浮世絵レンダリングのための和紙繊維モデル構築

尹 新　　赤間 亮　　田中 弘美
立命館大学

浮世絵などの文化財は様々な自然要因を受け，劣化していく．このため，文化財をディジタル化し，コンピュータで半永久的に保存する研究は活発的に行っている．本研究では，バーチャルの浮世絵を表現するために，和紙の繊維モデルの構築手法を提案する．まず，光学異方性測定装置を用いて，入射光の方向を変え，浮世絵の写真を撮る．次に，それらの写真から浮世絵の各ピクセルの双方向反射分布関数BRDFから色の変化を解析し，和紙の繊維方向を抽出する．最後に構築した繊維モデルに基づいて，浮世絵のレンダリング例で本手法の有効性を示す．

Constructing the Fiber Model of Japanese Paper for Rendering Ukiyo-e

Xin Yin　　Ryo Akama　　Hiromi T.Tanaka

Ritsumeikan University

The cultural asset exposed in elements change in appearance. As this reason, some studies are done to make digital cultural asset and store them for long time. In this study, we proposed a technique to construct the fiber model for rendering the virtual Ukiyo-e. At first, change the direction of lighting and the photos of Ukiyo-e are taken. Then, the bidirectional reflectance distribution function (BRDF) of each pixel on the Ukiyo-e is obtained from these photos. Next, analysis theses BRDFs and the direction of fiber in Japanese paper can be extracted. Finally, some rendering results based on this fiber model are given to demonstrate the effect of our technique.

1. Introduction

The origin of the Ukiyo-e is describing the life of Kyoto in 16 century. After that, the techniques of making Ukiyo-e were developed and a lot of works were made. To make a work, the drawer, the engraver, and the printer need collaborating together. At first, the drawer draws the picture. Then the engraver makes the woodcut based on the picture. Finally, the printer put the pigment on the woodcut and the Ukiyo-e is print out.

For getting special effect, some techniques were developed. The technique of the Karazuri and the Kirazuri are introduced here. The Karazuri do not use any pigment and put the woodblock on the paper strongly, then the bump pattern are made. The Kirazuri use the mica and gold to represent the background of the Ukiyo-e. Shown as Figure 1, the pattern of the flower is made by the technique of the Karazuri and the background of the woman is made by the technique of Kirazuri. As the result of these print techniques, the color of the Ukiyo-e varies according to the position of the light source and the viewpoint.

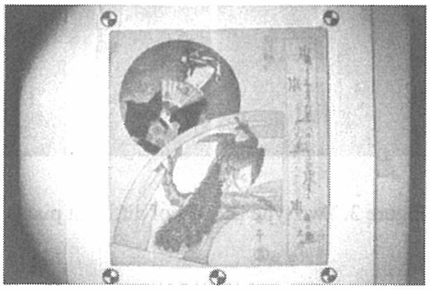

Figure 1. The photo of Ukiyo-e

Another special effect comes from the fiber in Japanese paper. The length of the fiber in the Japanese paper for Ukiyo-e is 7-8 times of that in general paper. Figure 2 show the photomicrographs of the Ukiyo-e surface. The fiber can be seen clearly in this photo. Even in the part where look like fill with the particles of pigment, the shape of the fibers can be seen clearly. Because the reflection of the fibers is anisotropic, we need designing an anisotropic rendering model to represent the effect of the fiber.

The drawing such as the paining and the watercolor show a beautiful appearance. To represent the effect of drawing, some rendering techniques such as the NPR (Non-Photorealistic Rendering) were developed in last two decades. These studies

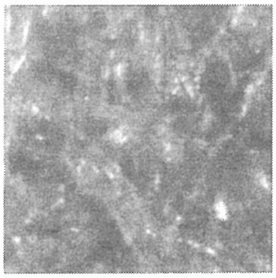

Figure 2. Photomicrographs of the Ukiyo-e

mainly focused on simulating the pen stroke and the distribution of pigment on the surface of paper. On another hand, the scattering of light is important to represent the appearance of the drawing also. The particle of pigment and the fiber in paper can affect the scattering of light and make a special effect on the surface of drawing. In this paper, we measured the appearance of one type ancient Japanese drawing named Ukiyo-e, and observed the isotropic reflection come from the pigment particle and the anisotropic reflection come from the fiber of Japanese paper. Based on this observed result, we proposed a rendering technique which can represent these two type reflection and can render the appearance of the Ukiyo-e on real-time.

