A CG Reproduction Method of Human Skin under Omni-directional Illumination

Chika IWASAKI*, Norihiro TANAKA**

**Nagano University, j11006ci@nagano.ac.jp*
*** Nagano University,n-tanaka@nagano.ac.jp*

Abstract: This paper describes a method for 3 dimensional computer graphics(3DCG) reproduction of human skin under omni-directional illumination. In this study, we propose a Multi-spectral rendering technique for the human skin. First, spatial distribution and spectral distribution is measured by RGB digital color camera with fish-eye lens in a scene. Any images are measured at any direction in the scene. Then, these images are composed into omni-directional image. Second, we propose a method for estimating spectral distribution from the omni-directional image. Finally, CG reproduction images of human skin are created under measured scene illumination. The validity of reproduction accuracy is confirmed by measuring color difference of real human skin and reproduction images.

***Key words:* Human skin, CG reproduction, Estimation of spectral distribution, Image Based Lighting , scene illumination**

1. Introduction

Scene illumination such as day light, open-air fire, concert hall is very important for the appearance of an object[1][2]. The appearance of the human skin is depending on scene illumination too. It is important that a CG reproduction system for human skin can reproduce scene illumination precisely. By the conventional RGB-based rendering technique, it is difficult to calculate scene illumination precisely. Therefore, we develop multi-spectral based rendering method for CG reproduction of the human skin. Because multi-spectral information is physical data peculiar to an object, the multi-spectral data is independent of color device such as a camera. The method called Image Based Lighting (IBL)[3] is known as the CG rendering method using the illumination environment of the real scene. In this method, High Dynamic Range (HDR) images[2] of the scene are measured as scene illumination information. In this study, we develop multi-spectral based IBL for CG rendering of the human skin. The IBL system can reproduce shade and luster of the skin under the real scene illumination environment. In order to predict a change of the shade of the skin under illumination environment, we describe surface reflection properties on the skin surface quantitatively. In this study, we describe the surface reflection properties on the skin surface as reflection model. In this study, we develop a mathematical model for describing the surface reflection process on the skin surface. The model is called as reflection model or surface light reflection model.

The paper describes five parts as follows, (1) development of a measuring method for omini-directional HDR image as spatial-distribution of the scene illumination, (2) Estimation of color signal (spectral distribution) from the omini-directional image, (3) Development of the reflection model for human skin, (4) CG rendering method for human skin under scene illumination with estimated color signal, (5) Implementation to GPU of the proposed method. Finally, the validity of reproduction accuracy is confirmed by measuring color difference of real human skin and reproduction images.

2. Multi-spectral omni-directional imaging

2.1 Omni-directional imaging with fish-eye lens

The spatial distribution and spectral distribution are measured by RGB digital color camera and fish-eye lens. Because measuring range of fish-eye lens is less than 180deg, the lens cannot measure all direction in the scene at a time. We measure plural images and compose it while changing a direction. Unlike normal lenses, the fish-eye lens is equidistant projection. A distance on image is y, focal length of the fish-eye lens is f, and half astamuse is ϕ. Then, the relation of these parameters can be described as $y = f\phi$. Figure 1 shows process of producing omni-directional image from composing the measured images. Where azimuth angle is θ, and elevation angle is φ.

