Appearance reproduction and multi-spectral imaging

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ABSTRACT

Multi-spectral imaging techniques are expected to solve the difficulties of cross-environment color reproduction for objects such as products for e-commerce or designing process, and human skin for tele-medicine. However, color is just one attribute for appearance of the objects. Other attributes such as glossiness, graininess and translucency should be also considered for practical cross-environment appearance reproduction. In this talk, the frame-work for appearance reproduction is introduced with relating the computer graphics, computer vision, and image processing techniques for our practical applications.

1. INTRODUCTION

As the world became smaller with the development of airplane, watchs in the world run faster with the development of the information technology. In the manufacturing industry, the cycle of the development becomes shorter, and it is required to supply the products which reflect the variable preference of the consumers. In this situation, color and appearance of products is one of the important points to reflect the impression for the product.

In the process of product development, the color and appearance are often evaluated by directly observing the trial pieces. The shape of products can be evaluated by making the mock up or showing the computer graphics image. However, it is difficult to evaluate the color and appearance without making a trial piece, since they are dependent on the viewing devices, environmental illuminant. It is said that the evaluation of color and appearance become bottle neck in the cycle of the development. Therefore, it is required to predict the color and appearance, and reproduce them on the display appropriately. In the case of corroborated development between the distant places, it is required to reproduce the color and appearance accurately through computer network.

In this paper, the basic points and a frame-work for the reproduction of color and appearance are introduced, and the case studies are also introduced based on the examples we have performed. The multi-spectral imaging is the key technology for the reproduction of color through the computer network. Although, the frame-work is introduced based on the application for development of products, this frame-work can be applied to the other applications such as the electric commerce, tele-medicine.

2. APPEARANCE REPRODUCION AND COMPUTER GRAPHICS

Figure 1 shows a flow of the evaluation for color and appearance of the trial pieces, which is simplified to show it clear. The trial piece is produced by processing the materials, and evaluated by human observer under some illuminant. The result of the evaluation is fed back to the processing, and the trial piece is improved based on this evaluation. However, huge effort and time are required for this iterative improvement, and this become bottle neck in the cycle of the product development.

By using the computer graphics, an image of the trial piece can be reproduced on the display based on the process in the computer as is shown in Figure 2. It is called Modeling to make the 3D

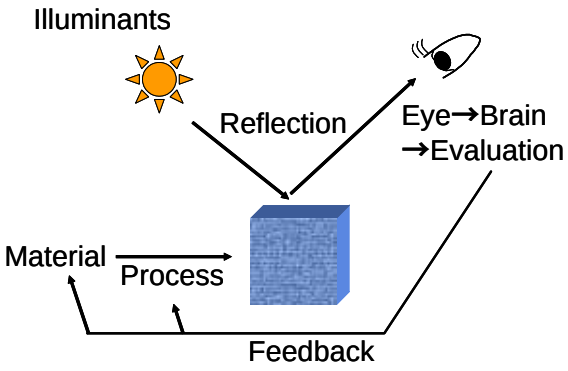

Figure 1: A flow of the evaluation for color and appearance of the trial pieces

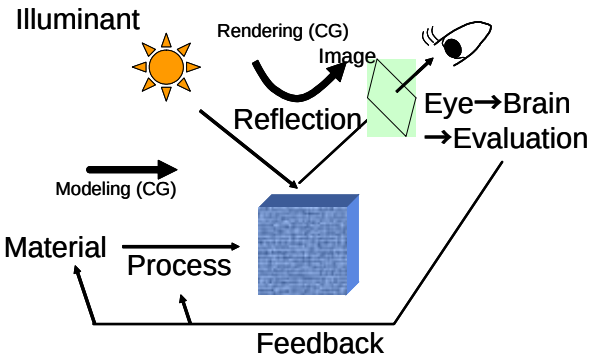

Figure 2: Appearance reproduction and computer graphics

shape and giving the property of reflection on the surface, and Rendering to make the image by casting the optical rays into the 3D shape. The process of rendering needs a long time by ray tracing to obtain the realistic image of the product. Therefore, it was difficult to show the image of the product in real-time under different viewing angle and illuminant. However, recent progress of the graphic processing unit on the graphic board changed the situation lots, and real-time rendering can be possible for the various type of appearance of the products by this hardware. Therefore, it is expected to use the computer graphics in the cycle of product development to evaluate the color and appearance. Moreover, the process of graphic hardware become programmable since 2003, and the more complicated reproduction of appearance become possible year by year.

