Device Independent Gloss Reproduction Model for E-commerce: Estimation of Radiance on Display

Tetsuo Ikeda[*], Norimichi Tsumura[*, **], and Yoichi Miyake[*]
[*]Department of Information and Image Sciences, Chiba University, Japan
[**]PRESTO, Japan Science and Technology Corporation, Japan

Abstract

In this paper, we introduce a method to estimate the radiance of the display without any special devices for our previously proposed device independent gloss reproduction system.[1] In this system, a gloss model is defined for matching the gloss on different devices. The model is written by BRDF on the surface and the radiance of the display. We can obtain the radiance of displays by using the proposed radiance estimation method. In the proposed radiance estimation method, all customers are asked to choose the visible pattern on the display. Based on the chosen pattern, the radiance of the display is estimated, and used to produce equally perceptible image on the display of each customer.

Introduction

It is important to reproduce equally perceptible images across different displays in the Internet shopping system. To solve the difference of color appearance between two displays, many studies have been done on the device independent color reproduction. However, a little has been studied on a device independent reproduction of glossiness of the object. In the e-commerce system, the gloss reproduction is also important for customer.

We have already developed the gloss reproduction system based on a perception of the human vision. In this system, a gloss model is defined for matching the gloss on different devices. The model is written by BRDF on the surface and the radiance of the display. The radiance of the display may be pre-defined in color management system such as sRGB or ICC profile. In this case, however, it is required to control the user's environment strictly, and this is not practical situation in the e-commerce system. To obtain the radiance of the display, users have to use some devices such as colorimeter or spectrophotometer for the measurement. However, this is also not practical situation in the e-commerce system.

In this paper, we introduce a method to estimate the radiance of the display without any special devices for our previously proposed device independent gloss reproduction system. In the proposed radiance estimation method, all customers are asked to choose the visible pattern on the display. Based on the chosen pattern, the radiance of the display is estimated, and used to produce equally perceptible image on the display of each customer.

In the next section, we will briefly review the previously proposed device independent gloss reproduction system. Then, a radiance estimation technique is proposed.

Device Independent Gloss Reproduction Model

A surface gloss model based on psychophysical properties was introduced by Ferwerda et al.[2] They developed the model that is not dependent on color of the object. In addition to their model, we develop the psychophysically based gloss model that takes account of the device independent gloss reproduction on different displays.

Psychophysical scaling technique was introduced to clarify the relationship between the attribute of human gloss perception and the physical properties of the glossiness of the object. Figure 1 shows the user interface of the experiment. The image on the left side of the figure is synthesized with various gloss properties using Phong's light reflection model[3] as Equation (1).

$$k_s(\theta) = A_1 \cos^{A_z} \theta, \quad k_d(\theta) = B_1 \cos\varphi, \tag{1}$$

where ks is the specular reflectance component of the object and kd is the diffuse reflectance component. θ, ϕ are angles compared to the mirror reflection and normal vector, respectively. The parameter $A1$ is the intensity of ks, $A3$ is the probe of ks and $B1$ is the intensity of kd. The intensity of ks is distributed along mirror reflection direction, and kd is distribute uniformly all direction. By changing $A1$ and $A3$, we can synthesize images that have various gloss properties. We synthesized images by changing 3 parameters; $A1$, $A3$ and maximum radiance of the display $Rmax$. A pixel value of the image I can be written with these parameters as Equation (2).