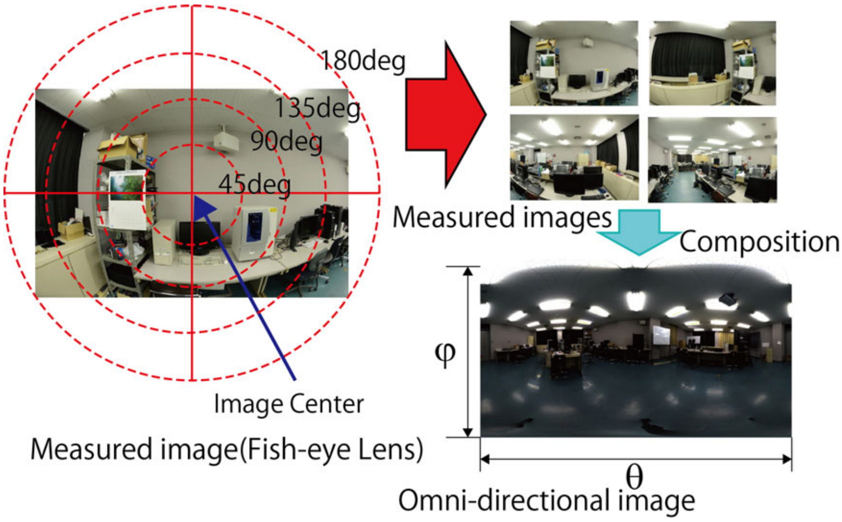


Figure 1. Process of producing omni-directional image from composing the measured images.

2.2 Estimation of spectral distribution from omni-directional image

We propose a method for estimating spectral distribution based on statistical method with color patches and a spectrophotometer. In this method, we assume that principal illumination in the scene consist of one type light source for calibrating spectral sensitivity of an RGB color camera. In this study, we described the spectral information as 61 dimensional vector that is sampled at 5nm intervals in the visible light wavelength region (400-700nm). $\mathbf{\Lambda}$ and $\mathbf{P}$ are $61 \times m$ matrix of m-tuple spectral distribution and $3 \times m$ matrix of m-tuple camera outputs, respectively. $\mathbf{t}$ is 61×3 matrix of camera sensitivity. The relation of these matrixes is described as $\mathbf{P} = \mathbf{\Lambda t}$. We estimated $\mathbf{t}$ as $\mathbf{t} = \mathbf{\Lambda}^{+}\mathbf{P}$ using pseudo inverse matrix $\mathbf{\Lambda}^{+}$ of matrix $\mathbf{\Lambda}$. Then, 3×1 matrix $\mathbf{e}$ of the spectral distribution of light source can be estimated as $\mathbf{e}^{T} = \boldsymbol{\rho}^{T}\mathbf{t}^{-1}$ using inverse matrix $\mathbf{t}^{-1}$ of $\mathbf{t}$.

3. Reflectio model for Human skin

The light reflection process on the human skin is described as the reflection model [4]. The reflection model is mathematical model which is described by reflection geometry and surface reflection properties [2]. Figure 2 shows the reflection geometry on the human skin surface. It should be noted that the reflection properties of an object's surface depend on its surface material, and these properties are related to both spectrum and geometry. Moreover, subsurface scattering occurs on the skin surface. Previous studies on rendering images of various objects were limited to color images using the RGB color identification system. An RGB color image is device-dependent and valid for only the fixed conditions of illumination and viewing. Multi-spectral information data is more important and useful than color information for rendering images of human skin. The appearance of human skin can be described as a mathematical model of a multi-spectral reflection model. The model is developed based on a wrap-lighting model. The color signal $C(\lambda)$ from the surface of human skin is a function of the wavelength λ. The reflection model of skin is described as follows:

$$C(\lambda) = \left\{ \alpha \mathbf{N} \cdot \mathbf{L} + \alpha \frac{\mathbf{N} \cdot \mathbf{L} + l}{1 + l} S_s(\lambda) \right\} S(\lambda) E'(\lambda), \quad \mathrm{E}'(\lambda) = \mathrm{E}(\lambda) \exp(-s \cdot \delta), \tag{1}$$

where α is the intensity of diffuse reflection on a skin's surface, **N** is the normal vector of the object's surface, **L** is the incident light vector, and **V** is the viewing vector. $S(\lambda)$ and $S_s(\lambda)$ are the spectral reflectance and scattering spectral reflectance, respectively. $E(\lambda)$ is the spectral distribution of illumination. δ and s are opacity of the material and length of the light path, respectively.

