Real-Time Rendering of Japanese Lacquerware

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Abstract

Japanese lacquerware has been used from long ago in Japanese daily life. Makie is a famous surface decoration technique using metallic powders, color pigments, and lacquer. We propose a method for real-time rendering of Makie. The optical properties of the Makie surface is represented using Bidirectional Reflectance Distribution Function (BRDF). Sphere environment maps are generated for the real-time visualization of BRDFs. A photo of Makie designed on a flat surface is taken with a digital camera. Masking textures with alpha channels are made from the photo for blending sphere maps. Multipass texture blending is used for real-time visualization of Makie decoration on general PCs.

Technical Area: Computer Graphics

Keywords: Real-time visualization, BRDF, multipass texture blending, photo-realistic rendering, image processing

1 Introduction

Japanese lacquer work called *urushi* is a traditional coating method for tableware, furniture, etc. Makie is one of the most famous decoration techniques using gold powder and color pigments. The surface of Makie decoration lacquerware is polished after several kinds of metal and color pigments are sprinkled on raw lacquer. It has complex optical effects depending on the direction of view.

Real raw lacquer production and metal pigments are expensive, so it is difficult to make many sample products. This research will simulate the product appearance before the real objects are made. We will discuss the real-time rendering of the Makie technique, using the current graphics hardware. Real-time rendering requires a speed of calculation of at least 25 frames per second. Bidirectional Reflectance Distribution Function (BRDF) is the standard representation of optical properties of a material on the surface. In general, rendering a scene with the BRDF defined on surfaces is a time-consuming task which cannot be done in real-time. Sphere environment mapping developed by Blinn and Newell [1] can approximate optical effects [2] and speed up the rendering. It is implemented on general PC video cards, so the BRDF is visualized at interactive speed.

We propose real-time visualization of Japanese lacquerware by blending multiple BRDFs corresponding to each pigment used. First, the design of Makie which is designed on a flat surface is taken by a digital camera. Second, the sphere map textures are generated by rendering a ball with a given BRDF and light sources. Usually, we have about three kinds of color pigments and metallic powder used in Japanese lacquerware. Therefore, we generate three sphere map textures mostly corresponding to gold, black, and red. Masking textures control blending of BRDFs with their alpha channels. Since gold powder and color pigments are usually mixed on the lacquer surface, we observe a *flip-flop* effect which means the changing of color from gold to that of the pigment depending on illumination and direction of view. To simulate the *flip-flop* effect, we carefully set the alpha channels of masking textures using image processing methods. A multipass texture blending technique will be used because several textures must be blended on a surface.

2 Makie Decoration

Japanese lacquerware has been used in Japan for a long time. The oldest is a comb made about 6800 years ago painted with red lacquer. The purpose for the lacquer coating is not only the decoration of tableware or furniture but also its preservation. Lacquerware is resistant to acid, alkali, alcohol, and heat.

Raw lacquer is made from the sap of urushi trees by heating and filtering. The sap is gathered by scratching the surface of urushi trees. Purified raw lacquer is a translucent brown viscous fluid and is processed into several types of lacquer. Only about 200 grams of the sap can be gathered from a roughly ten-year old tree, and the tree withers after that. Therefore, raw lacquer is precious and expensive.

Makie (see Figure 1) is a decoration technique of Japanese lacquerware. It began about 1200 years ago. To make a design, metallic powder and color pigments are sprinkled instead of painted with a writing brush.

Figure 1: A photo of a Makie decoration jewel box.

2.1 Procedure for Makie Coating

A pattern is designed on the wood surface dried at least for three years. The following is the simplified process of making Makie decoration.

1. The wood surface is smoothed and coated with raw lacquer.
2. Colored lacquer is coated evenly, and the surface is polished.
3. Patterns are painted with translucent lacquer, then metallic powders and color pigments are sprinkled onto the surface.
4. The lacquer is dried, and translucent lacquer is coated to fix the powders and pigments.
5. The surface is polished carefully.

Coating, drying, and polishing are repeated about twenty times in this process. In general, the whole process takes a month.

2.2 Optical Effects

Metallic powders, for example gold, silver, platinum, and copper or color pigments are sometimes sprinkled on the same area. Metallic powder radiance changes sharply near the specular direction, and color pigments change gradually. Therefore, the *flip-flop* effect is observed. If the light position is moved from the specular direction to another direction, the surface with gold powder and red pigments smoothly changes from gold to red. The Makie surface without metallic powder and color pigments is polished Japanese lacquer. It has a strong Fresnel reflection.

