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Representing Appearance of Ancient Japanese Drawing Named Ukiyo-e

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Abstract

Ukiyo-e is one traditional woodblock type Japanese drawing. Since it is made by special print technique and using Japanese paper which have very long fiber, Ukiyo-e show a beautiful appearance. In ancient age, the peerage gathered together for watching the appearance of this drawing. In this paper, the color variation of Ukiyo-e is investigated and is represented using a shading model which consider the reflection of the Japanese paper fiber. At first, a set of photos are taken. Then, from these photos, the normal of surface and fiber direction are obtained. Fitting the shading model parameters with the measured data, the appearance of Ukiyo-e can be rendered on a real-time speed. Finally, some experimental results are given to demonstrate the effect of our method.

Categories and Subject Descriptors (according to ACM CCS): I.3.3 [Computer Graphics]: Viewing algorithms

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 postion of the light source and the viewpoint.

Another special effect come from the fiber in Japanese paper. The length of the fiber in the Japanese paper for Ukiyo-e is 6.0-15.0 mm and 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 a anisotropic shading model to represent the effect of the fiber.

Figure 1: *The photos of Ukiyo-e.*

The drawing such as the paining and the watercolor show a beatiful 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 mainly focused on simulating the pen stroke and the distribution of pigment on the suface 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 draw-

Figure 2: *The photomicrographs of the Ukiyo-e.*

ing. 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 shading technique which can represent these two type reflection and can render the appearance of the Ukiyo-e on real-time.

1.1. Previous work

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 ([SWHS97] and [ZST*99]). Processing the 2D photos or the 3D geometric model is other method to generate the effect of drawing ([HRT04], [KKY04]). 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 ([T.O07]) or simulating the Ukiyo-e make process ([MSJ02]) can make the Ukiyo-e in virsual 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.

Our works based on the measured data and is relate to previous works on measuring spatially varying BRDFs (Bidirectional Reflectance Distribution Function) and BTF (Bidirectional Texture Function). This measurement usually set the light source and the camera on a hemisphere dome and take a lot of photos ([KGSJ99], [ACTP03], [MWAM05]). Using the taken photos, the BRDF or the BTF can be constructed to render photorealistic scene. Our measurement is similar to the [MWAM05], use high density samples to capture detail color variation on the surface of Ukiyo-e.

Because this measured data record the real color value of light scattering, the rendering using measured data can make the image with high reality. But the size of original measured BRDF and BTF data is very large. To decrease the size of data, two approaches are carried out. One approach is compressing the data ([MMS*05], [VT04]). This approach can decrease the size of original measured data. But it is still too large to render on real time. Another approach is computing the geometric parameters and reflection parameters from the meatured data, then use these parameters to render the scene ([ESKD97], [JDA05]). Our method belong to the second approach. We propose a shading model based on the measured data and can render Ukiyo-e on a real-time speed. The second approach need computing geometric parameter such as the normal on the suface, some previous works about how to obtain the geomentric paramenters will be introduced as follow.

Constructing the geometric parameter such as the normal on the surface from photo is carried out for a long term. The principle of photometric stereo ([Woo80]) can be used to construct the geometric parameter and the BRDFs. The normal of suface can be obtained by the color variation of different photos or video ([RTG97], [PF02], [RGG*03]). Comparing the reflection of examples such as ball to the reflection of the target object under same illumination conditions, the geometric parameter of the target object can be computed ([HS03]). With the developing of the techniques for scaning 3D geometric data by laser, it is possible to improve the precision of the reflection parameters for the high quality rendering by comparing with the scaning data ([RBMT98], [LKG*03]). For applying easily, the BRDF and normal on surface can be obtained using small number of photos([Geo03], [JDA05]). To decrease the errors of measuring, we measure the data in high density and construct the shading model to render the Ukiyo-e with high reality.

The fibers in the Japanese paper are long and some studies shown that the orientation of fiber is anisotropic([YTA*06], [TYA06]). As the result of these fiber reflection, the apearance of Ukiyo-e show anisotropic reflection. Some anisotropic shading models have been proposed based on the microfacet models and empirical models ([MP00], [G.J92]). These models assume that the reflection light is distribute on a narrow field. For the fiber shading model, the strongst reflection direction is along with a cone around the direction of the fiber ([SHM*03], [N.K06]). We develope this type fiber shading model and fit this model to the measured data in this paper.

