Reproducing an appearance of the objects using high bright projector

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Abstract
We propose a new method of image projection to reproduce an appearance of real object to mock object using high bright projector. To perform this projection precisely, it is very significant to execute the matching of reflected radiance corresponding to the real object. For the radiant matching, it is useful for the color matching to combine two methods, which are the PCA spline method and the LUT method. The result shows that the accuracy of color matching is less than ?E*$_{94}$=2 when high bright projector is used. Furthermore, we could reproduce the gloss property on mock object by adding the higher radiance on the expected gloss area, which is calculated by BRDF and geometry between projector and observer's eyes. Observer rating result showed that we could not distinguish the difference of gloss appearance between the real object and mock object.

Keywords:
Digital mock-up; Projector; Color matching; Reproduction of appearance.

1. Introduction

A digital mock-up has been increasingly used with the growth of 3D-CAD system (Computer Aided Design) and CG (Computer Graphics) for reproducing an appearance of the real objects in the industrial design. For the exact digital mock-up of real object, it is necessary to reproduce an accurate appearance of gloss, graininess, color, and texture. It is basically difficult to reproduce the accurate appearance of the real objects using a conventional display, since the dynamic range and contrast are not sufficient compared with real-world environments.

Recent years, a projector display system is attracted a great deal of attention with high dynamic range and contrast compared with conventional CRT display. Using the projector, many researchers execute the research of a new display system, and explore a possibility for the mixed-reality combined with CG[1-2)]. Since projector display system can be projected images on any objects, we can recognize as the reflected object, which is consistent with real object at visual sensation. However the purpose of the above research is not to correspond to the reality. For the reproduction of accurate digital mock-up, we must investigate how to control precisely the radiance and the color of projection system and how to reconstruct the accurate appearance.

In this paper, we propose a new display system using high bright projector which give exact matching of radiance and appearance between real object and mock object. Our systems are consist of two matching methods, one is the color matching method using the high bright projector. This method is performed by analysing the relation between input signals of projector and radiance of reflectance from projected object. Another method is contrast matching which control the radiance by using projected light. The gloss appearance of reflectance is calculated by BRDF (Bi-directional Reflectance Distribution Function), and the relative contrast between the gloss and the diffuse reflection is matched by control of luminance for both objects.

2. Concept of proposed display system

The purpose of our research is to generate the same appearance as the real object on a mock object. We explain a concrete method by illustration shown in Figure 1. Luminance emitted from projector is radiated onto the real and mock object. Both objects are installed by the parallel arrangement on the same screen, and the observer recognizes the radiance of reflectance from both objects as tristimulus value XYZ. If the radiance and the distribution of reflected both objects can be seen same, the accurate reproduction will be possible.

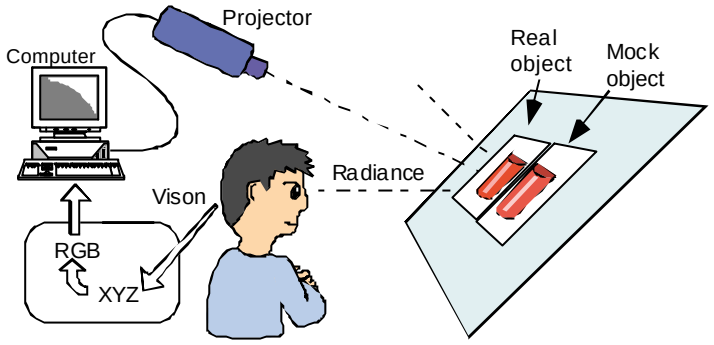

Figure 1: Schematic illustration of proposed display system

The relation between light from the projector and radiant of reflectance is expressed by,

$$L_r(x, y, \vec{w}) = f_r(x, y, \vec{w}', \vec{w}) \cdot E_r(x, y, \vec{w}'), \qquad (1)$$

where *L*r, *f*r and *E*r are reflected radiance from objects, BRDF, irradiance of projector respectively, and x, y are position on the reflected surface, $\vec{w}', \vec{w}$ are direction of incoming radiance and direction away from surface respectively. If the BRDF on the each object can be measured, the reflected radiance can be controlled by clarifying the relation between tristimulus value XYZ and irradiance of projector, namely RGB input value.

