Three-dimensional computer graphic simulation to develop base makeup for pearly skin

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[Short summary]

Pearls have attracted attention because of their elegant beauty. In this study, we propose applying the luster of pearls to cosmetic products. We conducted research on the influence of the optical phenomena of pearls embodied on a human face using a three-dimensional computer graphic (3DCG) simulation. The unique luster of pearls is the result of a complex optical phenomena caused by their multilayer structure. Nagata et al. suggested new optical models for the optical phenomena of pearls and succeeded in generating high-quality 3DCG images of pearls. We applied these optical models to a 3DCG model of the human face and generated images of a human face with the luster of pearls. Figure 1 shows the conceptual diagram of creating pearly skin. We also conducted a subjective evaluation of these images and examined the association between the optical phenomena of a pearl and the evaluation factors of a face. We found that the influence of blurring on the evaluation factors was the most effective among the optical phenomena of pearls when applied to a human face. The results indicate that the influence of blurring is a valuable indicator for the development of base makeup that has a pearly appearance.

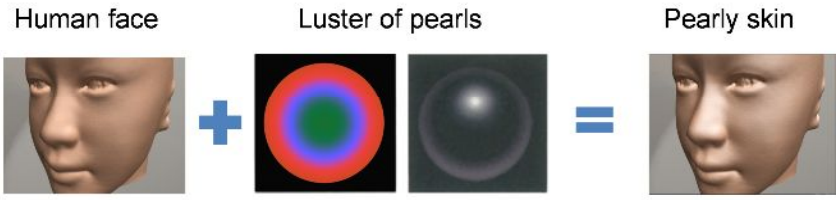


Figure 1: Conceptual diagram of creating pearly skin.

[Introduction]

Pearls, which are widely used in jewelry, have attracted attention since ancient times because of their elegant beauty. The charm of pearls, i.e., their smooth luster and deep gloss, is ideal for the skin of a woman. In this study, we propose applying the luster of pearls to cosmetic products. First, we conducted research on the influence of the optical phenomena of pearls embodied on a human face using a three-dimensional computer graphic (3DCG) simulation. Visual simulations using computer graphics have attracted considerable attention as a method of analysis by synthesis. The time and cost of conducting trials and evaluations can be significantly reduced using a 3DCG simulation. Pearls have

a multilayer thin-film structure and display a unique rainbow color pattern and lustrous iridescence owing to the diverse behaviors of light, such as refraction, interference, diffraction, and multiple reflections. Nagata et al. succeeded in achieving a realistic representation of a pearl by means of three principal factors, the interference, mirroring, and texture components, using physics-based modeling [1]. Dobashi et al. indicated that the blurring of light was an important fourth factor in improving the representation of a delicate appearance, and proposed a computational model and calculation algorithm [2]. Furthermore, a new model, the “partial coherent model,” which considers both coherent light and incoherent light used in the visualization of the interference phenomenon in [1] has been proposed. These studies successfully generated high-quality perfect sphere pearl CG images [1][2]. The authors of this paper applied the pearl visualization method to a free-form surface [3]. Using the method presented in [3], we represent the luster of pearls on a human face and generate CG images of a human face with the luster of pearls. We also conduct a subjective evaluation of these images and examine the association between the optical phenomena of a pearl and the evaluation factors of a face. The association has potential application in the field of cosmetic preproduction to help develop base makeup for pearly skin.

[Methodology]

Generating a Pearly Skin Face Image

In this study, we selected interference and blurring as suitable factors to represent the features of pearls on a human face.

The interference phenomenon observed in a pearl is the mixture of the interference of coherent light (dependent of the direction of the light source) and incoherent light (independent on the direction of the light source). The interference of coherent light is general thin-film interference. On the other hand, the interference of incoherent light is the phenomenon specific to pearls. The incident light is distributed to the whole pearl layer through repeated reflection and refraction. As a result, it appears as if each point in the layer has a point light source transmitting rays in all directions. Each ray causes local interference, and interference lights are propagated in all directions outside the pearl. This accounts for the fact that the hue of the interference light does not depend on the direction of the light source.

Blurring is the spread of light owing to the deviation of light from the direction of the regular reflection. The quite high transmittance of the nacreous layer causes light to be repeatedly reflected and transmitted inside the layer. As a result, the spread of light inside the layer tends to have the properties of reflection and transmission rather than scattering.

We simulated these optical phenomena of pearls, i.e., interference and blurring, as performed in previous studies [1][2][3].

We used the Bio Skin Doll as a model for the facial form and applied the optical phenomena of pearls to the doll. For the generation of 3DCG images, MAYA, a 3DCG software application, was used to represent the shape, texture, and optical properties of the doll.

We measured specular reflectivity of the Bio Skin Doll using a goniophotometer. In addition, we measured the color of the doll using a spectrophotometer. The texture component was extracted from a

photograph of the doll and was applied to bump mapping. Figure 2 shows the procedure employed to synthesize a 3DCG image of a face with pearly luster.