The main idea of our work come from [JDA05] and [MWAM05]. [JDA05] compute the normal on the surface of the isotropic reflection materials. [MWAM05] 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 it near a random distribution. The appearance of the Ukiyo-e blend two effect, one is the isotropic reflection come from the pigment, another is the anisotropic reflection come from the fiber in Japanese paper. Different to the [JDA05] and [MWAM05], we blend these two reflection together, and fit these two reflect models to the measured data. Because we combine two different shading model together, the errors between the model and the measured data are decreased and high quality rendering result can be obtained.

1.2. Overview

Figure 3 show the compute process of our approach. At first, change the position of light source and camera and a lot of photos are taken. Then the normal of surface and the direction of fiber are computed from these measured data. We design two type shading models which can represent the isotropic reflection of pigment and the anisotropic reflection of fiber in Japanese paper. Based on the normal of surface and the direction of fiber, the parameters of the shading models are computed. Finally, the appearance of Ukiyo-e are rendered using the shading model we proposed in this paper.

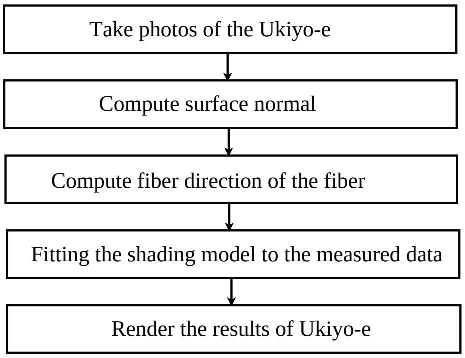

Figure 3: *The compute process.*

2. Measurment 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. Figure 4 show the photo of OGM. 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 correspondenting the 2D array and the position of lighting source on the hemisphere dome, A uniform concentric map ([SC97]) is used to set the position of light source. We use a 37 by 37 grids to set the position of light. To advoid the light source behind the arm of camera, the object table are turned 180 degrees. Some marks are set around the Ukiyo-e to calibrate the positon 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 [JDA05] is used to calibrate image. After calibrate the color and the pixel position, the BRDFs of each pixel can be computed.

Figure 5 show the two type BRDFs. In the field where is paper, a strong anisotropic reflection phenomennon can be observed. The highlight distribute along a line. In the field where is pigment, the anisotropic reflection become weak. The highlight centralize a point. These mean that we need to construct two shading models and combine them together to render the appearance of Ukiyo-e.

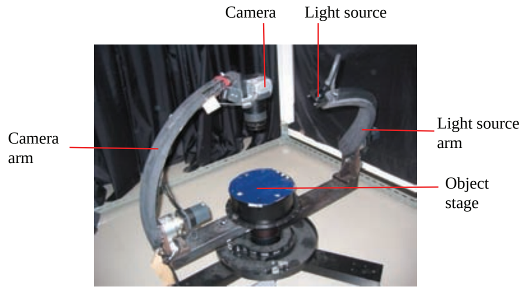

Figure 4: *Optical gyro measuring machine (OGM).*

Figure 5: *BRDFs of different pixel on the Ukiyo-e image.*

3. Shading model

From the measurment result, two type reflection phenomenon are observed. One is isotropic reflection come from the pigment, 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 6 (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 enter the fiber as a line and become a cone surface when it leave 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 reflect to air by the pigment directly. At this time, the light leave the surface of object is a line. Use α_{rp} 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.

$$I_p = I_{dp} + k_{sp} \bullet g(\sigma, \alpha_{hp}) / cos^2(\alpha_{rp}) \quad (1)$$

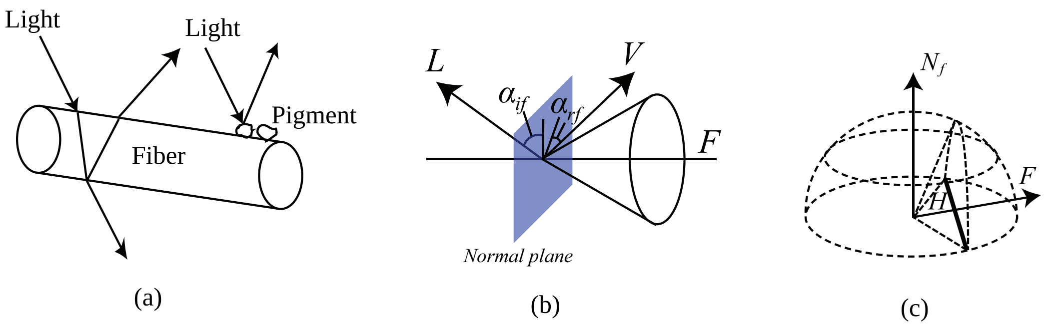

Figure 6: *Two type shading models of the Ukiyo-e.*

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

Simular to the shading model of the pigment, we can construct the reflection model of the fiber. Shown as Figure 6 (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 anlge between the viewpoint vector V and the normal plane Γ is $\alpha_r f$. If the viewpoint near the surface of the cone, the reflection light is strong. If viewpoint 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 tranditional 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.

