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Restoration of Color in Noh Masks Based on Retinex Algorithm

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Abstract
Noh is a famous traditional Japanese dramatic art. The restoration of ancient Noh masks is an important aspect of the preservation of cultural heritage. In this paper, we developed a technique based on Retinex algorithm and it can be applied to restore the color of 3D objects such as the Noh mask. The Retinex algorithm simulates the ability of human eye and can adjust the color of the 2D image. To apply the Retinex algorithm on the 3D surface, the shape of the object is taken into account. The original color of the target points can be got by reference to the color of the surrounding points sampled according to a uniform route. The effectiveness of this technique is demonstrated by the implementation results. This technique can be used to infer the color of other 3D objects also.

Categories and Subject Descriptors (according to ACM CCS): I.3.7 [Computer Graphics]: Color, shading, shadowing, and texture

1. Introduction

Objects of cultural assets which are exposed to the natural environment can undergo changes in appearance. The original colors may fade and some parts of the object may be lost. For this reason, much research has been undertaken into the preservation and restoration of cultural assets. Various digital restoration techniques have been developed for preservation and exhibition of cultural assets. In this paper, we introduce a technique for color restoration in Noh masks.

Noh is a famous Japanese traditional drama in which the faces of the players are covered with masks. One Noh mask is shown in the Figure 1. Noh masks are vulnerable to environmental weathering which can result in fading and loss of the surface pigments. The restoration of color in Noh masks is a challenging area of research.

Figure 1: *The photo of Noh mask.*

2. Previous Work

Long ago, the restoration of cultural objects was based on the rich knowledge and experience of craftsmen. More recently, digital techniques using image processing software have been developed, but like the craftsman of former times, the operator applies his or her knowledge and experience in restoring the color of the object. One example of this type of technique is [CN02], by which the color of an ancient drawing was restored perfectly. In addition, some color restoration techniques based on computer graphics (CG), such as [YT04], have been developed. In this technique, the three-dimensional (3D) shape of the object is measured by a machine. Next, the artist draws pictures based on the historical record, which are mapped onto the surface of the 3D model by computer. The color of an ancient statue was reproduced using this technique. This technique allows manual adjustment of detail based on the experience of the artist. But these techniques pain the color on the surface of object and lost some real information of color on the surface.

Automatic or semi-automatic color restoration techniques have also been developed. [SBJ05] used a technique which makes use of color information remaining on the object. A color that is lost may be reproduced by reference to the color information surrounding the missing section. [LLP00] developed a system for restoring the color base on the experience of the exporters. [BBC00] introduce some digital techniques which can clean the surface and repair the crack pattern on the objects. And [DC05] developed an algorithm, based on the ability of human eyes to adjust to environmental lighting conditions, for removing the influence of dirt on computer simulations of ancient drawings. This technique has mainly been used in the color restoration of oil paintings. These techniques mainly restore the color on 2D images. We propose a technique for restoring the color on 3D objects in this paper.

Usually, for restoring the color in the culture assets, the investigation of the pigment on the surface and segmenting the pigment field is needed. But there are some problems are not solved well. The same pigment can show different color if the pain method is different. So it is very difficult to understand original color in the culture assets even we know what pigment is used. By other hand, segmenting the pigment field well is not easy. The segment technique is developing now. To avoid these problems, we develop a technique to restore the color based on the information of the pigment on the surface directly. The color variation process is different. The craftsmen always restore the color by reference the color where is look new on the surface. This means that the different color on the surface implies the some rules of color variation process. If using the different color information on the surface well, the original color can be restored. The technique represented in this paper needs not segmenting the color field. The color of the target points is updated by the color of the surrounding sample points. Shown as Figur 2, The first step was measurement of the mesh and the color of the Noh mask. Next, we sample the variation in color over the 3D surface based on the surface normal variation and the color of the Noh mask was restored based on the Retinex (come for the retina and cortex) algorithm. Finally we show some implementation results and discuss this technique.