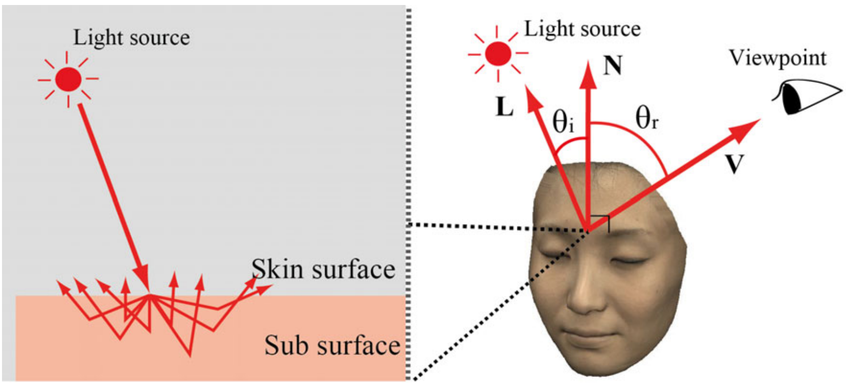


Figure 2. Geometric model of reflection from the skin's surface.

4. CG rendering method for human skin under scene illumination with estimated color signal

The spectral reflectance and reflection properties are estimated from images with different illumination and viewing angles. The measuring system consists of a lighting system, two goniometric rotating arms, and an RGB camera system. The intensity at the skin reflection point depends on the subsurface scattering parameter and the constant coefficient l. That is, the model function with unknown l and α is fitted to the intensity data of the skin surface acquired at different angles of θ_i and θ_r. After we obtained all the rendering parameters, we precisely created the CG image based on measurement data. The re-produced human skin was rendered under omni-directional illumination distribution in several scenes. To improve rendering performance, we made a reflectance map from the omni-directional scene illumination. The reflectance map is described as $I_{\mathrm{diffuse}}(\lambda, \theta, \phi)$, where (θ, ϕ) is a polar coordinate system. The color signal $C(\lambda)$ under omni-directional illumination is described as follows:

$$\begin{aligned} C(\lambda, \theta, \phi) &= \alpha I_{\mathrm{diffuse}}(\lambda, \theta, \phi) S(\lambda) E(\lambda, \theta, \phi) \\ &= \alpha \left\{ \mathbf{N} \cdot \mathbf{L}(\theta, \phi) + \frac{\mathbf{N} \cdot \mathbf{L}(\theta, \phi) + l}{1 + l} S_s(\lambda) \right\} S(\lambda) E(\lambda, \theta, \phi) \end{aligned}. \tag{2}$$

The tristimulus values X, Y, and Z of the spectral radiance are calculated from $C(\lambda,\theta,\phi)$. The model was implemented in the rendering system for human skin using an omni-directional illumination spectral distribution.

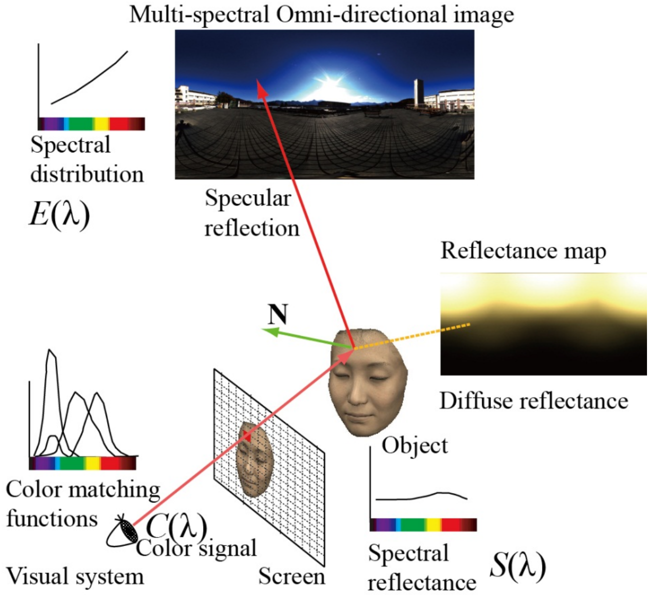


Figure 3. Rendering system for human skin.