As mentioned above, the NPR techniques mainly represent the effect of drawing such as painting, sculpture, block print, dyeing etc.. The effect of drawing can be made directly by simulating the pen stroke ([1], [2]). Processing the 2D photos or the 3D geometric model is other method to generate the effect of drawing ([3], [4]). These NPR techniques mainly simulate distribution of the pigment and represent the isotropic reflection of the pigment. Some works have been done to present the effect of the Ukiyo-e also. Processing 2D photos ([5]) or simulating the Ukiyo-e make process ([6]) can make the Ukiyo-e in virtual world. These works focus on simulating the isotropic color of the Ukiyo-e and doesn't simulate the light scattering on the Ukiyo-e. To our knowledge, we are the first time to simulate the light scattering properties of the Ukiyo-e.

The main idea of our work comes from [7] and [8]. The [7] computes the normal on the surface of the isotropic reflection materials. The [8] mainly compute the fiber direction in the wood and render the effect of the fiber. The fibers in the Japanese paper are more complex than the case of the wood. The direction of the fibers is near a random distribution. The appearance of the Ukiyo-e blends two effects, one is the isotropic reflection come from the pigment, and another is the anisotropic reflection come from the fiber in Japanese paper. Different to the [7] and [8], we blend these two reflection together, and fit these two reflect models to the measured data. Because we combine two different rendering models together, the errors between the model and the measured data are decreased and high quality rendering result can be obtained.

2. Measurement of Ukiyo-e

We use a system named OGM (Optical Gyro Measuring Machine) to take photos of Ukiyo-e. OGM is 4 axes measuring machine which can put the light source and the camera on any position of a hemisphere dome. For measuring the color variation on Ukiyo-e, the camera is fixed on the position perpendicular to the surface of Ukiyo-e. The position of light source is changed. The record of the position in computer is a 2D array. For correspondent the 2D array and the position of lighting source on the hemisphere dome, a uniform concentric map ([9]) is used to set the position of light source. We use a 35 by 35 grids to set the position of light. To avoid the light source behind the arm of camera, the object stage is turned 180 degrees. Some marks are set around the Ukiyo-e to calibrate the position of the pixel of the image of Ukiyo-e. To calibrate the light distribution on the surface, the photos of a white paper are taken also. The technique of [7] is used to calibrate image. After calibrate the color and the pixel position, the BRDFs of each pixel can be computed.

Figure 3 show the two type BRDFs. In the field where is paper, a strong anisotropic reflection phenomenon can be observed. The highlight distribute along a line. In the field where is pigment, the anisotropic reflection become weak. The highlight centralizes a point. These mean that we need to construct two rendering models and combine them

Figure 3. Two type BRDFs of different pixels

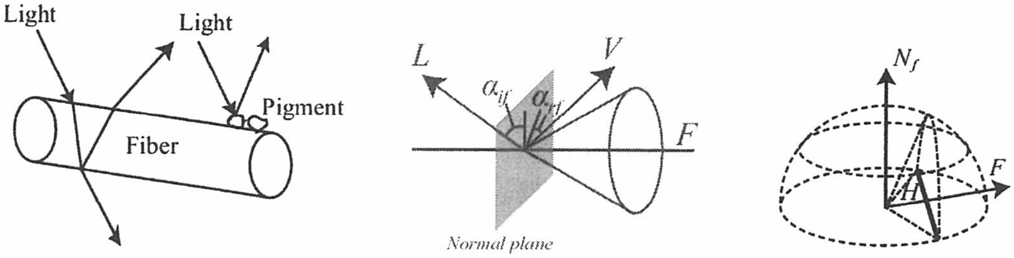

Figure 4. Two type rendering models

together to render the appearance of Ukiyo-e.