3. Background Knowledge on Noh masks

Noh masks are made from wood on which a design is pained([Iha02]). In creating a Noh mask, the first step is to carve and polish the wood to provide detail, so that a shape similar to that of the human face is obtained. Next, pigments are painted onto the wooden mask. As shown in Figure 3, the Noh mask has two surfaces, the back and the front. The back

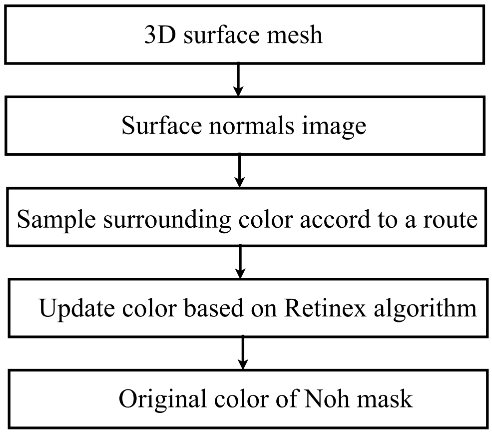
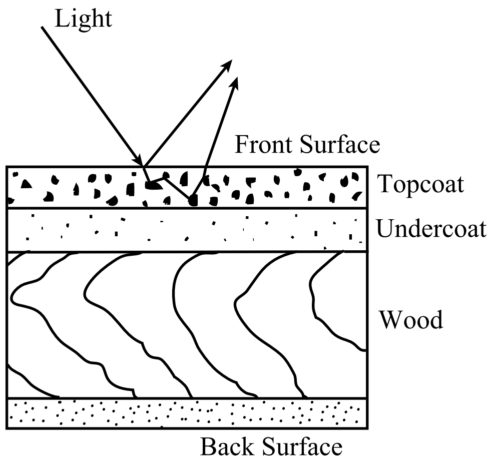


Figure 2: *Compute processing.*

surface is nearest to the face of the player, and is painted uniformly because it cannot be seen. The front surface is painted with various types of pigments. There are two types of coating: the undercoat and the topcoat. The undercoat is painted in a uniform color and represents the color of the skin. The topcoat is painted in different colors to show the hair, eyes, mouth and so on. Finally, certain other pigments are applied to the surface so that the Noh mask can be seen well on the stage.



There are two pigment coats on the front surface and one pigment coat on the back surface.

Figure 3: *Pigment of Noh mask.*

A glue is used to cause the pigments to adhere to the wood. Light passes through the glue and is reflected outward by pigment particles. When the glue deteriorates, some of the pigment particles are lost, with the result that the formerly smooth surface of the mask becomes rough and decreases in brightness. If the deterioration extends deep into the mask, some areas of pigment are lost completely, and the color of the mask cannot be seen. Since the pigment particles are mixed slowly, the color on surface look darker. One subject of restoring the color is to take off this dark efficiency.

4. Restoration of Color

The techniques used in ancient times for fashioning and painting Noh masks are not well understood. In addition, the variation of pigments is a complex process. For these reasons, it is very difficult to restore color completely. The key idea for restoring the color in this paper come from the [DC05] which use Retinex algorithm ([LM71]) to restore the color on 2D image. To update the color of a target point, the Retinex algorithm uses the color information found in the vicinity of the point. The influence of one pixel on another varies according to the distance between them. Similar to the Retinex algorithm, we also use the color information found in the vicinity. Then compute the color based on this information. The detail will be introduced in this section.

4.1. Measure the the Color and 3D Mesh

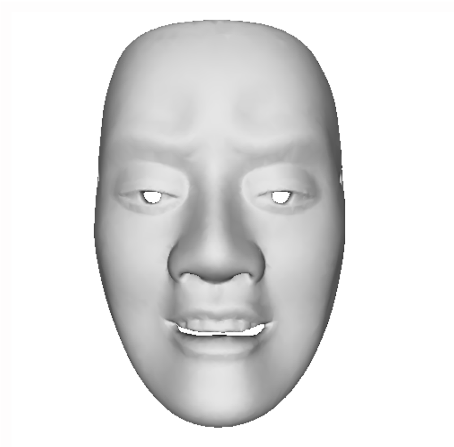
Because the Noh mask is a 3D object, the normal of the 3D object can cause variations when the color of the mask is measured. The same color may show a different value if the view point is different. For example, there are some highlight and shadow when take photo of a mask shown as Figure 1. To avoid this highlight effect, the mask is put into a white dome. In this white dome, the light is diffused and there is not highlight on the mask when take the mask photo. Use this method, we can get the initial color image of Noh mask without highlight.

