Image-Based Control of Skin Translucency

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Abstract

This paper introduces a method for skin translucency control of facial images. Controlling the skin translucency is one of the important tasks in the reproduction of posters, TV commercials, movies, and so on. As the first step of processing, we extracted the component maps of melanin, hemoglobin and shading from skin color images by the method of Tsumura et al. The extracted shading component is controlled to change the translucency of the skin by simple kernel operations for the component. The physical validity for the change of translucency is confirmed by using the images of optical skin phantoms.

Introduction

Controlling the skin translucency is one of the important tasks in the reproduction of posters, TV commercials, movies, and so on. The skin translucency is often controlled manually by an experienced operator in a time consuming process. Therefore, a useful method for controlling the skin translucency is expected to be developed in the fields of imaging to accelerate their reproduction processes.

The spread of high-resolution imaging systems such as high-definition television is of great importance to people in the entertainment world, such as actors, actresses, and newscasters, since their skin appearance can thus be revealed in great detail by these imaging systems. A method for controlling the skin translucency would be also useful in this field.

In this paper, we introduce a method for skin translucency control. A shading component is controlled to change the translucency of skin by simple kernel operations for the component. The shading component is extracted by the method of Tsumura et al.[1,2] which can separate the color images into the component maps of melanin, hemoglobin, and shading. The physical validity for the change of translucency is confirmed by images of optical skin phantoms. This control is also applied to real skin images.

Related work

Skin translucency is related to the subsurface scattering of light in the skin layers. In reproducing the skin translucency, the model based approach has recently experienced great progress for interactive rendering [3-7] with the calculation of the subsurface scattering. Jensen et al. [3]proposed a practical BSSRDF (Bi-directional Scattering Surface Reflectance Distribution Function) model based on the diffusion approximation of multiple scattering. Jensen and Buhler [4] decoupled the computation of irradiance from the evaluation of the diffusion approximation to speed up the rendering process. Based on this decoupling, the local response due to subsurface scattering can be stored as kernels for an irradiance map [5-7]. Our method to control the translucency is the same process as this kernel based process on an irradiance map, although our technique is an image-based approach. Goesele et al.8) illuminated individual surface points by a scanning laser projector, and the object's impulse response is recorded with a high-dynamic-range video camera to capture the translucent object. This technique can also be considered as an image-based approach, although tremendous measurements are impractical for human skin. No practical image-based model has been proposed yet for skin.

This paper proposes a practical image-based method for skin translucency control.

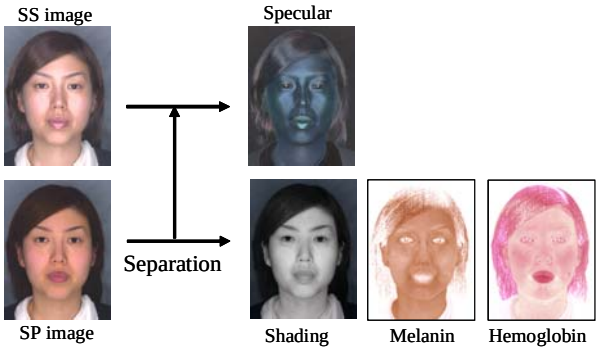


Figure 1. *Separation of two images with different polarizing filters into specular, shading, melanin, and hemoglobin components based on the method of Tsumura et al. [1,2]. In this paper, interactive separation is introduced into the original method to improve the separated results.*

Skin Components Separation

For the control of skin translucency, it is necessary to extract the shading components from color images as is written in the next section. We used the technique proposed by Tsumura et al. [1,2] to separate two images with different polarizing filters into specular, shading, melanin and hemoglobin components, as shown in Figure 1. Since the original process by Tsumura et al. [1,2] was unstable for obtaining well-separated components, we improved their technique by introducing an interactive operation for finding the basis vector of the components.