3. Rendering model

From the measurement result, two type reflection phenomena are observed. One is isotropic reflection come from the pigment, and another is anisotropic reflection come from the fiber in Japanese paper. Modeling these two type phenomenon and fit it to the measured data will introduced in this section.

3.1 Two type models

From the photomicrographs of Ukiyo-e, the distribution of the pigment and the fiber can be observed clearly. Shown as Figure 4 (a), the shape of fiber is approximated as a cylinder. If the light that refract from air to fiber and back to air, the inclination will maintain same. As the result, the light enters the fiber as a line and become a cone surface when it leaves the fiber. The axis of the cone is the direction of the fiber. If part of the paper surface is cove by some particles of pigment, the light will be reflected to air by the pigment directly. At this time, the light leave the surface of object is a line. Use α represent the angle between the surface normal N_p and viewpoint vector V, then the effect of pigment I_p can be expressed by next expression.

$$I_p = I_{dp} + k_{sp} \bullet g(\delta, \alpha_{hp}) / \cos^2(\alpha_{rp})$$

Here, I_{dp} is the diffusion reflection and k_{sp} is specular reflectance. $g(\sigma,\ \alpha_{hf})$ is a normalized Gaussian with zero mean and standard deviation. This model can be used to represent the effect of pigment on the surface of Ukiyo-e.

Similar to the rendering model of the pigment, we can construct the reflection model of the fiber. Shown as Figure 4 (b), the blue plane is the normal plane Γ perpendicular to the fiber direction F. The angle between the light vector L and the normal plane Γ is α_{if}. The angle between the viewpoint vector V and the normal plane Γ is α_{rf}. If the viewpoint is near the surface of the cone, the reflection light is strong. If viewpoint is far from the surface of the cone, the reflection light is weak. So we can construct the reflection model of the fiber by developing the traditional reflection model such as Torrance-Sparrow model. The main difference between the fiber reflection model and the traditional reflection model is using the cone replace the vector of regular reflection. The effect of the fiber I_f can be represent by next expression.

$$I_f = I_{df} + k_{sf} \bullet g(\delta, \alpha_{hf}) / \cos^2(\alpha_{rf})$$

Here, I_{df} is the diffusion reflection of fiber. k_{sf} is the specular reflectance of fiber. $g(\sigma,\ \alpha_{hf})$ is the normalized Gaussian same as the above. α_{hf} is the halfangle between the normal plane Γ and the viewpoint vector V. Then combine these two type effects of pigment and fiber, we can get final color of Ukiyo-e as follow.

$$I = I_{dp} \bullet \beta + I_{df} \bullet (1-\beta)$$

This expression means that the final appearance of the Ukiyo-e is the linear interpolation of the effect of pigment and the effect of fiber. The next work is fitting this rendering model to the measured data and decides the parameters of this model on each pixels of the image.

3.2 Computing the geometry parameter

The Ukiyo-e is near to a plane. The geometry parameters in here are the normal of micro geometric surface and the direction of fiber. Even the micro geometric surface can be obtained by integration from the normal, but we need not constructing the micro geometric surface. Using the information of the normal and the direction of fiber, we can render the appearance of Ukiyo-e well.

The common of two type rendering model is the normal N in the middle of the strongest reflection R and the light vector L. The difference between these two cases is that the normal of the fiber is a normal plane perpendicular to the fiber direction. As this reason, we can get the normal by computing the strongest reflection direction. As enough density data are captured by the OGM, it is ease to find the strongest reflection direction R. Then the normal can be computed by $N=(L+R)/2$. The left figure in Figure 5 shows the image of the surface normal. The values of RGB represent the XYZ values of normal N. The bump image can be seen from this image. (For printing it clearly, the contrast is enlarged.)

The direction of the fiber F is the axis of the cone on which the highlight can be seen. As the result, the highlight of fiber reflection is a line on the hemisphere. Figure 4 (c) shows the relationship of the Normal N_f, highlight line H and the fiber direction F. The F is perpendicular to the plane which is parallel to the N and the H. The H can be obtained by computing the line of the highlight (H) using least squares method. Then the direction of the fiber can be got by $F=N\times H$. The right figure in Figure 5 shows the image of the fiber direction. The values of RGB represent the XYZ value of the fiber direction F. Now we know the normal N and direction of fiber F. Fitting parameters of the model to the measured data will be introduced next.

