An Evaluation of the Relationship between Impression and the Physical Properties of Human Skin

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1 Introduction

The visual expression of a surface quality of human skin is required in a wide range of fields, such as in cosmetics industry. It is much harder, however, to generate intuitively and accurately a computer graphics (CG) image of human skin that has a desired impression without professional knowledge and skills because of its complex physical properties. It is necessary to model the linkage between the visual impressions and physical properties of human skin in order to effectively determine parameters for the generation of CG images.

In this research, we focus on the physical properties of bare skin, clarify impression factors of bare skin and formulate the relationship between these impression factors and physical quantities of bare skin. This will enable us to estimate an impression from a human skin image and derive physical quantities for the accurate generation of human skin images that have desired impressions.

2 Generating a human skin image based on physical quantities

In order to model the relationship between an impression and a physical quantities of human skin, it is necessary to clarify the impressions of human skin. Here, we generated CG images controlled by typical physical quantities mentioned later as visual stimuli in a subjective evaluation experiment for investigating impression factors.

2.1 Biophysically-Based Model

We used biophysical quantities of human skin as parameters for the generation of CG images. Stephen, Ian D. et al. reported that the blood circulation, melanin and β-carotene influence "healthy exterior"[Stephen et al. 2011]. It is reasonable, therefore, to support that biophysical quantities of human skin can be linked to impression factors.

We adopted the Biophysically-Based Model[Iglesias-Guitian et al. 2015] to render human skin images accurately based on physical quantities. In this model, bare skin consists of 5 layers. The parameters such as the scattering coefficient and the absorption coefficient, which are required to render a human skin image, were determined from the proportion of eumelanin and pheomelanin in the melanin, the proportion of oxyhemoglobin and deoxyhemoglobin in the hemoglobin, the melanin, the hemoglobin, β-carotene and the quantity of water in each layer. Subsequently, we accurately rendered human skin images based on these parameters by the Monte Carlo simulation. Finally, we obtained various human skin images by changing the quantity of 7 coloring matters except β-carotene and the quantity of water. Moreover, this model can express a change in the surface quality of human skin caused by the changes of thickness and fine surface roughness due to aging.

2.2 Generating visual stimuli

We controlled 3 typical physical quantities of human skin, the amount of melanin, the amount of hemoglobin and "configuration characteristics," which include skin thickness and the height of fine surface roughness, as parameters for generating human skin images. These physical quantities cause a stronger visual influence on an impression of bare skin than other physical quantities. Table 1 shows the levels of each physical quantity of human skin.

We rendered 75 human skin images with varying parameters using PBRT [Pharr et al. 2010] as a physically-based renderer. The rendering results of melanin 9% are shown in Figure 1. In rendering, we utilized the same 3D model and texture in order to remove influences caused by caused by parameters other than these three. Moreover, we rotated viewpoints at 5 degree intervals and rendered 5 images in order to express differences due to a viewpoint (Figure 2). Finally, we trimmed away everything except cheek positions of the human skin images, and adopted these images as visual stimuli for a subjective evaluation experiment. Figure 3 shows human skin images in each amount of melanin and hemoglobin when the configuration characteristic were 30 and 80.

Table 1: *Parameters*

Physical property	Set value
melanin pheomelanin:94%, eumelanin:6%	0 ~ 36% (by 9%)
hemoglobin oxyhemoglobin:64%, deoxyhemoglobin:36%	0.1 ~ 20.1% (by 5%)
bilirubin	0.014%
configuration characteristic	30, 55, 80

Figure 1: *Rendering result*

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Figure 2: *Human skin images with rotating viewpoint*

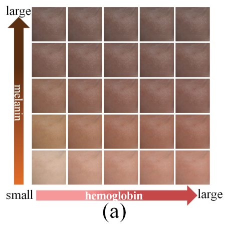

Figure 3: *Human skin images were rendered in each amount of melanin, hemoglobin and (a) configuration characteristic at age 30, (b) configuration characteristic at age 80.*