We define $\boldsymbol{v}_{ps}$ as the color vector taken by the P-polarized illumination and S-polarized filter in front of the camera at the current pixel, and $\boldsymbol{v}_{pp}$ is the vector taken by the P-polarized illumination and P-polarized filter. The diffuse reflectance components $\boldsymbol{v}_d$ are calculated as $\boldsymbol{v}_d = 2\boldsymbol{v}_{ps}$ and the specular reflectance components $\boldsymbol{v}_{sp}$ are calculated as $\boldsymbol{v}_{sp} = 2(\boldsymbol{v}_{pp} - \boldsymbol{v}_{ps})$. The diffuse reflection is transformed into the density space as $\boldsymbol{v}_d^{\log} = -\log(\boldsymbol{v}_d)$. The diffuse component in the density space is separated into the component vector of the melanin, hemoglobin and shading components as follows,

$$\boldsymbol{c} = B^{-1}\boldsymbol{v}_d^{\log} \quad (1)$$

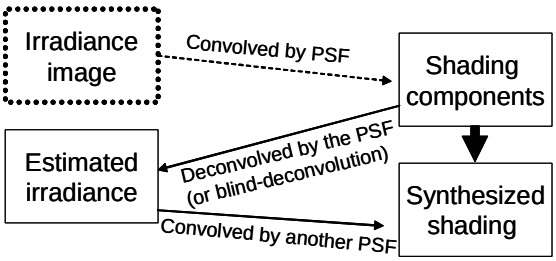


Figure 2. *Estimation of irradiance by deconvolving the point spread function (PSF) of the medium. The new shading component is simply calculated by convolution between the estimated irradiance and another PSF.*

where $B = [\boldsymbol{b}_M \quad \boldsymbol{b}_H \quad \boldsymbol{1}]$ and $\boldsymbol{b}_M$, $\boldsymbol{b}_H$ are the basis vectors for melanin and hemoglobin, respectively, in the density space, and $\boldsymbol{1}$ is the vector for shading.

The basis vectors for melanin and hemoglobin components, $\boldsymbol{b}_M$, $\boldsymbol{b}_H$, are extracted by using the independent components analysis, as was done by Tsumura et al. [1,2].

Since their original method occasionally fails to extract the components in our imaging system, we modified the technique by introducing the two-step interactive process. From the pattern of the texture of the components, it is easy to evaluate the separated map of components, whether they are well separated or not. The first step of the interactive technique iterates the independent component analysis by changing the region of the analysis, and then the separation is evaluated by the user. The iteration will finish if the separation is evaluated as generally valid. The second step of the interactive technique is performed interactively to adjust the basis vectors, $\boldsymbol{b}_M$, $\boldsymbol{b}_H$, to adequately separate the melanin, hemoglobin and shading components. The adjustment is performed using the graphical user interface to move the basis vector in two-dimensional space, and the resultant separations are visualized in real time.

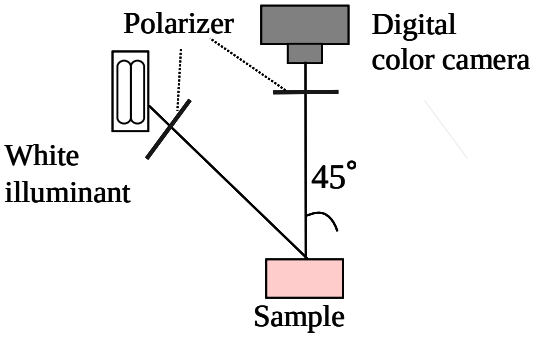
Image-based translucency control

The extracted shading component is used to control the translucency of skin appearance. Since the local response due to subsurface scattering can be represented as kernels for an irradiance map [5-7], the shading component image $Sh(x, y)$ can be expressed by the irradiance $L(x, y)$ and kernel $K(x, y; x', y')$ as follows.

$$Sh(x, y) = \iint L(x', y')K(x, y; x', y')dx'dy' \tag{2}$$

In this paper, the kernel is assumed homogeneous in the image and is expressed by the point spread function (PSF) as $PSF(x, y) = K(x, y; x', y')$. As shown in Figure 2, the shading component is simply calculated by convolution between the irradiance and PSF as follows.