The color in the computer graphics was R, G and B and α for a long time. The attribute α defines the transmittance of the surface. However, these four attributes were not enough to reproduce the change of color by illuminates and inter-reflection. Recently, necessity of spectral rendering is recognized[1], and studied actively. With the progress of programmable graphics hardware, the spectral rendering will be practically used in the real-time rendering.

3. APPEARANCE REPRODUCION AND COMPUTER VISION

As is written in Section 2, the techniques of realistic reproduction are very substantial these days by the progress of computer graphics. However, there are many products which will take a huge time to model the 3D shape or will be impossible to simulate the process in the computer. For example, in the development of cosmetics, making the model of human face is very important to evaluate the cosmetics on the face, but impossible to make the realistic human face which is customized for the individual.

Image based modelling is studied for these objects that will be difficult to make the 3D shape from pieces. The 3D shape and reflectance properties are estimated from the images which are taken by changing the view points and positions of illuminant. The realistic image under arbitrary view points and arbitrary illuminants can be synthesized from the estimated 3D shape and reflectance properties. These are application of computer vision technologies which recover the scene from the images.

The inverse rendering in Figure 3 indicates the process to extract the reflectance property and 3D shape which are not influenced by illuminates and viewing angle from the taken images. By extracting the unique property of the object, it is possible to predict the image under various conditions. The inverse modelling indicates the process to decompose the reflectance property or 3D shape into the material or elements. This make possible to predict the change of appearance by changing the material property. By using the computer graphics and computer vision technologies based on the characteristic of object, it is possible to synthesize the image under various process and environment.