5. Experimental results

We estimated color signal as spectral distribution in three scenes. First scene is a room illumination which is consisting of fluorescent lamp. Second scene is a hall which is consisting of incandescent lamp. Third scene is outdoor scene which is consisting of sun light. Figure 4 is color chart (Gretag Macbeth color chart SG) for experimentation. Figure 5 is estimation results of color signal of color patch of the color chart. The accuracy of the estimated spectral distribution was examined at three areas in figure 4. In this experimentation, we measured the color chart under the three scenes. Figure 5, Figure 6 and Figure 7 show the estimation results of spectral distributions, where the solid curves represent the estimated spectral distributions, the broken curve represent the spectral distribution measured by the spectrophotometer. A comparison between two curves in each graph suggests the reliability of the proposed estimation algorithms. Figure 8, Figure 9 and Figure 10 shows estimation results of spectral distribution as omni-directional image and reflectance map in each scene. Figure 11 is a measured human data and its spectral reflectance [5]. Figure 12, 13, 14 is CG reproduction results of the human data under each scene illumination.

6. Conclusions

We proposed a method for estimating scene illumination in the scene for CG reproducing the human skin. First, the spectral distribution was estimated from the image data. Next, reflection properties were modeled using the reflection model of the human skin. The performance of the proposed method was examined in detail in an experiment using real human skin. We showed the estimation results for the spectral distribution. The overall feasibility of the proposed method was confirmed based on computer graphics images created using the estimated scene illuminations.

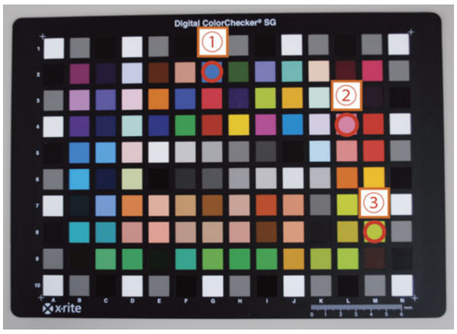
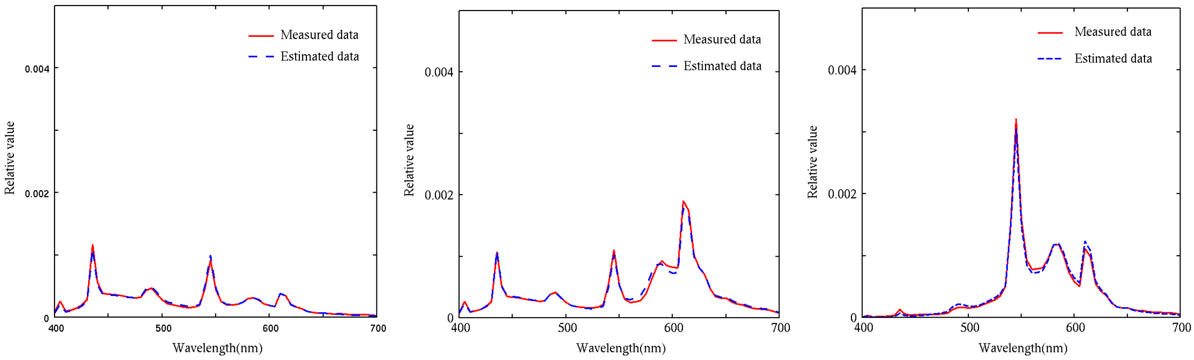
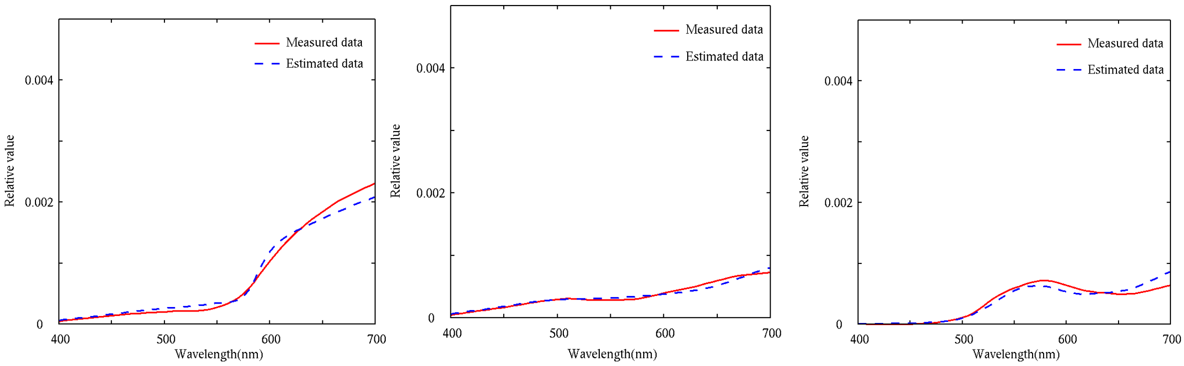