$$I = R_{\max}(A_1 \cos^{A_3}\theta + B_1 \cos\varphi) \; . \tag{2}$$

Figure 1. Subjective evaluation for the glossiness modeling

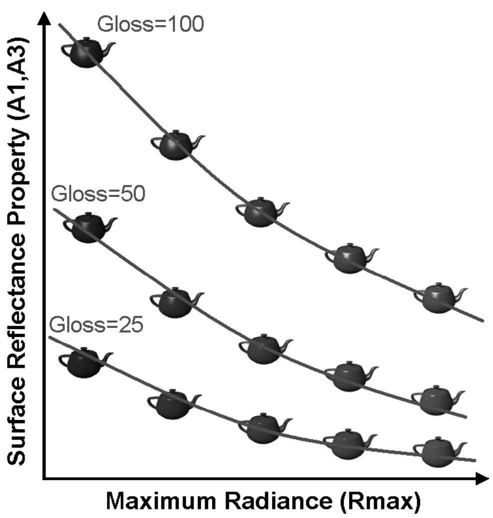

Figure 2. Schematic chart of the gloss model

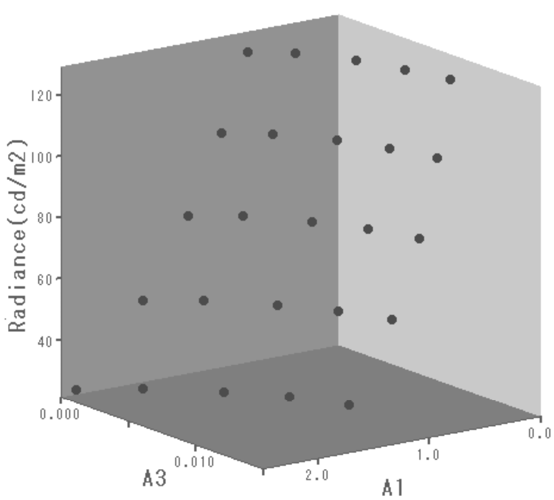

Figure 3. Isogloss contours (Gloss=79)

(a)Original image on high radiance display *(b)Original image on low radiance display* *(c)Compensated image on low radiance display*

Figure 4. Gloss matching experiment

Observers evaluate the image by using the slider on the right side of Figure 1. At each time, observers were asked to evaluate the glossiness of the teapot in the image on the scale from 0 (no glossiness) to 100 (very strong glossiness). The total number of observers is 6 and the data obtained from all observers is analyzed by the magnitude estimation technique. Magnitude estimation is one of the psychophysical scaling techniques designed to reveal a functional relationships between the physical properties of the object and perceptual attributes. By applying the data into magnitude estimation, we derive a model equation as Equation (3).

$$Gloss = 5.4\sqrt{R_{\max}} + 414.9\sqrt{A_3} + 54.7\sqrt{A_1} - 76.3 \ , \qquad (3)$$

where *Gloss* is value of the glossiness. Figure 2 shows the schematic chart of the proposed gloss model. The glossiness is the function of maximum radiance of display R_{max} and surface reflectance property A_1, A_3, and the isogloss contour can be drawn in this figure.

We apply this model into device independent gloss reproduction. The radiance R_{max} of the display depends on the devices each other. We can keep *Gloss* by compensating the difference of R_{max} with $A1$ and $A3$ along the model equation as shown in isogloss contour in Figure 2. The images along the isogloss contour are equally perceptible. Figure 4(a), (b) shows the image on high R_{max} display where *Gloss* of 79, and low R_{max} display where *Gloss* of 49, respectively.

Figure 3 shows the isogloss contours for *Gloss* of 79. Figure 4(c) shows the image compensated along the isogloss contour by keeping the radiance R_{max} in Figure 4(b). By using images along the contour, we can produce images with same glossiness on different displays.

This model equation that we derived as Equation (3) contains the maximum radiance of the display R_{max}. In practical web shopping, however, it is impossible for customers to prepare some special devices to measure the maximum radiance of the display. In the next section, we introduce the radiance estimation method to get the maximum radiance of the customer's display.