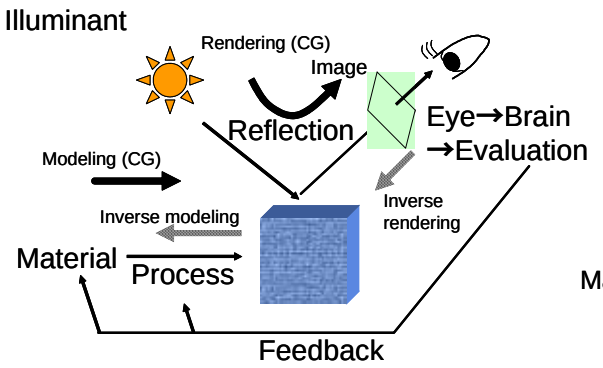

Figure 3: Appearance reproduction and computer vision

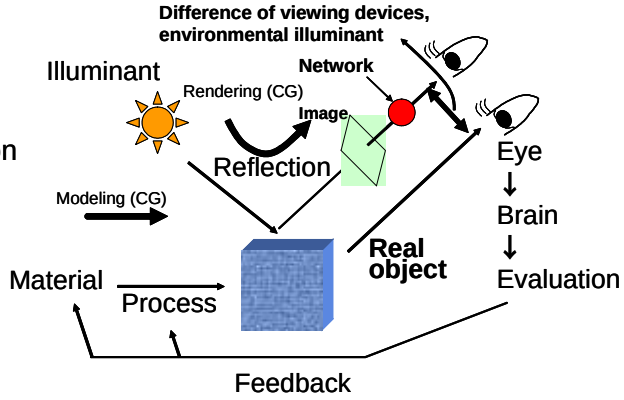

Figure 4: Appearance reproduction and computer network

4. APPEARANCE REPRODUCION AND COMPUTER NETWORK

In the recent process of the product development, it is required to evaluate the products through the computer network to save the time to move between the distant places. Moreover, this is compulsory requirement for the e-commerce and tele-medicine. At this time, as is shown in Figure 4, the change of environmental illuminants and viewing devices are much more important since it influence to the observers sensation. Therefore, it is necessary to consider this change to reproduce the color and appearance appropriately. The spectral imaging is a key technology for the accurate reproduction under various environmental illuminants. The gloss is also one of the important attribute of the appearance. The perceived gloss will be changed with the change of viewing devices. The effective compression of high dynamic range of radiance is necessary for appropriate reproduction of the gloss on the products.

5. CASE STUDIES

5.1 3D COLOR PROOF SYSTEM[2] (APPEARANCE AND COMPUTER GRAPHICS)

There are many kinds of 3D prints such as beverage cans, PET bottles, snack packages, and so on in our life. In the field of B to B e-commerce system on designing and marketing of products, it is required to display measured or simulated images of the 3D prints as is shown in Figure 5. However, these images tend to be higher dynamic range than the luminance range of usual monitor because the 3D prints are made of smooth materials such as papers, plastics, and metals that have sharp and strong specular reflection. Therefore, the images of 3D prints cannot be displayed without certain image processing for dynamic range compression.

Accurate reproduction of contrast gloss and that of color and shading are trade-off in tone

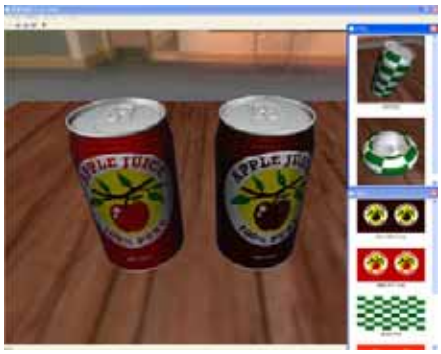

Figure 5: Software to evaluate appearance of the products (with DIC Corp.)

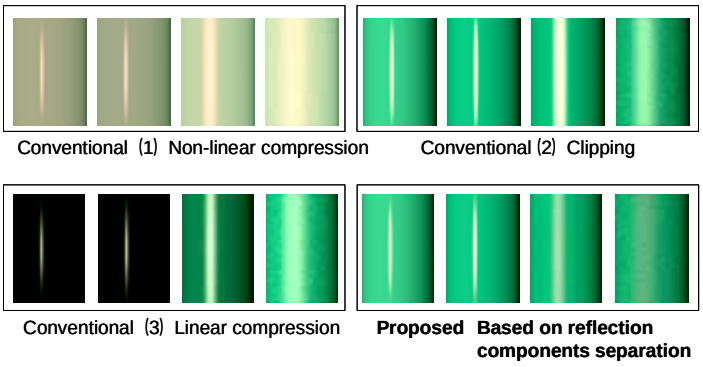

Figure 6: Resultant image by conventional and proposed range compression methods.

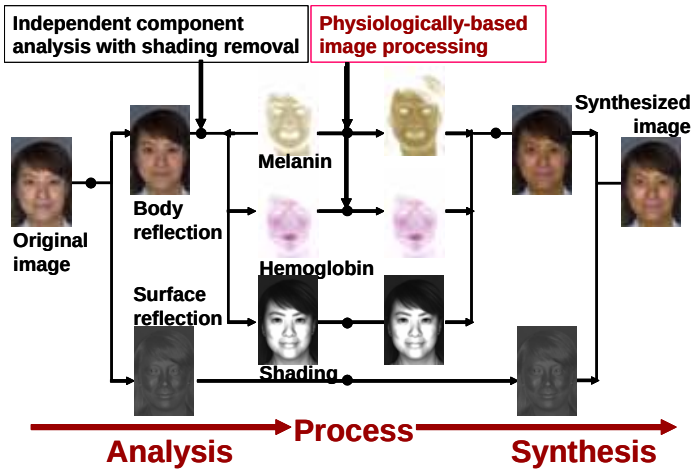

Figure 7: Image based skin color analysis and synthesis (with Kao Corp.)