The 3D surface data were obtained using a 3D object measurement machine (Vivid 910). Using exist software to compose these data together, the 3D mesh surface shown as Figure 4 is got. The 3D mesh will be used to get the image which show the normal of the surface and the image which show the vector from surface to camera. These image is useful to decide the sample position when renew the color on the surface late.

Since the mesh is 3D and the color image is 2D, the registration process between the 3D mesh and the 2D image is necessary. Three reference points are used. Two points are the center of the eyes. One point is the center of the mouth. Then the 3D mesh is rotated and scaled until these three points are match each other. After this process, the mesh is look from same viewpoint with the 2D photo of the Noh mask.

4.2. Sample on 3D Surface

As mentioned before, when update a point (called target point) color, the surrounding point (called sample point) color information is reference. To get uniform samples, a sample route shown in Figure 5 is used. The color of point A is updated based on the colors of the surrounding points (circle points). [YS05] has introduced the concept of aesthetic curves. We assume that these curves are beautiful because color information obtained as along with these curves are uniform. To decrease the compute cost, the expression of the curves is simplify and is represented in polar coordinates as follow:



This surface model is constructed from about 20 different patches and compose with 20,000 triangles.

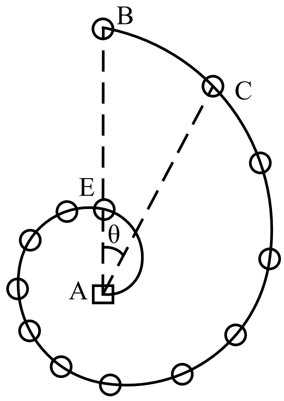
Figure 4: *3D mesh of Noh mask.*

$$\begin{cases} R_2 = a \cdot R_1 \\ \theta = b \end{cases} . \quad (1)$$

Where R is the length between the point A and sample points. For example, R_1 is the length of AB and the R_2 is the length of AC. Shown as Figure 5, θ is the variation in angle. a and b are constants. In this paper, a is 0.9 and b is $\pi/6$. The surrounding points (circle points) are distributed according to this curve, and the color of point A is calculated from te color of the surrounding points (B, C etc.).

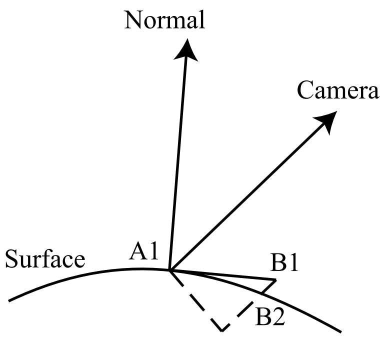
But the surface of the object is 3D. It is necessary to adjust the sample method on the surface according to the normal of the surface. Shown as in Figure 6, A1 is the point which needs updating the color. B1 is the sample point which is compute by the exoression (1). B2 is the projection of B1 on the surface according to the vector to the camera. As the result, the sample point on the 3D surface is the B2. For decide this new position, there are parameters connect to the shape of object are used. One is the normal of surface which can be used to compute position of B1. Another is the vector from surface to the camera and is used to decide the position of B2.

For generating the route, the normal information and the vector to the camera information is draw into the normals



The color of target point (point A) is updated by the color of surrounding sample points (point B etc.) according to this uniform route.

Figure 5: *The sample route.*



The sample position is adjusted from B1 to B2 parallel with the vector of camera.

Figure 6: *Adjustment of the sample route.*

image and the camera-vector image shown as Figure 7. The values of the RGB color show the xyz values of the vectors. By this translation, the 3D problem is translated to the 2D problem. As the result, the process of restoring the color becomes simple. The sample route can be adjusted from these vector images.In the normals image, three states of the route on the different position of the surface are shown. Then according to these routes, the color of the target points is updated.

4.3. Update the Color

This color updating is calculated in the logarithmic field using the LMS color system. RGB color values are converted into LMS values in the logarithmic field, and the color of each point is then updated along the new route. Finally, the LMS color values in the logarithmic are converted back to the RGB system. The discussion at next is in the LMS color system.