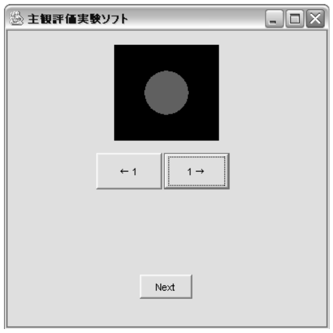

Figure 5. Subjective evaluation for radiance estimation

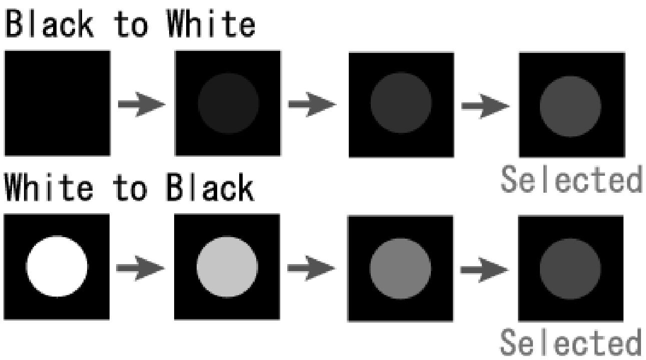

Figure 6. Schematic flow of changing from black to white and white to black

Radiance Estimation Method

Through the evaluation by observers, we can realize the radiance estimation method without any special devices such as colorimeter or spectrophotometer. We noticed that the appearance of the grayscale patch displayed on the display is related to the maximum radiance of the display. On a dark display with low maximum radiance, a dark-gray patch displayed on the screen is not distinguishable from a black background. On the other hand, on a bright display with high maximum radiance, same dark-gray patch is still distinguishable from the black background. We noticed that how dark patch the user can distinguish from black background is strongly related to the maximum radiance of the display. Based on the visual experiment, we can estimate the maximum radiance of the display.

We introduce the psychophysical scaling technique to clarify the relationship between the appearance of the patch and the maximum radiance of the display. Figure 5 shows the user interface of the experiment. In the experiment, a patch is displayed on the center of the screen. Observer can control the brightness of the patch from black to white or white to black as shown in Figure 6. By comparing the patch and black background, the observer can select the just distinguishable patch from background. Figure 7 shows the experimental result where the brightness of the patch is changed from black to white. Horizontal axis indicates the pixel value of the selected patch by observer. Vertical axis shows the radiance of the display.

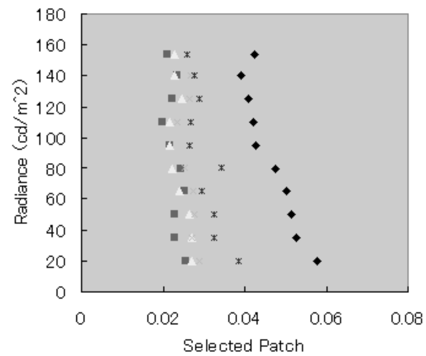

Figure 7. Experimental result of changing from black to white

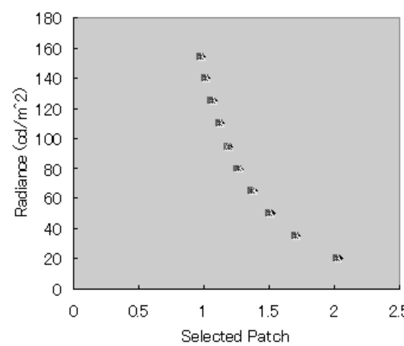

Figure 8. Experimental result of changing from white to black

Figure 8 shows the experimental result where the brightness of the patch is changed from white to black.

The results in Figure 7 shows that the selected patches in the case of changes from black to white are individually dependent, and will not be used in our system. On the other hand, the results in Figure 8 shows that the selected patches in the case of changes from white to black are individually independent, and will be used in our system for stable estimation of the radiance of the display.

Applying the data in Figure 8 to the regression analysis, we derive a model equation as;

$$R_{\max} = 138.1 \times \left(\frac{V_{patch}}{255}\right)^2 - 533.7 \times \left(\frac{V_{patch}}{255}\right) + 537.0 \text{ ,} \quad (4)$$

where R_{max} is the maximum radiance of the display, and this is same variable in Equation (3). V_{patch} is the pixel value of the just distinguishable patch. By using this model equation, we can estimate the maximum radiance of the display without any special devices.