3 Subjective evaluation experiment

We conducted a subjective evaluation experiment to investigate the impression factors of bare skin. Prior to this experiment, we collected 21 adjectives for low-order impression and 15 adjectives for high-order impression, which describe the condition of bare skin appropriately as an adjective scale. Adjectives for low-order impression include "moist", "soft", "resilient", "glossy", "shiny", "translucency", "dry", "color evenness", "white", "oily", "sticky", "fatty", "arid", "less moist", "desiccated", "muddy", "dull", "color unevenness", "bloated", "chunky" and "yellow". Adjectives for high-order impression include "ruddy", "lively", "youthful", "pure", "beautiful", "neat", "simple", "natural", "general", "subdued", "clam", "mature", "tired", "unhealthy" and "unattractive". These adjectives are the Japanese language.We rendered 75 human skin images mentioned in Section 2 as visual stimuli.

3.1 Method

The subjects of this experiment were 10 Japanese college students in their 20s (6 men; 4 women; average=22.5; SD=0.67). They evaluated 36 adjective scales about 75 human skin images in 7 stages.

3.2 Results and discussion

We performed a factor analysis for rating the data using the maximum likelihood method and the Promax rotation. As a result of the factor analysis, we extracted 3 factors based on the Kaiser-Guttman criterion. In low-order impressions, we determined that Factor 1 is "sticky," given that the factor loadings for "oily" and "sticky" were high. Factor 2 is "translucent," given that the factor loadings for "white" and "translucency" were high. Factor 3 is "moist," given the factor loadings for "moist" and "glossy." In high-order impressions, we determined that Factor 1 is "beautiful," given that the factor loadings for "neat" and "beautiful" were high. Factor 2 is "vital," given that the factor loadings for "ruddy" and "lively" were high.

4 Modeling the relationship between visual impressions and physical properties

We developed a predictive model to associate the impression factors in low and high-order and physical quantities. We constructed the 3-layered model that enables us to estimate the high-order impressions through the low-order impressions from the physical properties. The model is shown in Figure 4.

As shown in Figure 4, it was revealed that the "transparency" was contributed by melanin and hemoglobin. This result supports the results in a previous work[Masuda et al. 2005], which reported that the amount of light absorption diminishes and the transparent increases with decreasing melanin or hemoglobin. "Sticky" and "moist" are similar impressions. However, "sticky" has a positive correlation with the amount of melanin, and "moist" has a negative correlation with the amount of melanin. Moreover, "sticky" is influenced by the amount of hemoglobin. It means that "sticky" increases when human skin turns pinker or darker, and "moist" increases when human skin becomes fairer. In addition, "sticky" has a contrary correlation with "moist" to high-order impression. That is to say, "sticky" and "moist" are quite different impressions.

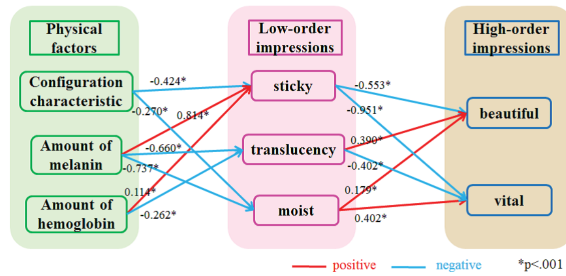

Figure 4: *3-layered model*

5 Conclusion

In this work, we modeled and evaluated the relationship between the impression factors and physical properties of human skin. First, we generated human skin CG images controlled by typical physical quantities. Next, we conducted a subjective evaluation experiment using collected adjective words and generated human skin images to investigate the impression factors of bare skin. Finally, we associated the impression factors in low and high-order and physical quantities of bare skin. As a result, we confirmed detailed differences of sticky and moist, which are unknown to experts in this field. The developed model enables us to estimate impression factors from a human skin image, and derive physical quantities for the accurate generation of a human skin image that has a desired impression.

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