

Realistic Representation by Digital Archives of the Nishi Hongwanji Temple

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ABSTRACT:

Nishi Hongwanji Temple holds a large collection from the Momoyama era, including paintings and artifacts as well as the Momoyama style architecture. To preserve these cultural properties we are investigating preservation, conservation and conservation documentation methods. Under the auspices of the Nishi Hongwanji digital archive project, pigment data and measuring data from digital images are gathered and a database is developed. In the present study, pigments on ‘shouhekiga,’ pictures on (room) partitions, or ‘ranma,’ Japanese traditional transoms, are analyzed, and 3D computer graphics are constructed using analysis data of pigments and gold foil. We analyzed the surfaces of ‘shouhekiga’ and ‘ranma’ from macro and micro views. In macro-viewing analysis, surface color-painted areas are identified by high-resolution digital images and multi-band IR (Infra Red) digital images. In micro-viewing analysis, the pigments were identified and its dimensions measured by X-ray fluorescence (XRF), reflectance spectra measuring and digital microscopic analysis. Using the above analysis results we tried to construct a virtual three-dimensional spatial representation of a room. The virtual room has macro and micro representation. In the macro representation, painted color has been reconstructed from the discolored pictures; in the micro representation, a realistic rendering is obtained through granularity and reflectance spectra of the pigments. Finally, by integrating these results, we were able to generate a three-dimensional representation of a room in Nishi Hongwanji Temple.

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. Iwanari [1], Hirose [2], Aii and others have established digital archives of cultural properties of Nishi Hongwanji—a highly challenging task, considering that the temple has a large number of gilded art objects which, in digital archiving, require reproduction of the reflective characteristics of gold foil discretely affixed to small complex surfaces.

In the study presented here, we analyzed traces of pigments found on Nishi Hongwanji’s *shouhekiga* (paintings on room partitions) in order to digitally restore their original colors and three-dimensionally express the fine surfaces of the paintings using a reflection model that considers the pigment reflective characteristics. Likewise, we digitally expressed finely gilded surfaces using a reflection model that considers the reflective characteristics of gold foil. Finally, by integrating these results, we were able to generate a 3D representation of a room in Nishi Hongwanji Temple.

2. Nishi Hongwanji Temple

Nishi Hongwanji Temple is located near Shichijo-Horikawa intersection in Kyoto, on a vast site of 36,000 *tsubo* (approx. 11,880 m²) bestowed by Hideyoshi Toyotomi in 1591. The temple complex contains numerous architectural masterpieces, including Karamon, Hiunkaku (both designated National

Treasures), Shoin and Mikagedo, as well as other cultural assets such as *shouhekiga* and *ranma* (see below for descriptions).

2.1. *Shouhekiga* in Tora-no-ma (“tiger room”)

Shouhekiga is a polychromatic picture painted on a room partition comprising a wood panel over which *washi* (Japanese paper) is spread. Pigments, *gofun* (whitewash) and *nikawa* (glue) are used for the painting. The *shouhekiga* in Tora-no-ma in Nishi Hongwanji, created during the Momoyama era (1568 - 1600) and officially titled *Chikurin Gunko-zu*, comprises a series of paintings depicting tigers in a bamboo grove, as the title indicates. Today, the partitions in Tora-no-ma are still in use, in the same manner as when they were first installed as an integral part of the room. However, the paintings have mostly become discolored, with pigments fading away, since no special measures have been taken for protection against sunlight and dust. In some parts of the paintings, the pigments have blackened due to resins applied for preservation, making it next to impossible to make out the details. Other areas, on the other hand, retain clear colors and contours, although the pigments have faded or discolored.

2.2. *Ranma* in Shiro Shoin (“white study room”)

Ranma refers to the space provided for lighting or ventilation between *shouhekiga* or sliding doors and the ceiling. The term also refers to a decorative openwork panel fitted into such a space. Nishi Hongwanji’s *ranma*, produced during the Momoyama era, have undergone repeated restorations. Pigments on the *ranma* have faded, as they have on the *shouhekiga* in Tora-no-ma. Subject to little chemical change,

the gold foil spread on the *ranma* retains its brilliance, though it has diminished somewhat, owing to accumulations of dust and dirt over the years.