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

Here, I_{df} is the diffusion reflection of fiber. $k_s f$ 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.

$$I = I_{dp} \bullet \beta + I_{df} \bullet (1 - \beta) \qquad (3)$$

This expression mean 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 shading model to the measured data and the decide 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 is 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 shading model is the normal N in the middle of the strongst reflection R and the light vector L. The differnt between these two case 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 capted 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 figer in Figure 7 show the image of the surface normal. The value of RGB represent the XYZ value of normal N. The bump image can be seen from this image.(For print 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 highligh of fiber reflection is a line on the hemisphere. Figer 6 (c) show the relationship of the Normal N_f, highlight line H and the fiber direction F. The F 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 figer in Figure 7 show the image of the fiber direction.The value 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 neasured 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.

$$\rho = \sum (I - M_{uv}) \qquad (4)$$

Here, I is the theory value of the shading model introduced above. M_{uv} is the measured BDRF data by the OGM. u and

v is the coordinates of the measured BRDF image. For get the correct parameters of the shading 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 inital 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 shading model. These values are stored as the texture, and use these texture, 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 a Ukiyo-e which was made in hundreds years ago.The research project of "Kyoto Art Entertainment Innovation Research" of Centre of Excellence Program for the 21st Century is carried out by computer science researchers and hummanbeing researchers. As this reason, the experiment samples can be got easily. Two Ukiyo-e belong to the Ritsumeikan University and one Ukiyo-e belong to the British Museum is used for experiment.

The normal got by our method can be used to render the bump effect of the Ukiyo-e. To see the bump effect clearly, the part of the ukiyo-e is used to reder. 11 show the rendering result. The left image is the rendering result based on the normal map. The right small image is the color map got by the scaner. When print the Ukiyo-e, the woodblock is put on the paper, the some part of surface is low and the other part is high and the bump pattern are made. This bump effect can be seen well from our rendering result.

We compare the case with the fiber effect and without fiber effect also. Shown as Figure 9, the left one is the rendering resutl 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 hollow 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.

Using the parameters got from the measured data, the effect of fiber for the Ukiyo-e which are not measured can be generated also. 10 show the rendering result of a famous Ukiyo-e preserved in the British Museum. The color map is a photo of this Ukiyo-e. To construct the fiber map, the Fast Fourier Transform (FFT) is used to analysis the orientation of fiber in the Japanese paper same as [YTA*06] and [TYA06]. Then the fiber lines are set according to the anisotropic orientation of the fiber. Shown as the 10, the left image is the constructed fiber map. The value of the RGB represent the value of fiber direction vector. The right image is the rendering result. The pattern like noise on the face of person is the fiber reflection effect. This experiment show our method can be used to render the reality Ukiyo-e from one picture.

The image shown in Figure 11 is the rendering result using the shading 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 methode 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 modelling the detail of the fiber in the Japanese paper from images need to be developed. We also plan develope 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.

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References

[ACTP03] A.GARDNER, C.TCHOU, T.HAWKINS, P.DEBEVEC: Linear light source reflectometry. *ACM Transactions on Graphics 22*, 3 (2003), 749–758.

[ESKD97] E.P.F.LAFORTUNE, S.C.FOO, K.E.TORRANCE, D.P.GREENBERG: Non-linear approximation of reflectance functions. *Proceedings of SIGGRAPH 1997* (1997), 117–126.

[Geo03] GEORGHIADES A. S.: Recovering 3-d shape and reflectance from a small number of photographs. *Proceedings of Eurographics Workshop on Rendering* (2003), 230–240.

[G.J92] G.J.WARD: Measuring and modeling anisotropic reflection. *Proceedings of SIGGRAPH 1992* (1992), 265–272.

[HRT04] H.JOHAN, R.HASHIMOTO, T.NISHITA: Creating watercolor style images taking into account painting techniques. *the Journal of the Society for Art and Science 3*, 4 (2004), 207–215.

[HS03] HERTZMANN A., SEITZ S. M.: Shape and materials by example: A photometric stereo approach. *Proceedings of the IEEE Conference on Computer Vision and Pattern Recognition* (2003), 533–540.

[JDA05] J.A.PATERSON, D.CLAUS, A.W.FITZGIBBON: Brdf and geometry capture from extended inhomogeneous samples using flash photography. *Computer Graphics Forum 24*, 3 (2005), 383–391.