$$Sh(x, y) = \iint L(x', y')PSF(x - x', y - y')dx'dy' \tag{3}$$



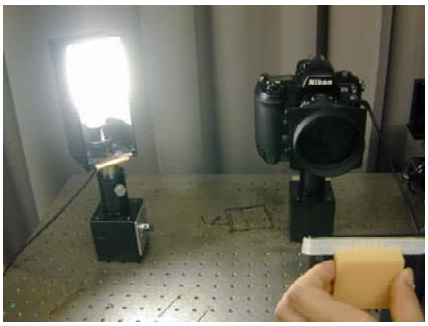


Figure 4. *Imaging system to take the image of the phantoms*

Based on the above insight, it is easily understood that the irradiance can be estimated by deconvolving the PSF (if it is known) or blindly deconvolving for the shading component. The estimated irradiance can be convolved by another PSF to get the synthesized appearance of the skin translucency. In the following paragraphs, we will confirm the physical validity of our proposed method by using the optical skin phantoms.

Figure 3(a) shows the phantoms prepared by changing the scattering coefficients of the medium. The particles of the foundation used in cosmetic material are induced into the silicon to change the scattering coefficient. The induced foundation is 0.5%, 0.2%, 0.15%, 0.1% and 0.05% from left to right in Figure 3. There are lined cuts at each phantom to imitate wrinkles on the skin. The shapes of the cuts are the same for all phantoms, since the cuts are modeled after the same mold. Figure 4 shows the imaging geometry for taking the image of the phantoms. The sample is illuminated from 45 degrees and the image is taken from 0 degrees. The polarized filters are used to remove the specular reflection. Figure 3(b) shows the image taken of the phantoms, and the change of translucency can be seen with the change of the amount of induced foundation. The PSFs are also measured by using the similar method of Jensen et al. 3). Figure 3(d) shows PSFs in the logarithmic space, which is measured for each phantom.

Figure 5 shows the result of deconvolution of the image for the 0.5% phantom. We cannot feel the translucency from the resultant image, and the contrast by cuts is well reconstructed as if it is a plastic. We apply the other PSFs of the phantoms to this deconvolved image from the 0.5% phantom. Figure 3(c) shows the resultant synthesis for the 0.2%, 0.15%, 0.1% and 0.05% PSFs. Comparing Figures 3(b) and (c), we can see that our image-based translucency control works very well in these samples.