This control of the radiance and the expression of the reflected distribution seem to be able to be represented by using conventional CRT display. However, our projection method has the following advantages.

- A mode in observing the color can be corresponding to real object because the same reproduction as the reflected object is possible by using the projector, which is different from the displayed object on CRT.
- A detail texture on the object can be reproduced if mock object is made of the same material as the real object.
- The adjustment of the contrast can be used as a control parameter because the light from the projector is effective as the illumination to the real object.

From the above reasons, our system has the advantage more than the conventional CRT displays. Moreover, it is possible to simulate the variation in the appearance by adjusting the control parameter.

3. Color matching by using projector

To control the radiance from the reflection object, it is necessary to clarify the relation between the signal to the projector and light from the project. A conventional color match technique is applicable as a basic method. However, the DLP projector uses a clear filter in addition to

ordinary RGB filter to improve the brightness. Owing to the clear filter, the additive color mixing is not approved, therefore, the color match process becomes complex[3,4]. The complexity of the color match process leads to an increase in the number of measurements, it becomes a problem when it is used on the commerce. We analysed the luminescence characteristic of the projector, and the match technique with good accuracy was developed by a little measurement. Concretely, we use the color matching to combine two methods, which are the PCA (Principal Component Analysis) spline method and the LUT (Look-Up Table) method [5].

Figure 2 shows the flow chart of calculation. First, we measure the tristimulus value XYZ according to RGB input for all color space and estimate them by using the PCA spline method. If the ΔE^* between measured color and estimated color is less than a threshold, the value of RGB are recorded as the PCA cluster. Next, the other color proceeds to the next step. If the ΔE^* using the LUT is less than the threshold, the color space is divided into each LUT cluster repeatedly.

The result of color matching is shown in figure 3. We measure the tristimulus value XYZ of printed color such as the Macbeth color chart, and evaluate the color difference between printed color and projected color. The accuracy of color matching is less than $?E^*_{94}=2$ when DLP projector is used.