Figure 4. Measured image of a color chart(Gretag Macbeth color chart SG).



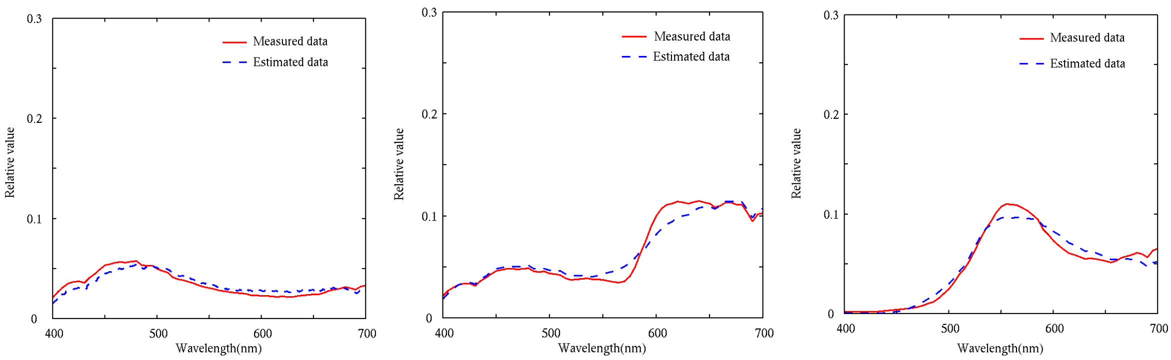
(1) Area 1 (2) Area 2 (3) Area 3

Figure 5. Estimation results of spectral distribution in the room scene with fluorescent lamp.



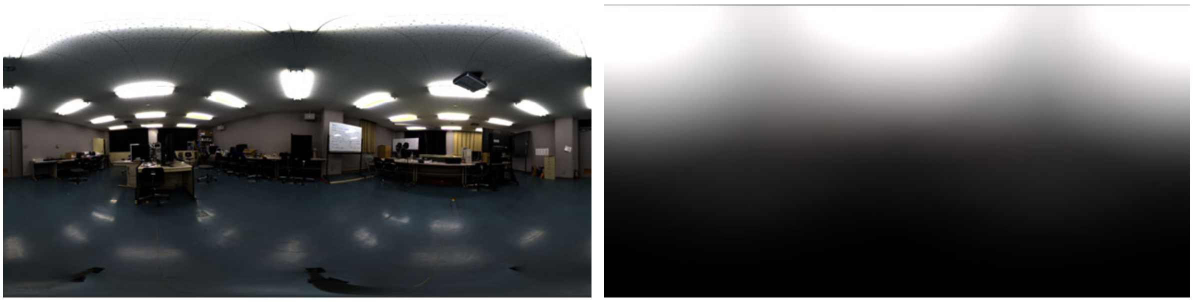
(1) Area 1 (2) Area 2 (3) Area 3

Figure 6. Estimation results of spectral distribution in the hall scene with incandescent lamp.