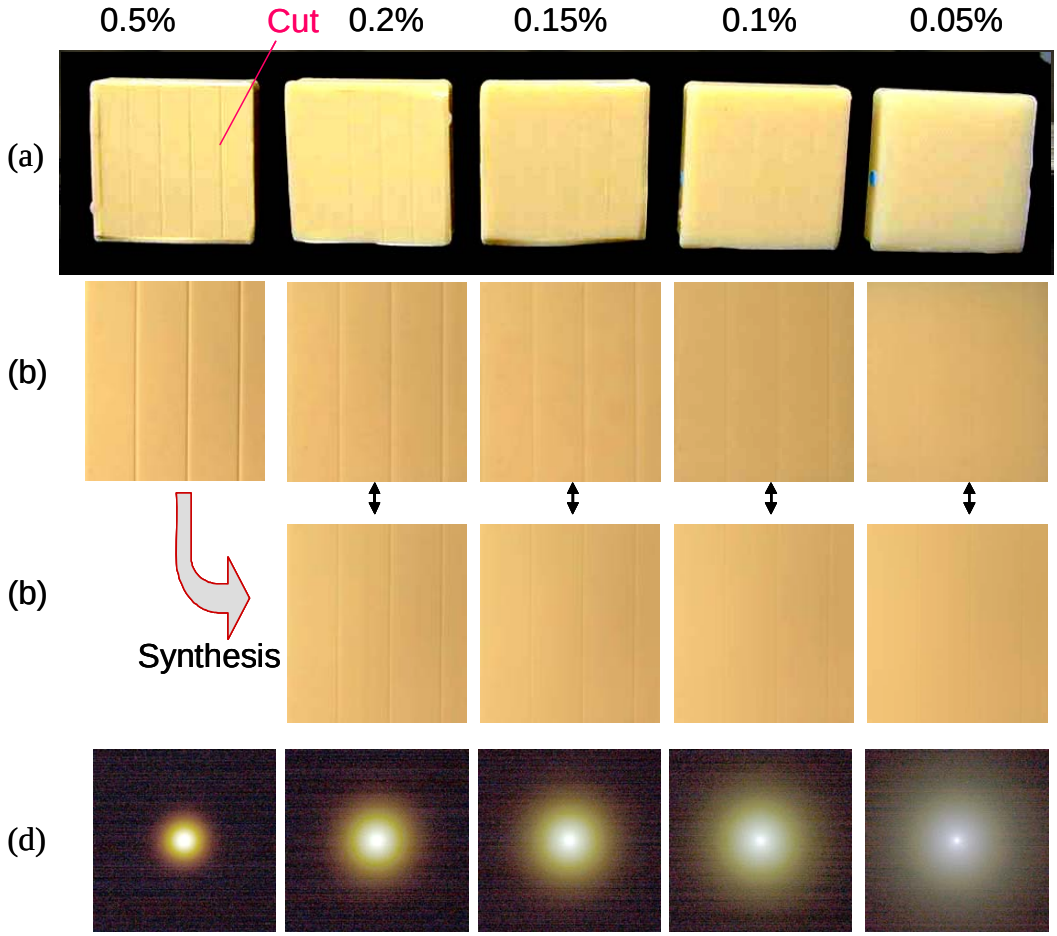


Figure 3. *The physical validity of the proposed control of translucency. (a) optical skin phantoms prepared by changing the scattering coefficients of the medium. The particles of foundation used in cosmetic material are induced into the silicon to change the scattering coefficient. The induced foundation is 0.05%, 0.2%, 0.15%, 0.1%, 0.5% from left to right, (b) Images of the phantoms. The change of translucency can be seen with the change of the amount of induced foundation, (c) The resultant syntheses for 0.2%, 0.15%, 0.1%, 0.05% PSFs for a real image of 0.5% density. (d) PSF for each phantom.*

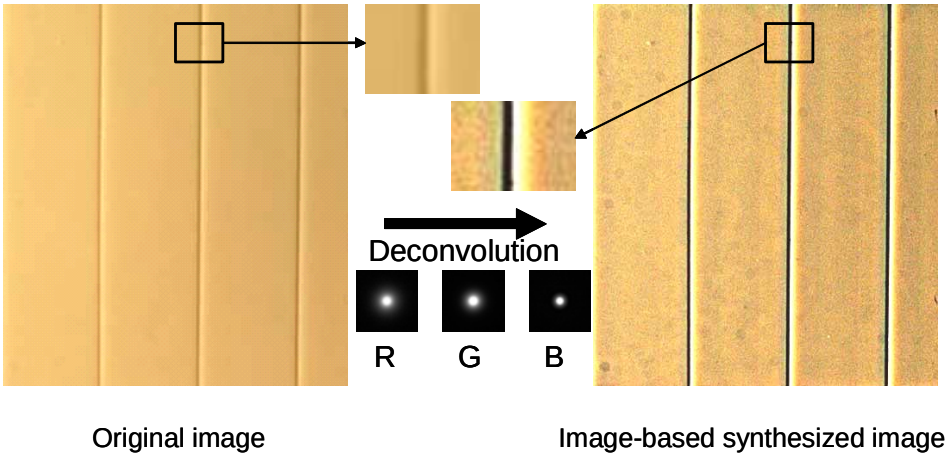


Figure 5. *The result of deconvolution for the image of the 0.5% phantom by using the PSF measurement*