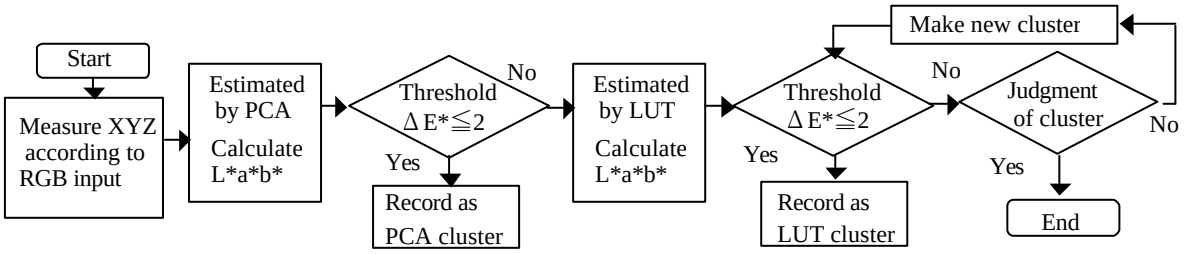

Figure 2: the flow chart of calculation for color matching

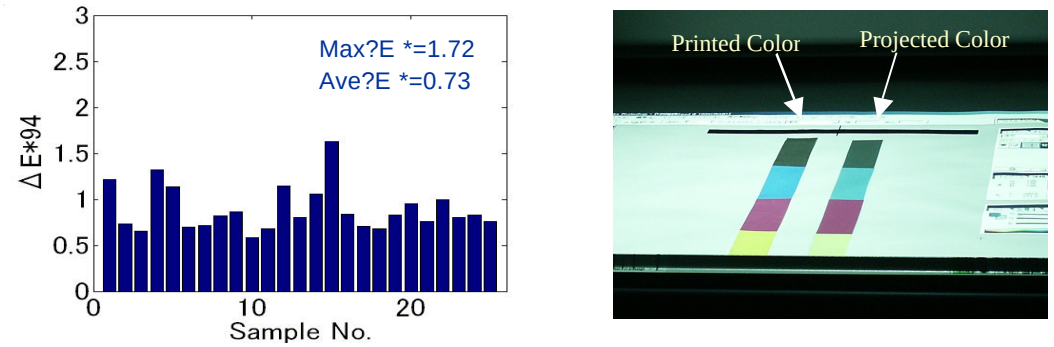

Figure 3: Result of color matching between printed color and projected color

4. Contrast matching and evaluation of the proposed system

We construct the prototype of the projection system, and the proposal technique is evaluated in this section. Figure 4 shows the geometric illustration of our system. The evaluation is executed by the same composition as described in the section 3. Both objects are installed by the parallel arrangement on the same screen, and one is an object that becomes a showpiece object, namely real object, and another one is a mock object which has different reflectance. Though the shape of both objects is the same, the showpiece object is covered by the coated paper around the object. On the other hand, a mock object is covered by the mat paper. The shape of the object and BRDF both paper is measured before, and the position of the projector, the screen, and observer's eyes is fixed.

The experiment on reproduction is executed by projecting the appearance on the mock object. However, if the showpiece object have strong gloss reflection on their surface, it is usually difficult to reproduce the absolute radiance and contrast on the mock surface. Therefore, we adapt

the idea which is to match the relative contrast generated between the gloss and the diffuse reflection. To adjust the power of illumination to the showpiece object, we can display the appearance of strong gloss reflectance relatively, since the power of radiance on gloss reflection depends on the illuminated radiance.

Figure 5 shows the result of reproducing the appearance by using the proposal technique. When the gloss appearance that is calculated by BRDF is added to mock object, the same appearance as the showpiece object is reproduced in the mock object. Moreover, the relative contrast between the gloss and the diffuse reflection is matched by control of luminance for both objects. As the result, we could not distinguish the difference of gloss appearance between the real object and mock object.

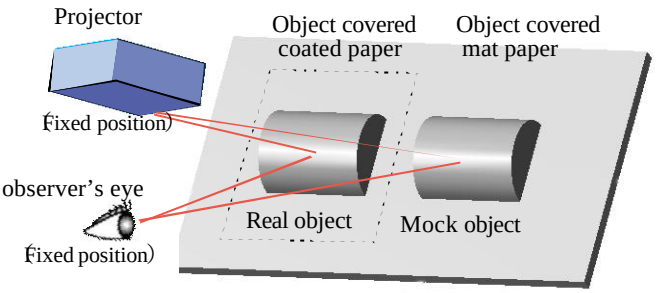

Figure 4: Geometric illustration of our system

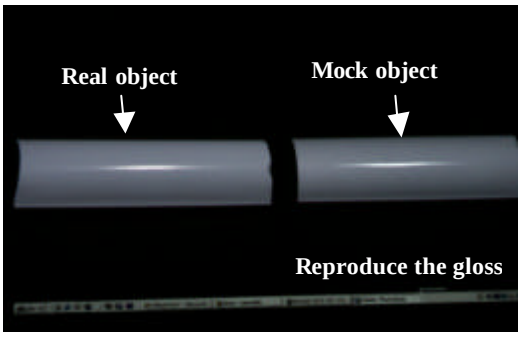

Figure 5: Experimental results of the proposed display system

5. Conclusions

We propose a new display system using high bright projector which give exact matching of radiance and appearance between real object and mock object. Our systems are consist of two matching methods, one is the color matching method using the high bright projector, and the other is the appearance matching using the projection image. For the radiant matching, it is useful for the color matching to combine two methods, which are the PCA spline method and the LUT method. The result shows that the accuracy of color matching is less than $?E^*_{94}=2$ when high bright projector is used. For the contrast matching, we control the distribution of reflected radiance by using projected image. The gloss appearance of reflectance is calculated by BRDF and the relative contrast between the gloss and the diffuse reflection is matched by control of luminance for both objects. Observer rating result showed that we could not distinguish the difference of appearance between real object and projected mock object. As the result, we believe that the developed display system of appearance is a very significant for future application such as digital mockup and industrial design.

References

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