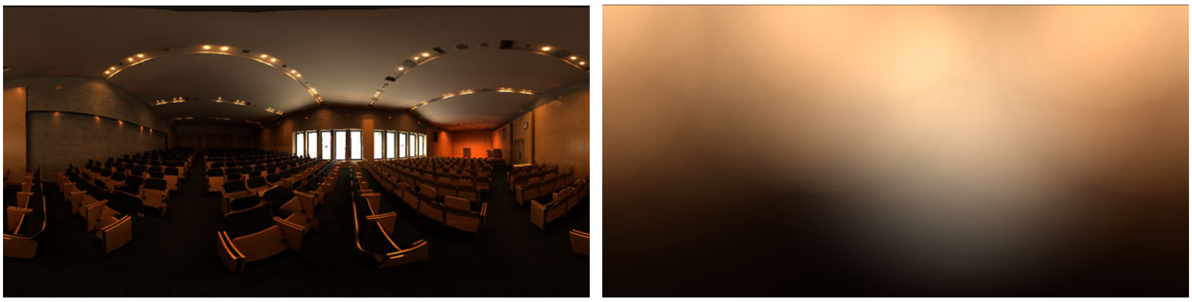
(1) Area 1 (2) Area 2 (3) Area 3

Figure 7. Estimation results of spectral distribution in the outdoor scene with sun light.



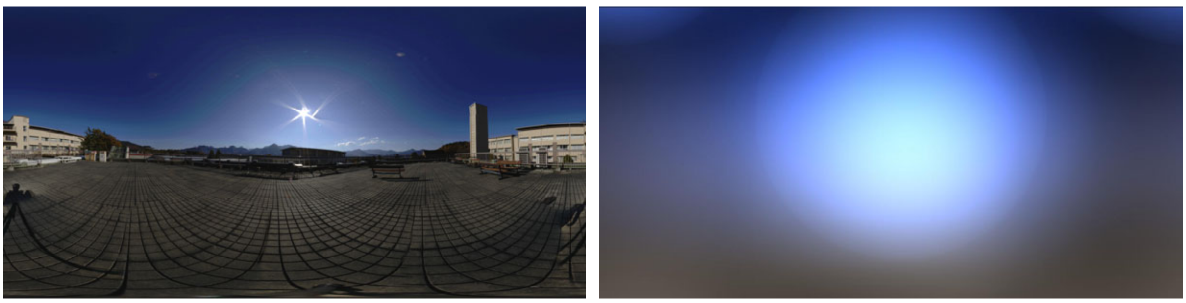
(a) Omni-directional image (b) Reflectance map

Figure 8. Estimation results of scene illumination in the room with incandescent lamp.



(a) Omni-directional image (b) Reflectance map

Figure 9. Estimation results of scene illumination in the hall with incandescent lamp.



(a) Omni-directional image (b) Reflectance map

Figure 10. Estimation results of scene illumination in the outdoor scene with sun light.