3 Sphere Environment Mapping

Tabulated BRDFs are used to visualize the complex optical properties, but rendering using BRDFs is a time consuming-task. Since our purpose is to visualize at interactive rates, it is currently difficult to use BRDF directly on the Japanese lacquerware surface. Therefore, BRDFs are integrated into sphere maps which can be visualized using general graphic hardware.

A sphere map is equivalent to an orthographic view of a reflective sphere. To make a sphere map, the sphere mesh is prepared in the same scene as the target object is illuminated. The vertices of the mesh are rendered by a ray-tracing algorithm using BRDF of the target object. The reflected radiance L in the outgoing direction $\overrightarrow{\omega_o}$ is given as

$$L(\overrightarrow{\omega_o}) = \sum_k f(\overrightarrow{\omega_{ik}}, \overrightarrow{\omega_o}) I_k(\overrightarrow{\omega_{ik}}),$$

where f is BRDF, $\overrightarrow{\omega_{ik}}$ is the direction to the k-th light source, and I_k is the incident radiance incoming from the k-th light source to the sphere. The pixels of faces are interpolated using Gouraud shading. Figure 2 shows generated sphere maps.

Figure 2: Sphere maps used in rendering. Light sources are the sun and sky doom. On the left is the sphere map for gold powder, in the center is a polished black lacquer surface including Fresnel reflection, and on the right is a sphere map for color pigment.

4 Blending of Multiple BRDFs

General Makie designs include metallic powders, color pigments, and polished lacquer surfaces. Each BRDF is integrated into sphere maps respectively. This section describes how BRDFs are blended.

The photo of Makie decoration on a flat panel is taken with a digital camera (see upper left of Figure 4.) This photo is preprocessed and used for rendering. Daylight illumination is best for taking photos of Japanese lacquerware. They must not include too bright or too dark an area.

4.1 Masking for Polished Japanese Lacquer Surfaces

BRDFs are blended using alpha channels in masking textures. Our Makie simulation requires two masking textures for gold powder and the polished Japanese lacquer surfaces. If only lacquer is painted on some area with no pattern, we can easily separate the lacquer from patterns. The border lines between lacquer and patterns are confirmed by a user, so the alpha channel of the lacqured area is changed to transparent with an image editor. The lower right picture of Figure 4 is a masking channel for a lacquer with extracted design.

4.2 Masking for Gold Powder and Color Pigments

Because gold powder and color pigments are often sprinkled on the same area, the image processing method is adopted to make textures for blending. Figure 3 shows how a pixel of a CCD matrix in a digital camera is taken. Metallic powders and color pigments are smaller than the pixel, so the colors in the pixel are mixed additively. Therefore, the BRDF of a Makie surface is the sum of the fractions of the metallic powder's and color pigments' BRDFs:

$$f = p f_{metallic} + \sum_l q_l f_l \quad (1)$$

where f is the BRDF of the surface, p and $f_{metallic}$ are the fraction and the BRDF of metallic powder, and q_l and f_l is the fraction and the BRDF of the l-th color pigment.

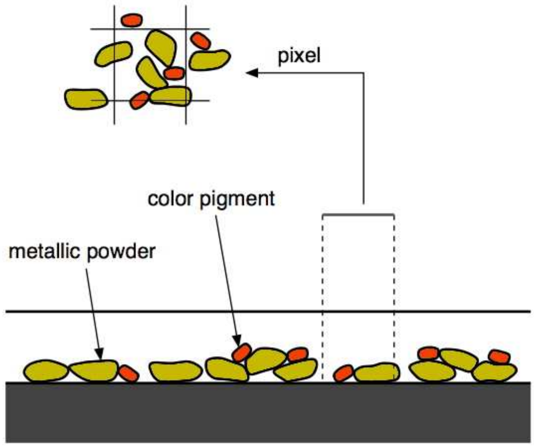

Figure 3: CCD pixel

The radiance of a pixel in a texture can be calculated as the sum of the BRDFs by using the incoming radiance. The pixel radiance $\mathbf{T}$(i,j) is given as

$$\mathbf{T}(i,j) = p(i,j)\mathbf{m} + \sum_l q_l(i,j)\mathbf{c}_l \quad (2)$$

where $\mathbf{m}$ and $\mathbf{c}_l$ are RGB colors of a surface where only metallic powder and only the l-th color pigment are used. The fractions p and q_l are constrained by $p + \sum_l q_l = 1$ at pixels in patterns and $p + \sum_l q_l < 1$ at pixels in the boundaries of patterns. The weights used for texture blending of metallic powder and color pigments are driven by $p(i, j)$ and $q_l(i, j)$. When $p(i, j)$ and $q_l(i, j)$ are obtained [3], the masking texture for metallic powder and the pattern texture without the metallic components (see Figure 4) are generated.