3.3 Fitting the data

Fitting the model to the measured data is a nonlinear optimization problem. This problem is to find parameters which can let the value of ρ in next express is minimal.

$$\rho = \sum (I - M_{uv})$$

Here, I is the theory value of the rendering model introduced above. M_{uv} is the measured BDRF data by the OGM. u and v are the coordinates of the measured BRDF image. For get the correct parameters of the rendering model, the good initial estimate is important. The initial diffusion value is using the mean value of the color. The initial parameter of Gaussian is computed from measured data directly. The initial β is 0.5. Then the parameters can be got by the steepest descent method. Now, we have all the value of parameters of the rendering model. These values are stored as the texture. Using these textures, the appearance of the Ukiyo-e can be rendered.

4. Results

The Experiment is carried out based on the GPU (Graphics Processing Unit) and can render the Ukiyo-e on real time. The graph card is NVIDIA GeForce 6800 GS. And, this Experiment is carried out using an Ukiyo-e which was made in hundreds years ago.

We compare the case with the fiber effect and without fiber effect also. Shown as Figure 6, the left one is the rendering result only using the normal of surface. The result looks like the plastic more than the paper. The right one is the rendering result using the normal of surface and the direction of fiber together. There are some natural noise on the center of the image and the image become bright. The edge of the Karazuri becomes soft according to the effecting of the fiber in the paper and looks more like the paper than the plastic.

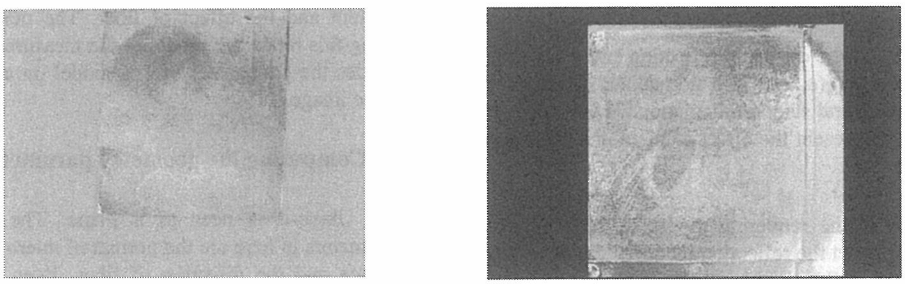

Figure 5. Normal image and fiber direction image.

The image shown in Figure 7 is the rendering result using the rendering model proposed in this paper. When the viewpoint is changed, the color of the surface is different also. The bump pattern of flower and snow made by Karazuri and the effect of the golden particle are visible and invisible according to the position of light source. This result is similar to the phenomenon that occurs on the real Ukiyo-e.

All parameters of the model is stored by the texture, the size is about 1/100 of the original BRDFs data. Using the GPU rendering technique, the rendering can carried out at a speed of real-time. Because our method is based real measured data, we can get rendering result with high reality.

5. Conclusion

In this paper, a technique for rendering of ancient Japanese drawing named Ukiyo-e is proposed. It is first time to measure the reflection property of the Ukiyo-e materials and rendering the appearance of it consider of the fiber effect in the Japanese paper. Our method can fit real data well because the isotropic reflection and anisotropic reflection is combined together. This technique can also be used for rendering other similar objects such as the cloth. In the future, new techniques for modeling the detail of the fiber in the Japanese paper from images need to be developed. We also plan to develop a VR system which permit person watch the Ukiyo-e in hand and can feel the touch feeling of the Ukiyo-e at same time.