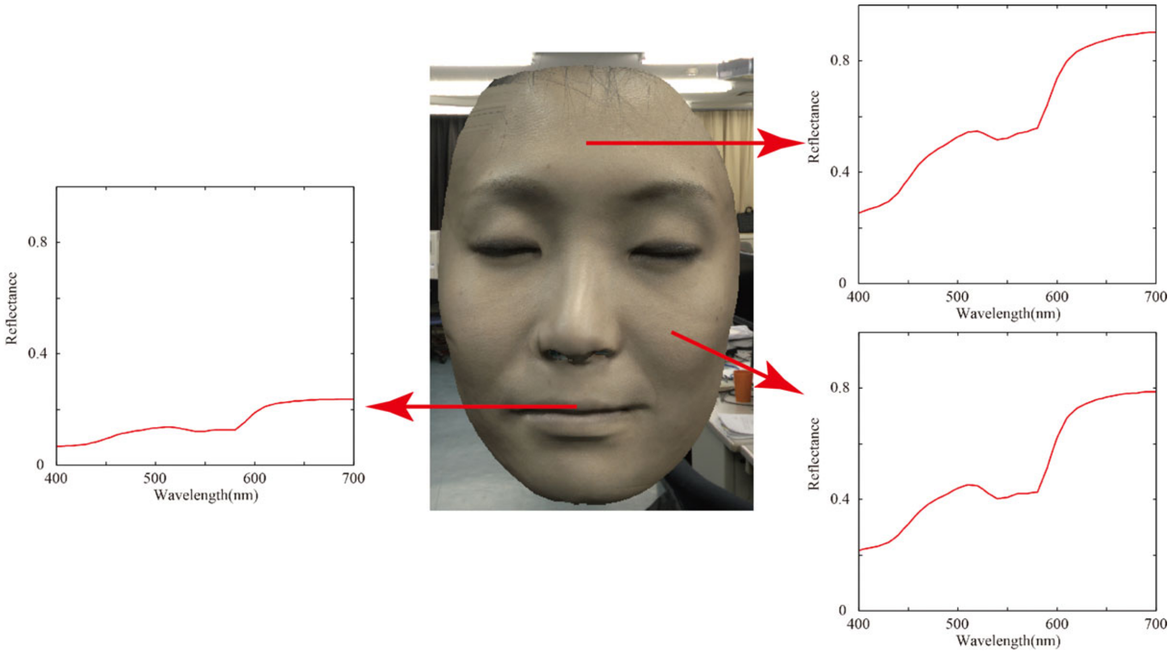


Figure 11. Human model and its spectral reflectance.

Figure 12. CG reproduction results of human skin in the room (CG image).

Figure 13. CG reproduction results of human skin in the hall (CG image).

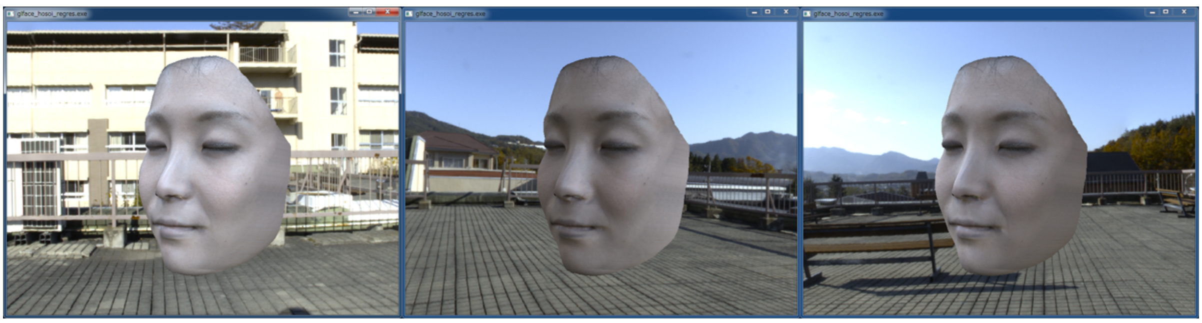


Figure 14. CG reproduction results of human skin in the outdoor scene (CG image).

References

[1] C. C. Chiao, T. W. Cronin, and D. Osorio (2000) Color signals in natural scenes: Characteristics of reflectance spectra and effects of natural illuminants, J. Opt. Soc. Am. A 17, 218

[2] N. Tanaka, K. Mochizuki and J. Woo (2009) A Real-time Rendering Method of Art Objects Based on Multi-spectral Reflection Model, Proc. of IASDR, 4 pages

[3] P. E. Debevec (1998) Rendering Synthetic objects into real scenes:bridging traditional and image-based graphics with global illumination and high dynamic range photography, Proc. Of SIGGRAPH 98, pp.189-198

[4] P. Hanrahan and W. Krueger (1993) Reflection from layered surfaces due to subsurface scattering, Proc. of SIGGRAPH, pp. 165-174

[5] N. Tanaka, K. Mochizuki and J. Woo (2012) Imaging and rendering of human skin an RGB color camera, AIC 2012, 4 pages