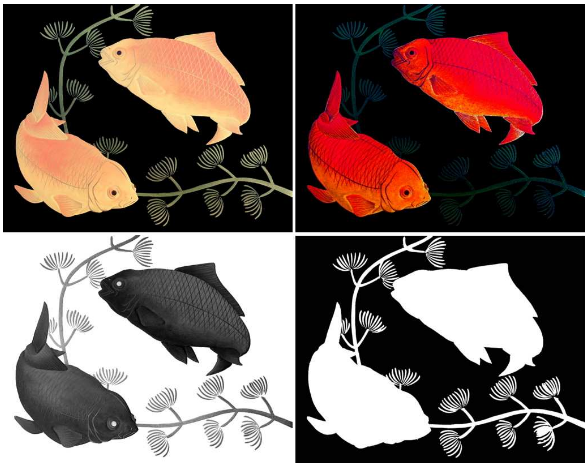

Figure 4: The original digital photo and generated textures. The upper left is a digital photo of Makie design on a flat surface. The others are textures used in rendering. The upper right is a residual texture without the metallic component. The lower left and right are masking textures for metallic powders and polished lacquer surfaces, respectively.

5 Implementation

Our real-time visualization application is implemented on Microsoft DirectX 8, which is the API of 3D computer graphics. All sphere environment maps and masking textures are blended using alpha channels. The sphere maps and masking textures for metallic powder, each color pigment, and lacquer surfaces are required for rendering, so at least six textures are blended. Since even some high performance video cards like NVIDIA Geforce4 Ti cannot render six textures in one pass, rendering passes must be designed carefully. Multipass texture blending including single-pass multiple texture blending is implemented in our application.

Single-pass multiple texture blending is a texture calculation method using texture stages. Textures are blended in one pass. It means that rendering occurs once, so this technique is fast. However, it is limited in the number of blended textures. There are eight texture stages in general, but the number of maximum simultaneous textures is two or four on current low-end PCs. Therefore, it is not good to blend more than two textures in a pass.

Multipass texture blending repeats rendering. Textures are divided into rendering passes. After the first pass is rendered, the texels of the second pass and the rendered pixels of the first pass are blended. Each pass and rendered results are blended, so the target object is rendered several times. Therefore, this technique is slower and has fewer kinds of blending instruction than single-pass multiple texture blending. The benefit of multipass texture blending is that there is no limitation to the number of blendings.

In our implementation, all passes except the first pass include a mask channel and sphere map. Each masking texture and the corresponding sphere map are blended as single component. This blending instruction cannot be used in multipass texture blending, so this process must be implemented in a single pass. All rendering passes are blended by multipass texture blending using the masking textures' alpha channels. Figure 5 shows a diagram of the rendering pass of our rendering example.

We can observe shadowing effects due to thichness of pattern (see Figure 6). Similar effect has been simulated by bidirectional texture function(BTF) [4] requiring large amount of photographs approximating the BRDF in preprocessing step. The real-time implementation of this approach is very hard. Another possibility is to use normal map [5] which can be implemented on hardware. Normal map textures include surface perturbation vectors in RGB channels. A normal map is calculated from a height field map, therefore measuring of surface bumps on patterns is our future work.

