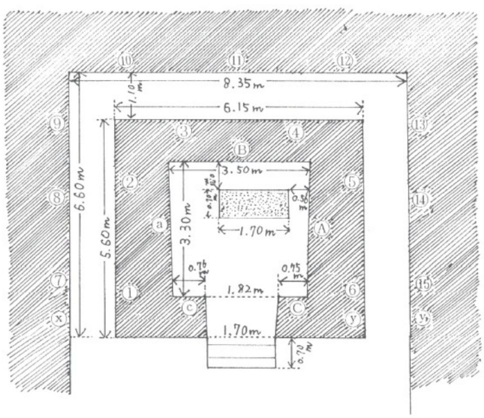


Fig. 7. Measurement of the Bezeklik No.4 Cave

composed of dome-shaped and the barrel type. The width of the corridor is about 1.2m and the height is about 3m.

4.1 Collection of Wall Painting Data and Database Building

Though a restoration object is the wall paintings of the cave No. 4, there are many lack parts. To fill the missed parts, we consider that it refers to the wall painting of other similar cave. Then, we use the wall painting of the cave No. 9 which similar to the No. 4. (A pictorial book for the No. 9 one was published.) The wall painting is classified based on the item shown in Table 2, the image-database is made. (Fig. 8.) For reconstruction of the wall painting, lack parts of wall painting are analogized religiously and statistically using the database.

Table 2. Classification attributes of wall painting

Attribute	Title
Cave number	Number of Cave which painted the wall painting
Title number	Title number for each wall painting
ID	Characters' identification numbers
File name	Image data file name
Source	Source of the wall painting data or publication (drawings, the actual locale, and museum etc.)
Character	Characters‘name (bodhisattva, biku etc.)
Item	Item (flower, bread etc.)
Hair	Decoration applied to hair (hat or turban, etc.)
Cloth	Kind of cloth (kesa, armor etc.)
Ear	Shape of ear, ear item (long, earring etc.)
Face direction	Direction of face (left, front etc.)
Nimbus	Color of Hicasom (green, red etc.)

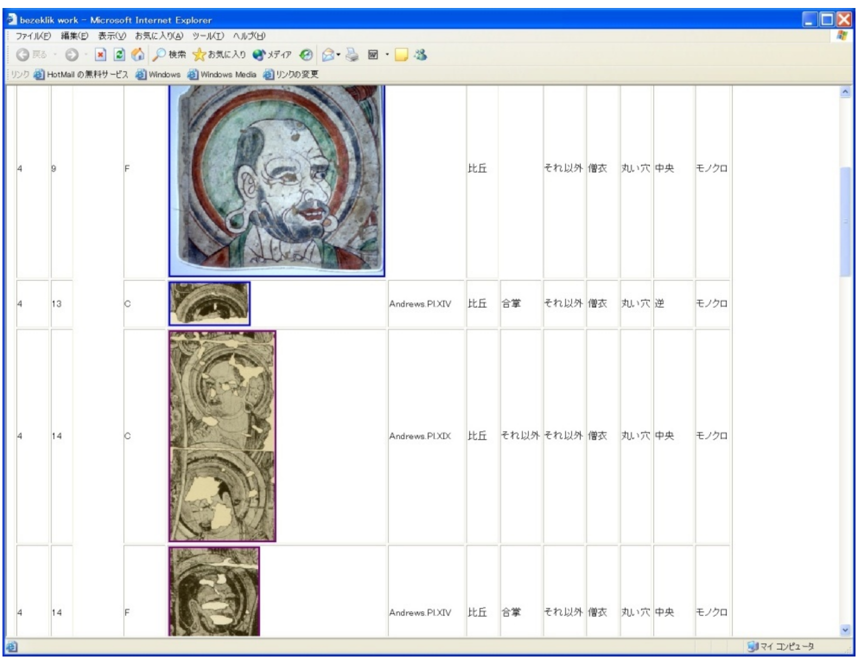


Fig. 8. Wall painting database

4.2 Analysis of The Wall Painting

The groundwork and pigments of the Bezeklik wall painting are given in Table. 3. Using i1 (made by Gretag Macbeth), we measured the spectrum characteristic of the groundwork and pigments for gypsum, lime, vermilion, yellow ocher, azurite, malachite, and the carbon obtained by marketing now. The color tone changes by roughness of pigments. If pigments fine the color brightness grew stronger.