Fig1. *Ranma* in Shiro Shoin, Nishi Hongwanji Temple

2.3. Nishi Hongwanji Digital Archives

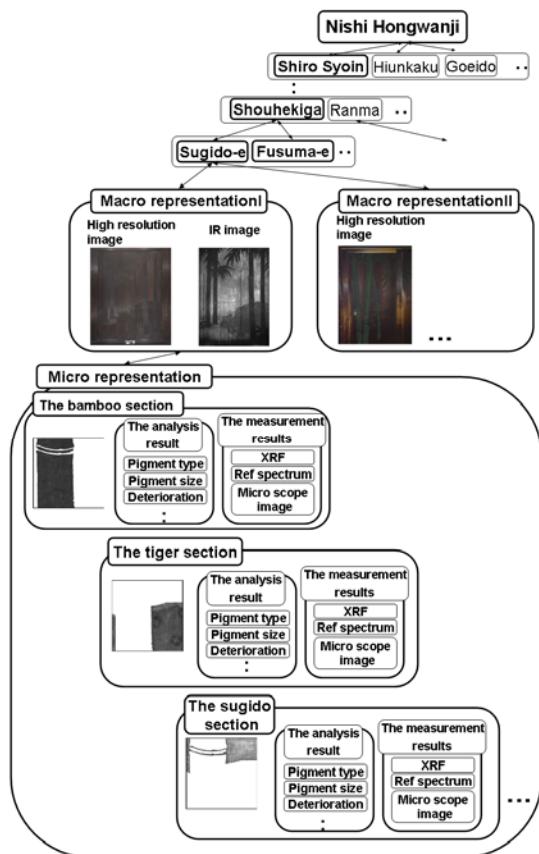


Fig2. Nishi Hongwanji Digital Archives structure

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 below—has been developed for Nishi Hongwanji Digital Archives, to take into account the factors affecting the conditions of the respective paintings.

3. Color Restoration

3.1. 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 Fig3. and Table 1).



Fig3. *Iwa enogu* numbers and gradations

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

Hirose *et al.* attempted to identify the types and characteristics of pigments used in the paintings, on the basis of the following three measurements:

- 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* (ocher) is used in the tiger sections.

3.2. Color restoration by Color Transfer

Using the results of *shouhekiga* analysis by Hirose *et al.*, we attempted to restore the colors of Tora-no-ma in Nishi Hongwanji. For color restoration, we employed the technology called Color Transfer [3], which involves coloring black-and-white or dynamic images on the basis of reference images.

As base images on which to restore colors, Hirose *et al.* used infrared photographic images, which clearly show contours not easily visible to the naked eye. We did the same in our study.

Infrared photographic images are extremely highly defined, comprising 12,000 vertical pixels and 10,000 horizontal pixels. On these images, we demarcated the paintings as bamboo, tiger, tiger contour and ground sections. Based on the measurement results, we composed palettes of colors as described below, including *rokusho* No. 8 for the bamboo sections, *oudo* for the tiger sections and wood panel color for the ground sections.

Using these palettes, we undertook to color the *shouhekiga* base images in the following steps:

① Demarcate sections.

We demarcated sections of digitalized *shouhekiga* images.

② Draw up a histogram of hues.

We prepared a histogram of hues of the infrared photographic images, demarcated into sections.

③ Select pigments from the pigment database.

From the pigment database, we selected the color images of pigments used in each of the sections demarcated in Step 1.

④ Draw up a histogram of hues.

We converted into scales the color images of pigments selected in Step 3 to prepare grayscale images, based on which a histogram of hues was drawn up. In this process, the values of hues were matched to color data.