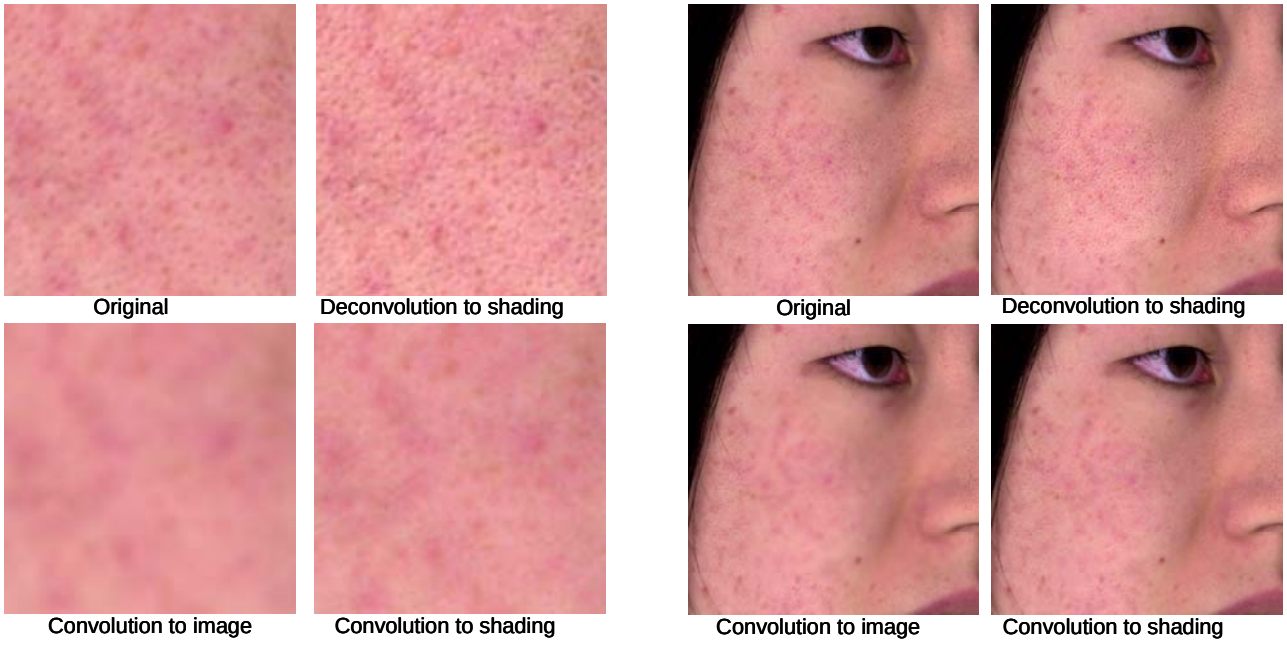


Figure 6. *Change of skin translucency*

Experimental results

We applied this control to real skin images. The shading components are separated from the real skin images by using the method of Tsumura et al.1,2). The blind deconvolution is applied to the shading components since the PSF is not known in the skin image. Then another PSF is applied to the deconvolved image to get the synthesized appearance of the increased translucency. Figure 6 shows the results of the images: (a) original image, (b) deconvolved image for shading components, (c) convolved image for the shading component, (d) convolved image for all RGB components in the color image. It is seen that the translucency of skin is controlled by our proposed method. On the other hand, the convolved images for the color image show that conventional blurring cannot control the translucency of the skin.

Conclusion

The shading component is extracted from the color image by using the method by Tsumura et al. The shading component was controlled to change the translucency of the skin by a simple convolution process. The resultant images showed the effectiveness of the proposed method to control the skin translucency realistically.

Acknowledgment

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Author Biography

Norimichi Tsumura was born in Wakayama, Japan, on 3 April 1967. He received the B.E., M.E. and Dr. Eng degrees in applied physics from Osaka University in 1990, 1992 and 1995, respectively. He moved to the Department of Information and Computer Sciences, Chiba University in April 1995, as an assistant professor. He was a visiting scientist in University of Rochester from March 1999 to January 2000. He is currently associate professor in Department of Information and Image Sciences, Chiba University since February 2002, also a researcher in PRESTO, Japan Science and Technology Corporation (JST) since December 2001. He got the Optics Prize for Young Scientists (The Optical Society of Japan) in 1995, Applied Optics Prize for the excellent research and presentation (The Japan Society of Applied Optics) in 2000, Charles E. Ives Award (Journal Award: IS&T) in 2002 and 2005. He is interested in the color image processing, computer vision, computer graphics and biomedical optics.