Table 3. The groundwork and pigments of the Bezeklik wall painting [3]

Groundwork	Red	yellow	blue	green	black
gypsum, lime	vermilion, bengara	Yellow ocher	azurite	malachite	carbon

4.3 Reconstruction of The Wall Painting

For reconstruction of the wall painting, we consider a positional matching for fragments of the wall painting (drawing, photographic image in the cave and at museums) which are exist. (Fig.9.) Since the wall painting of the cave No. 4 is very similar to one of the cave No. 9, characters in wall painting are also similar. Although the wall painting of the cave No. 9 do not exist now, the facsimile, i.e. drawing, of it is exist. Using digital high vision broad casting, we consider a zoom of an arbitrary position on the reconstructed wall painting, thus a resolution is 7,000 x 7,000 pixels. A digital reconstruction procedure of the cave No. 4 is as follows.

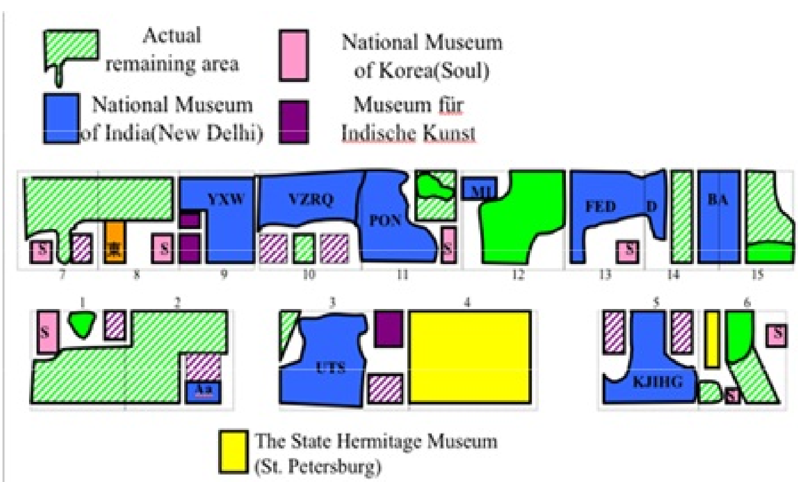


Fig. 9. Wall paintings of No.4 were divided by foreign expeditions

(a) Cave No. 9 (b) Positional match of wall painting fragments (c) Wall painting restoration result

Fig. 10. Reconstruction of wall painting

First, we carry out a positional matching for fragments of the wall painting (Fig.10.(b)) such that a location of characters of drawings for No. 9 cave wall paintings. (Fig. 10.(a)) Each fragment is in National Museum of India (NewDelhi), Museum für Indische Kunst (Berlin-Dahlem). Right and left fragments of Museum für Indische Kunst are not exist, but its drawings are exist.

Next, the lack part of the wall painting is filled using the image database of wall paints. Fragments are chosen religiously and statistically by shape of hands, shape of clothes, expression of face and so on. The fragments are done rotation, reduction, and expansion, and fill the lack space.

Finally, the tone of the entire wall painting is corrected. In this paper the appearance of the wall painting at the time of be drawn is reproduced. To achieve this, the spectrum characteristic of the fragment in existence wall painting is measured, it is necessary to investigate the level of deterioration while comparing it with pigments previously shown. However, it was difficult to measure the spectrum characteristic of the fragment of the wall painting. Then the basic color (Blue, white, green, red, flesh-colored, black, tea, and bitter orange) used by the wall painting based on the analysis result of pigments previously described was made. The tone is corrected based on these. Fig.10.(c) shows the result of correcting the tone.

5 3D- Models' Generation of The Cave No. 4

The purpose to generate three dimension model is to present to the user the position of the wall painting in a buddhist temple intuitively. There is a method of measuring actual cave with the range finder for the method of generating three dimension model of cave. But, by occasion of the above-mentioned, three dimension model is generated based on the data measured in drawing and several places open to the public without doing an accurate measurement here. The cave No. 4 is VR reconstructed by doing the wall painting restored to the generated three dimension model ahead in texture mapping. Fig.11.(a) shows the appearance of a present cave shrine, Fig.11.(b) shows the result of VR restoring of the cave shrine.

(a) Present (b) CG reproduction

Fig. 11. Three dimension reconstruction result

6 Expression of Wall Painting That Uses Virtual Source of Light

Here, we consider the method of expression of the wall painting previously restored. When cave shrine builds the worshipper is thought the wax candle to be light, and tries to reproduce this appearance virtual. That is, the user operates a virtual source of light, mode of expression into which optical how to see wall painting changes virtual.