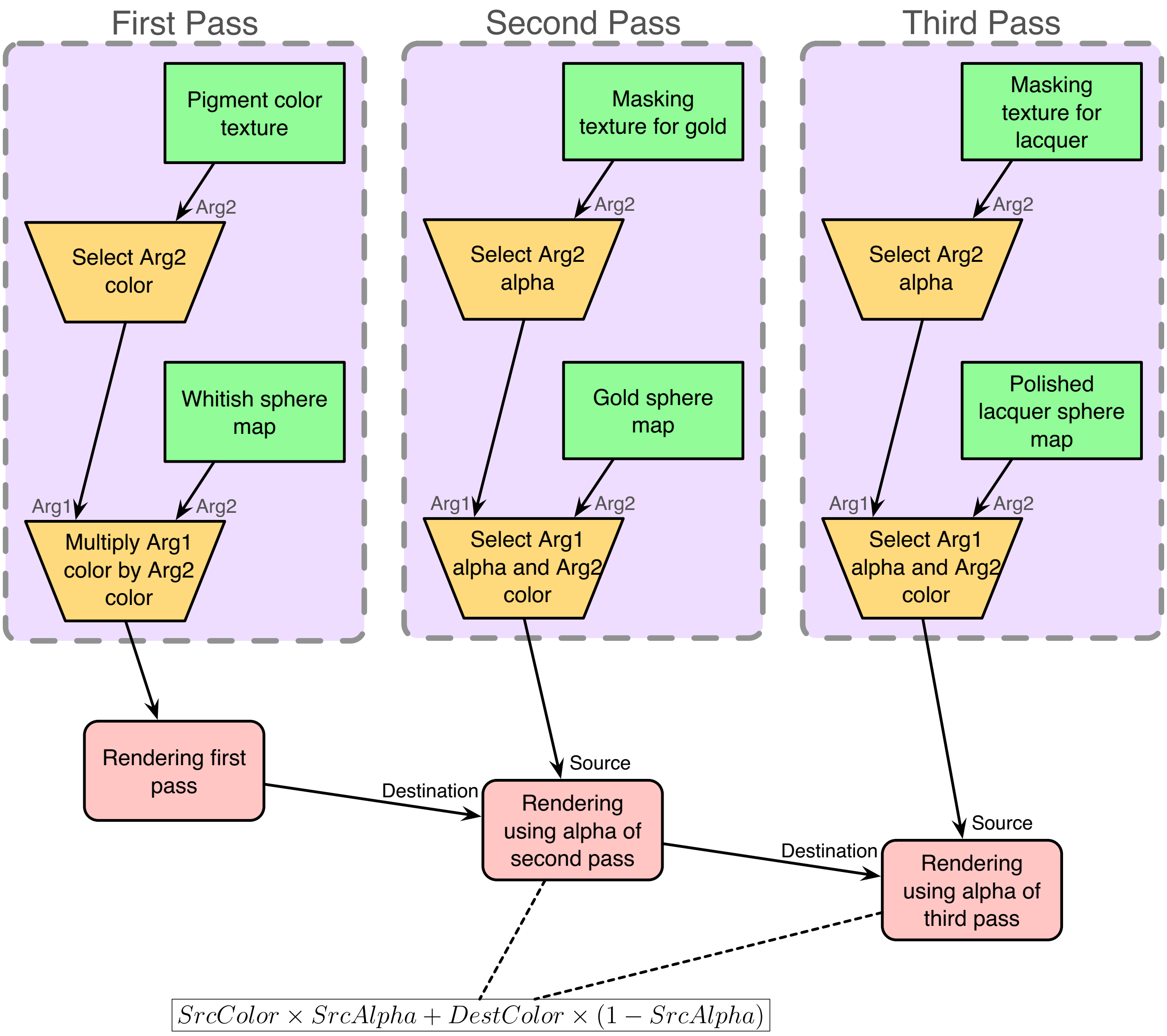

Figure 5: The diagram of rendering passes. The rendering result of the first pass and the output of the second pass are blended using the alpha channel of the second pass. Afterwards, the blended rendering result and the output of the third pass are blended using the alpha channel of the third pass.

Figure 6: Bumps on a pattern.

6 Results

The three sphere environment maps shown in Figure 2, a residual texture, and the two masking textures shown in Figure 4 are used in our demonstration. All textures are blended according to a schema shown in Figure 5. Frame rates of our rendering method are not enough on low-end laptop PCs. However, on general PCs, our application works at the interactive rate of 60f/s. Figure 7 shows a few rendered frames using a total of six textures mapped on a tray.

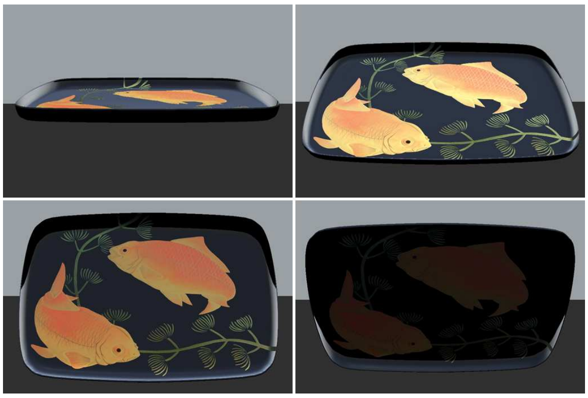

Figure 7: Rendered frames.

Fresnel reflection is observed in the upper left picture of Figure 7. The polished black lacquer surface seems whitish by this effect. The upper right and lower left pictures show the *flip-flop* effect. Because gold powder and red pigment are sprinkled on the pattern of goldfish, it changes skin color smoothly from gold to red.

7 Conclusion

Interactive photo-realistic visualization is difficult to achieve because accurate lighting requires heavy calculation. BRDFs are integrated into sphere maps, and masking textures are made for blending textures using hardware-acceleration. Textures are rendered using multipass texture blending. The proposed interactive rendering method can visualize the Makie decoration very closely to real samples, as many lacquer producers stated. The optical effects of Makie-like Fresnel reflection and the *flip-flop* effect are also observed in our Makie simulation application. Current graphics hardware can run this application at interactive rates of approximately 60f/s.

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