The speed of the pigment variation on surface is different,so these different information can be used to restore the original color of the mask. Usually, the process of the pigment variation is similar on the different superficial position. If the position is near, the pigment variation is more similar. As this reason, when update the color of a target point. The color of the sample points along with the route will give some contribution to the color of the target point. The near points give more contribution. Based on this idea, the next expression is constructed:

$$NP = OP + \sum_{i=1}^{N} ((OP_i' - OP)/(k^{(N-i+1)})) \ . \qquad (2)$$

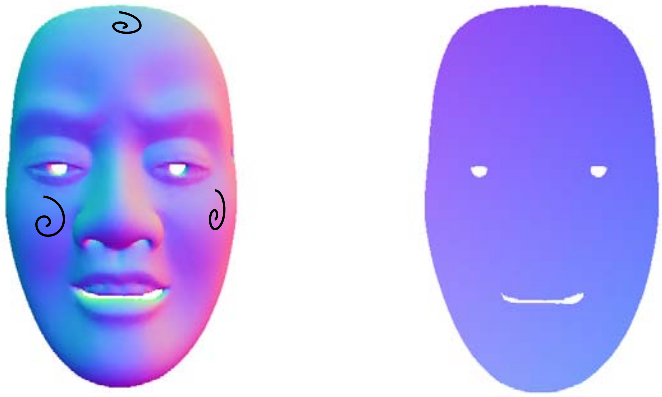
Here, NP is the new color of the target point; OP is the old color of the target point; OP_i' is the old color of the sample points (points B and C in Figure 5). i is the index of the sample points along with the sample route. N is the total number of the sample points and is 12 in this paper. If the index i is small, the distance between the sample point and the target point is large. k is a constant and is the parameter that control the amount of influence one point has on another. In this paper, k is 2.0. This update process is done by some times. If the same pigment shows the same color, it is mean that the original color is got and the compute process is finished.

Despite the pigment variation process is not understood well, the difference of the color on surface can help us to know something about the pigment variation. The compute process that mentioned above can infer the original color of the pigment automatically.

5. Implementation and Discussion

Implementation is carried out using two Noh masks. One was made in about thirty years ago. The other mask is famous one that was made in about three hundreds years ago. Shown as in Figure 8, the current mask (top left image) color is a little dark. After the cleaning process, the color becomes new and is bright (top right image). This mask is made in thirty years ago. The maker of the mask says that the color is similar to the original one in his memory. Another mask was made about three hundreds years ago and nobody know the original color. At this case, the photo is projected to a column surface and a 2D texture is got. The sample algorithm and cleaning process is same as above. And then the result texture is mapped back on the 3D mesh surface. The color of the accient Noh mask before restoration (bottom left image) is dark. After the restoration process (bottom right image), all of the color is bright and look like a new one. Especially, the color of the skin and the red color of the lip is look well.

The Retinex algoritm can decrease the same color component such as light effect.The dirty on surface is a same color componet also, so the Retinex algorithm is successful to remove the uniform dirty effect on the surface. In future, it is



The value of RGB color represent the value of xyz of the surface normal (left image) and the camera vector (right image).These two image is used to adjust the sample route on the 3D surface.The black curves in normal image show the route adjusted.

Figure 7: *Normal image and camera-vetor image.*

need to evaluate the result by scientific method. The technique in this paper is a digital technique to restore the color of the Noh mask. It is not consider the weathering process of the pigments of the Noh mask. And because the classes of the ancient Noh pigments is different from that used today, It is need to investigate the weathering of these classes pigments in future. In some cases, the pigment of Noh mask is lost. The technique presented in this paper can not restore the original color of Noh mask in this case. So it is need to analysis the original pigment types and restore it by developing a new technique. This technique need not segment the pigment field and can be applied on the 3D object easily. These are the main advantages of this technique.

6. Summary

In this paper, we describe the color restoration of a Noh mask by use of a sample route which takes into account the 3D shape of the object. The effectiveness of this technique is demonstrated by the results obtained. The technique can also be used to restore color in other 3D objects. To further develop this work, we intend to calculate the influence of weathering on the pigment colors in order to obtain a better result. We will also attempt to develop a new rendering technique which takes into account the pigment microstructure of the Noh mask.

Acknowledgments

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