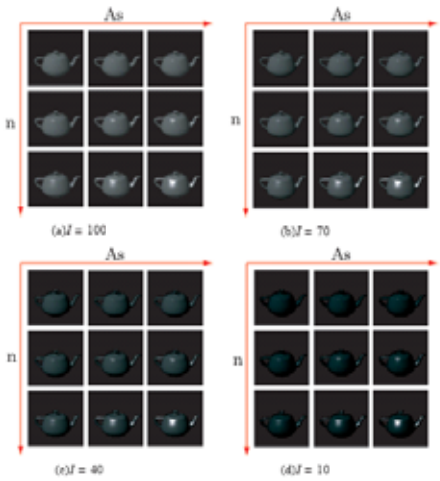

Figure 8: Images used to make the gloss model

mapping. For the accurate reproduction of contrast gloss, it is required to decrease luminance in non-highlight area. The resultant tone mapped images tend to be unsatisfactorily dark except highlight area. On the contrary, it is required to clip luminance in highlight area into the maximum monitor luminance for the accurate reproduction of color and shading. The resultant tone mapped images tend to have less contrast gloss than real objects have.

We proposed to map luminance of diffuse reflection and specular reflection in different ways. It is easy to separate diffuse and specular reflections in rendered images. The BRDF used in the rendering process is formulated as a sum of both reflections. Rendering using BRDF formula of diffuse (specular) reflection gives images of diffuse (specular) reflection. Figure 6 shows the effectiveness of the proposed method.

5.2 IMAGE-BASED SKIN COLOR ANALYSIS AND SYNTHESIS[3] (APPEARANCE AND COMPUTER VISION)

The reproduction of human skin color may be considered the most important function of various imaging systems. With the recent progress of various imaging systems, such as mobile phones with CCD cameras, cosmetic advisory systems, and telemedicine systems, the reproduction of skin color has become increasingly important for image communication, cosmetic recommendations, medical diagnosis, and so on. We proposed an E-cosmetic function for digital images, based on physics and physiologically-based image processing as is shown in Figure 7. A practical skin color analysis/synthesis technique is introduced for this function by extracting hemoglobin and melanin information from a single skin color image taken by digital camera.

5.3 DEVICE INDEPENDENT GLOSS REPRODUCTION[4] (APPEARANCE AND COMPUTER NETWROK)

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 developed the gloss reproduction system based on a perception of the human vision by using the various images of glossiness and radiance of display as is shown in Figure 8. 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. Figure 9 shows an example of the isogloss, which is obtained based on the gloss model. Figure 10(a), (b) shows

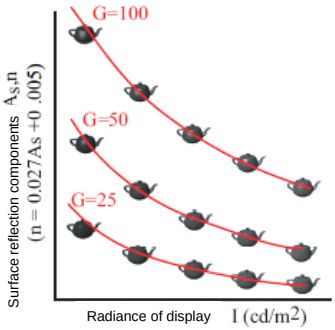

Figure 9: Iso-gloss counters

(a) Original image (b) Before the compensation (c) After the compensation

Figure 10: Device independent gloss reproduction based on the iso-gloss counters

the imageson high radiance display and low radiance display, respectively. The same data is displayed on each device, although the appearance of gloss looks different. Figure 10(c) shows the image compensated along the isogloss contour by keeping the radiance in Figure 10(b). By using images along the contour, we can produce images with same glossiness on different displays.

6. CONCLUSIONS AND AKNOLEGEMNET

The basic points and the frame-work for the reproduction of color and appearance were introduced. The parts of this frame-work have already practiced in various industries. I just summarized those into a frame-work. Dr. Ojima in Kao corporation gave me a great suggestion to summarize this, and Prof. Miyake , Prof. Haneishi and members in our laboratory also gave me a lot of suggestions to summarize this and to perform the case studies. I appreciate their helps to complete this summary

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