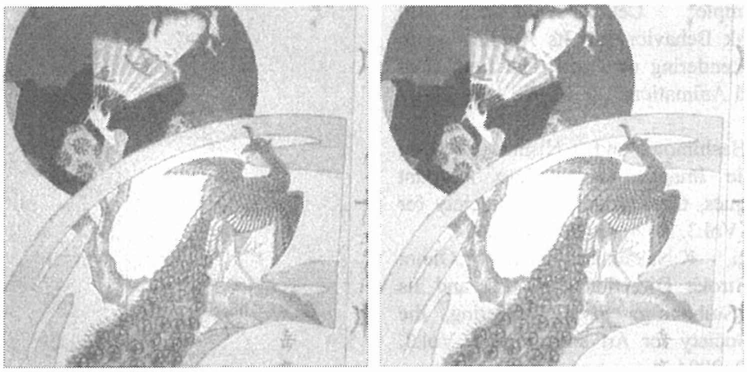

Figure 6. Rendering results with and without fiber reflection effect.

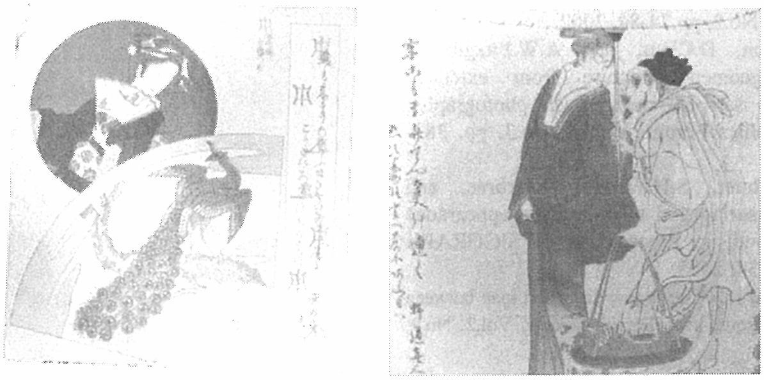

Figure 7. Experimental results

Acknowledgments

This work was supported partly by the Grants-in-Aid for Scientific "Research Scientific Research(A) 17200013" and "Encouragement of Young Scientists(B) 19700104" of Japan Society for the Promotion of Science. This work was also supported partly by "Kyoto Art Entertainment Innovation Research" of Centre of Excellence Program for the 21st Century of Japan Society for the Promotion of Science.

References

[1] M.P.Salisbury, M.T.Wong, J.F.Hughes, and D.H.Salesin: Orientable Textures for Image-Based Pen-and-Ink Illustration, in Proceedings of SIGGRAPH 1997, pp. 401-406, 1997.

[2] Q.Zhang, Y.Sato, J.Takahashi, K.Muraoka, and N.Chiba: Simple Cellular-Automaton-based Simulation of Ink Behavior and Its Application to Suibokuga-like Rendering of Trees, The Journal of Visualization and Animation, Vol.10, No.1, pp.27-37, 1999.

[3] H.Johan, R.Hashimoto, and T.Nishita: Creating Watercolor Style Images Taking into Account Painting Techniques, the Journal of the Society for Art and Science, Vol.3, No.4, pp.207-215, 2004.

[4] K.Kawasaki, K.Nakamaru, and Y.Ohno: Generation of Stroke Direction for NPR and Its Application to Suiboku-ga Style Rendering, the Journal of the Society for Art and Science, Vol.3, No.4, pp.235-243, 2004.

[5] T.Okamoto: http://www.tatuharu.com/. 2007.

[6] M.Okada, S.Mizuno, and J.Toriwaki: Virtual Sculpting and Virtual Woodblock Printing by Model-Driven Scheme, the Journal of the Society for Art and Science, Vol.1, No.2, pp.74-84, 2002.

[7] J.A.Paterson, D.Claus, and A.W.Fitzgibbon: BRDF and geometry capture from extended inhomogeneous samples using flash photography, Computer Graphics Forum, Vol.24, No.3, pp. 383-391, 2005.

[8] S.R.Marschner, S.H.Westin, A.Arbree, and J.T.Moon: Measuring and modeling the appearance of finished wood, in Proceedings of SIGGRAPH 2005, pp. 727-734, 2005.

[9] P. Shirley, and K. Chiu: A low distortion map between disk and square, Journal of Graphics Tools, Vol.2, No.3, pp.45-52, 1997.