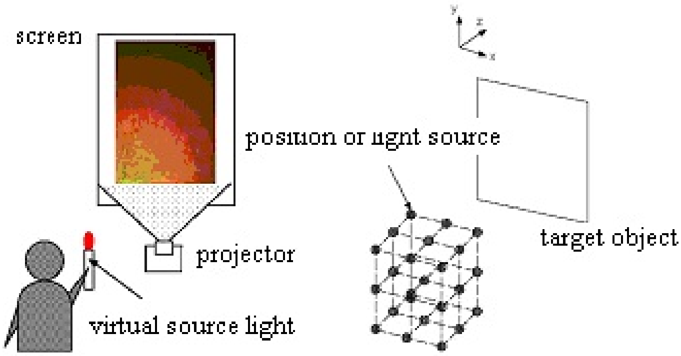
There are some relation researches, technique for projecting optical pattern to screen object, interaction concerning lighting and shadow was achieved by using absorbed screen (CABIN)[3]. Here, it pays attention to the reflection distribution of the source of light, neither a precise reflection model nor shape information in a real environment are used, the reflection distribution filter is generated from the reflection distribution image taken a picture. The reflection distribution filter is the one with the RGBA value (light source color and penetration level). A virtual effect of the lighting can be achieved by the alpha blending of restored wall painting and reflection distribution filter. When an actual object doesn't exist, the effect of the lighting can be achieved virtual by using this reflection distribution filter.

6.1 Generation of Reflection Distribution Filter

The reflection distribution filter is generated as follows.

1. The screen where the wall painting is projected to the position of the object body is set up. (Fig.12.(b)) The source of light uses the wax candle. Moreover, the moving range of the source of light assumes the cube as shown in Fig.12.(b). It takes an image of the screen that is a plane of projection, while changing the source of light position. (Fig.13.(a))
2. It regularizes it (takes to 0 from 1) based on the maximum value of the brightness of the obtained image. The penetration level (α value) is set based on the regularized image, and the reflection distribution filter is generated.

3. Using the generated reflection distribution filter (It has the RGBA value) and using the restored wall painting image (Fig.13.(b)), the image compositing is done by alpha blending. (Fig.13.(c))



(a) Outline (b) Taking a picture method

Fig. 12. Achievement of virtual source of light that uses reflection distribution filter

(a) (b) (c)

Fig. 13. Image compositing that uses reflection distribution filter

6.2 Interaction by The Virtual Source of Light

To change the optical image of the wall painting it is necessary to presume the position of a virtual source of light according to the position of the virtual source of light (i.e. penlight) that the user had. That is, the luminescence part of a virtual source of light is assumed to be a marker. It takes image of the marker with two cameras. The position of a virtual source of light is presumed by using the obtained stereo image. A synthetic image corresponding to the presumed position is displayed. Thus, when the position of taking a picture and the position of a virtual source of light are the same, a synthetic image is displayed as it is. When the position of a virtual source of light is different the weight putting is done to the image in neighborhood at the virtual source of light position and the image is generated. Fig.14. shows the result of doing the interaction by using a virtual source of light.

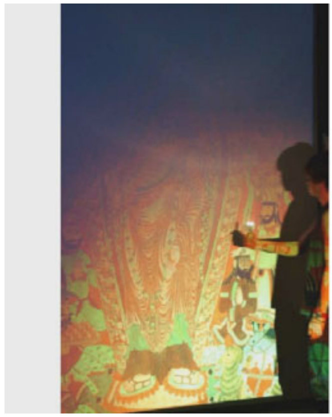


Fig. 14. Expression of wall painting that uses virtual source of light

7 Conclusion

In this paper presented here, we performed digital color restoration of Nishi Hongwanji's cultural properties using data stored in digital archives, such as pigment types, granule diameters, reflection spectra and multi-band photographic images. Using color-restored images thus obtained, we generated digital representations of *shouhekiga* in Tora-no-ma using the reflection model, taking into consideration pigment characteristics and gilded surfaces using the gold foil reflection model. Finally, we created a three-dimensional spatial representation. Second cases, we try to do VR reconstruction. For the restoration of the wall painting, the wall painting that lies scattered in all parts of the world is digitalized, a positional match is done, the lack area was analogized and the tone was corrected. Moreover, three dimension model is generated based on a open to the public drawing and local measurement data, and texture mapping did the wall painting restored to three dimension model. For expression of wall painting in addition, without assuming a complex reflection model, the effect of the lighting can be simply achieved by using the reflection distribution filter. Moreover, expressing the presence became possible through the interaction with the user. One wall painting image is projected in front of the user, and a virtual effect of the lighting has been achieved under the present situation.

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