⑤ Match the histograms.

The histograms of hues based on the infrared photographic images and on the pigment images can peak at different values, because normal pigments and discolored pigments are being compared. In this study, therefore, the pigment histogram was divided into ranges larger or smaller than the peak value, to which discolored pigment histogram ranges larger or smaller than the peak value were then matched respectively.

⑥ Prepare pallets of colors.

We prepared pallets of colors based on the color data that were matched with the values of pigment hues in Step 5.

⑦ Apply colors to the sections.

We applied colors to each of the sections demarcated in Step 1, using a corresponding pallet of colors.

⑧ Unite the sections.

The demarcated sections were united at the end.

3.3. Color restoration: results and observations

Colors restored in the bamboo and ground sections appeared more realistic because of the large numbers of colors on the corresponding pallets. On the other hand, color restoration in the tiger sections turned out monochromatic, due to the small number of colors on the pallet. Fig4. shows an example of integrated color-restored sections.

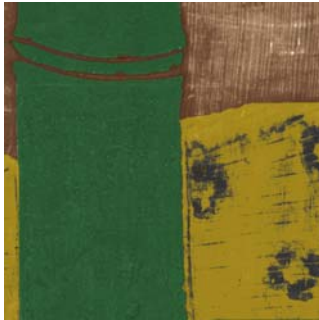


Fig4. Color restoration by Color Transfer

4. Reflection Models

4.1. Pigment reflection model

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)).

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

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

where 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



Fig5. Representation of *shouhekiga* using pigment reflection model

4.2. 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 [4] 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:

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

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

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).

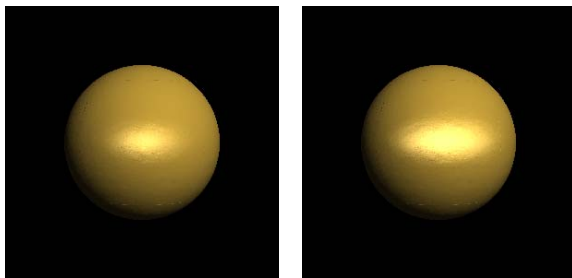
Since the minute surfaces of *shouhekiga* and *ranma* are uneven, the mutual interference of microfacets must also be taken into consideration. This can be expressed by the following formulas:

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

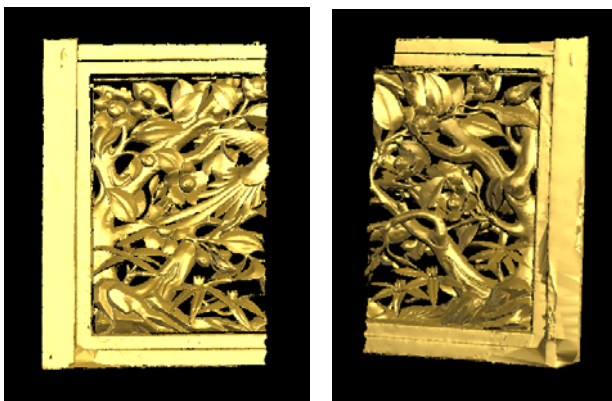
$$G_{in}(n, k_2, h, k_1) = 2 \frac{(n, h)(n, k_1)}{(k_2, h)} \quad (5)$$

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

The Figure compares representations obtained using the Ashikhmin model and our gold foil reflection model. *Ranma* portion representations [5] 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.



(a) Ashikhmin model (b) Proposed reflection model
Fig6. Existing and proposed models compared



(a) Part of *ranma* (front) (b) Part of *ranma* (back)
Fig7. Representation of *ranma* using gold foil reflection model

5. Three-Dimensional Spatial Representation of Nishi Hongwanji

5.1. Generation of a three-dimensional spatial image

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.

5.2. Three-dimensional spatial representation: experiment and results

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.



Fig8. Three-dimensional spatial representation of Tora-no-ma

6. Conclusion

In the study 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 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.

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*.

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