[KGSJ99] K.J.DANA, GINNEKEN B., S.K.NAYAR, J.J.KOENDERINK: Reflectance and texture of real-world surfaces. *ACM Transactions on Graphics 18*, 1 (1999), 1–34.

[KKY04] K.KAWASAKI, K.NAKAMARU, 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 3*, 4 (2004), 235–243.

[LKG*03] LENSCH H. P. A., KAUTZ J., GOESELE M., HEIDRICH W., SEIDEL H. P.: Image-based reconstruction of spatial appearance and geometric detail. *ACM Transactions on Graphics 22* (2 2003), 234–257.

[MMS*05] MULLER G., MESETH J., SATTLER M., SARLETTE R., KLEIN R.: Acquisition, synthesis, and rendering of bidirectional texture functions. *Computer Graphics Forum 24*, 1 (2005), 83–109.

[MP00] M.ASHIKHMIN, P.S.SHIRLEY: An anisotropic phong brdf model. *Journal of Graphics Tools 5*, 2 (2000), 25–32.

[MSJ02] M.OKADA, S.MIZUNO, J.TORIWAKI: Virtual sculpting and virtual woodblock printing by model-driven scheme. *the Journal of the Society for Art and Science 1*, 2 (2002), 74–84.

[MWAM05] MARSCHNER S. R., WESTIN S. H., ARBREE A., MOON J. T.: Measuring and modeling the appearance of finished wood. *Proceedings of SIGGRAPH 2005* (2005), 727–734.

[N.K06] N.KAWAI: Reproducing reflection properties of natural textures onto real object surfaces. *Proceedings of the 4th International Workshop on Texture* (2006), 101–106.

[PF02] PATERSON J. A., FITZGIBBON A. W.: Flexible bump map capture from video. *Proceedings of the Eurographics 2002 conference, short papers* (2002).

[RBMT98] RUSHMEIER H., BERNARDINI F., MITTLEMAN J., TAUBIN G.: Acquiring input for rendering at appropriate levels of detail: Digitizing a pieto. *Proceedings of Eurographics Workshop on Rendering* (1998), 81–92.

[RGG*03] RUSHMEIER H., GOMES J., GIORDANO F., EL-SHISHINY H., MAGERLEIN K., BERNARDINT F.: Design and use of an in-museum system for artifact capture. *IEEE/CVPR Workshop on Applications of Computer Vision in Archaeology* (2003).

[RTG97] RUSHMEIER H., TAUBIN G., GUEZIEC A.: Applying shape from lighting variation to bump map capture. *Proceedings of Eurographics Workshop on Rendering* (1997), 35–44.

[SC97] SHIRLEY P., CHIU K.: A low distortion map between disk and square. *Journal of Graphics Tools 2*, 3 (1997), 45–52.

[SHM*03] S.R.MARSCHNER, H.W.JENSEN, M.CAMMARANO, S.WORLEY, P.HANRAHAN: Light scattering from human hair fibers. *ACM Transactions on Graphics 22*, 3 (2003), 780–791.

[SWHS97] SALISBURY M. P., WONG M. T., HUGHES J. F., SALESIN D. H.: Orientable textures for image-based pen-and-ink illustration. *Proceedings of SIGGRAPH 1997* (1997), 401–406.

[T.O07] T.OKAMOTO: http://www.tatuharu.com/.

[TYA06] T.ENOMAE, Y.H.HAN, , A.ISOGAI: Nondestructive determination of fiber orientation distribution of fiber surface by image analysis. *Nordic Pulp and Paper Research Journal 21*, 2 (2006), 253–259.

[VT04] VASILESCU, TERZOPOULOS D.: Tensortextures: multilinear image-based rendering. *ACM Transactions on Graphics 23*, 3 (2004), 336–342.

[Woo80] WOODHAM R. J.: Photometric method for determining surface orientation from multiple images. *Optical Engineering 19*, 1 (1980), 139–144.

[YTA*06] Y.H.HAN, T.ENOMAE, A.ISOGAI, H.YAMAMOTO, S.HASEGAWA, J.J.SONG, S.W.JANG: Traditional papermaking techniques revealed by fiber orientation in historical papers. *Studies in conservation 52*, 4 (2006), 267–276.

[ZST*99] ZHANG Q., SATO Y., TAKAHASHI J., MURAOKA K., CHIBA N.: Simple cellular-automaton-based simulation of ink behavior and its application to suibokuga-like rendering of trees. *The Journal of Visualization and Animation 10*, 1 (1999), 27–37.