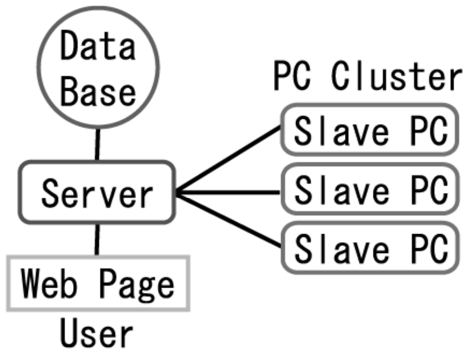

Figure 9. Image reproduction system

Device Independent Image Reproduction System

We have developed a gloss reproduction system by using methods that were mentioned above. By combining Equation (3) and (4), we can estimate the gloss property compensated to the display of each user.

Since the display is different among each user, it is impossible for the image reproduction system to prepare all images compensated to all displays. It is required for the system to generate an image compensated to each display on the point of accessing. In this paper, we develop the real-time rendering system where PC Cluster is used to realize the fast image generation by parallel distributed processing. The PC Cluster is a set of multiple low-performance PCs and behaves as one high-performance parallel computer.

Figure 9 shows a schematic diagram of the image reproduction system. The server is connected with PC Cluster and Data Base. The PC Cluster is constructed from several slave PCs with Java technology and connected by CORBA technology. The Data Base is constructed with PostgreSQL. The server also produces a web page with Java Applet and Java Server Pages as an interface to the user. On the web page, all users asked to select the patch as shown in the previous section, and the maximum radiance is estimated from the selected patches. The estimated maximum radiance of the display is preserved in the Data Base. Based on the maximum radiance, glossiness properties are calculated and the PC Cluster begins to generate images adjusted to each display. Finally, the user can watch the adjusted images on the web page.

Conclusion

In this paper, to realize the device independent image reproduction system, we developed the gloss reproduction model and the radiance estimation method with subjective evaluation experiments based on the psychophysical scaling technique. By using these two methods with network programming technology, we have developed the gloss reproduction system.

References

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Biographies

Tetsudo Ikeda was born in Fukushima, Japan, on 13th September 1979. He received B.E. degree in department of information and image science from Chiba University in 2002. Now, he is the master course student in Chiba University. He is interested in Java programming for web and ubiquitous computing technology.

Norimichi Tsumura was born in Wakayama, Japan, on 3rd April 1967. He received the B.E., M.E. and D.E. in applied physics from Osaka University in 1990, 1992 and 1995, respectively. He moved to the Department of Information and Image Sciences, Chiba University in April 1995, as assistant professor. He is currently associate professor since 2002, and also researcher at PREST, Japan Science and Technology Corporation (JST). He was visiting scientist in University of Rochester from March 1999 to January 2000. He got the Optics Prize for Young Scientists (The Optical Society of Japan) in 1995, and Applied Optics Prize for the excellent research and presentation (The Japan Society of Applied Optics) in 2000. He received the Charles E. Ives award in 2002 from the IS&T. He is interested in the color image processing, computer vision, computer graphics and biomedical optics.

Yoichi Miyake has been professor in the Department of Information and Image Sciences, Chiba University since 1989. He received the B.S. and M.E. in Image Science from Chiba University in 1966 and 1968, respectively. He received Ph.D. from the Tokyo Institute of Technology. During 1978 and 1979 he was an academic guest of Swiss Federal Institute of Technology. In 1997, he was a guest professor of University of Rochester. He received the Charles E. Ives award in 1991 from the IS&T. He became a fellow of IS&T in 1995. He also received Electronic Imaging Honoree of the Year in 2000 from SPIE and IS&T. He is one of the pioneers of multi-spectral imaging. He was served as president of Japanese Association of Science and Technology for Identification and the Society of Photographic Science and Technology of Japan. He is currently served as vice president of IS&T.