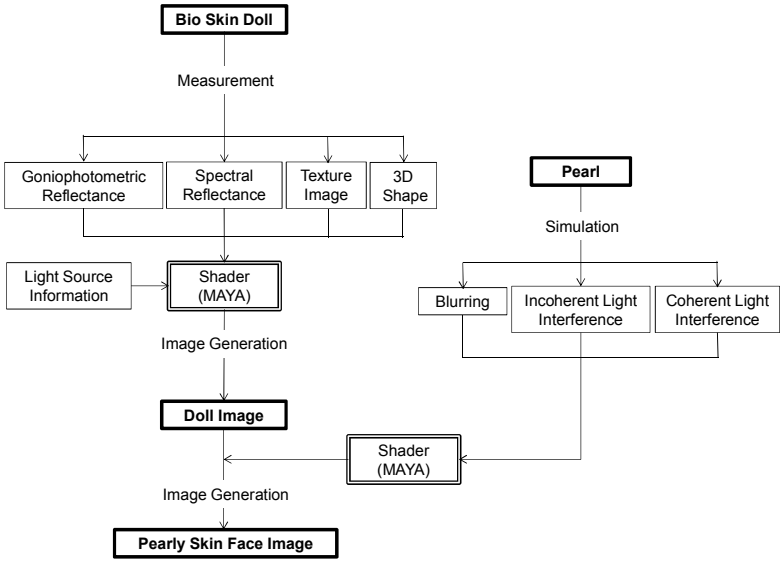


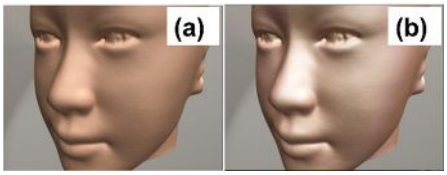
Figure 2: The procedure for synthesizing a 3DCG image for a face with pearly luster.

Evaluation of Pearly Skin Face Images

We generated Bio Skin Doll images using the methods described above with different levels of blurring, interference of coherent light, and interference of incoherent light. We evaluated these images by surveying 215 women. We then analyzed how each optical phenomenon influences the evaluation factors. In particular, we defined as dependent variables the factors that affect base makeup finishing, such as coverage effects, smoothness, finishing, concealment of pores, luster, skin color preference, oily glare, and translucency. Here we utilized the parameters of the optical phenomena of pearls as explanatory variables to perform a multiple linear regression analysis.

[Results]

We applied the simulated optical phenomena of pearls to the doll and succeeded in generating 3DCG images of a face with a pearly luster, as shown in Figure 3. We subsequently evaluated the generated images with different levels of optical phenomena of pearls, as shown in Figure 4 (A–G). Some of the images were rated high. For example, images A and B received the highest ratings. Table 1 shows the blurring, interference of coherent light, and interference of incoherent light values, and the ratings received for each Bio Skin Doll image. Figure 5 shows the rating values of the evaluation factors of a face. Each image received different ratings from an evaluation of base makeup finishing.



(a) Bio Skin Doll (b) Bio Skin Doll with pearly luster

Figure3 : Generated Bio Skin Doll images.

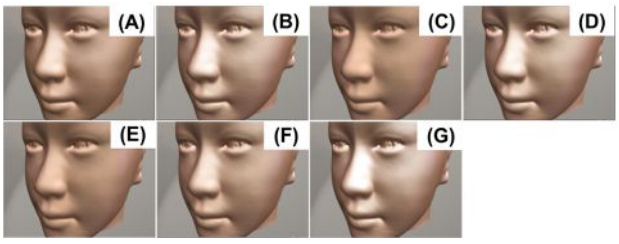


Figure 4: Generated Bio Skin Doll images with different levels of blurring, interference of coherent light, and interference of incoherent light.

Table 1: Parameters and Received Rating Values of Each Bio Skin Doll Image

Image	Blurring	Interference of Coherent Light	Interference of Incoherent Light	Rating Value
A	2	-	-	**3.5**
B	2	-	0.002	**3.5**
C	-	-	0.003	2.8
D	3	-	0.003	3.3
E	-	10	0.002	2.9
F	2	10	0.002	3.4
G	4	10	0.002	3.2

Table 2 shows the standardized partial regression coefficients obtained by the multiple linear regression analysis. We found the influence of blurring to be the most effective in terms of evaluation factors. Thus, greater the level of blurriness, higher are the ratings for the other factors, such as finishing, luster, skin color preference, oily glare, and translucency. Therefore, it can be concluded that influence of blurring on the evaluation factors was the most effective among the optical phenomena of pearls when applied to a human face.

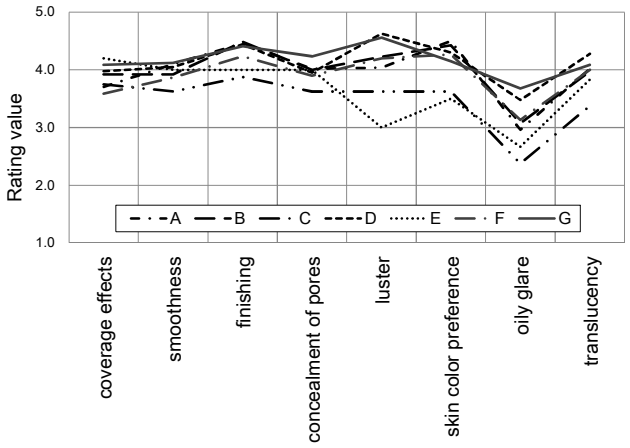


Figure 5: Rating values for each Bio Skin Doll image.

Table 2: Standardized Partial Regression Coefficients Obtained by Multiple Linear Regression Analysis

dependent variables \ explanatory variables	blurring	incoherent light interference	coherent light interference
coverage effects	ns	ns	ns
smoothness	ns	ns	ns
finishing	**0.193***	ns	-0.169*
concealment of pores	ns	ns	ns
luster	**0.336*****	ns	ns
skin color preference	**0.162***	-0.137*	-0.165*
oily glare	**0.319*****	ns	ns
translucency	**0.152***	ns	ns

*p<0.05. ***p<0.001. ns : not significant

[Conclusion]

We succeeded in generating facial images with a pearly luster by simulating the optical phenomena of pearls and applying the results of the simulation to the Bio Skin Doll. We then generated Bio Skin Doll images using different levels of interference and blurring, and subsequently evaluated these images, some of which received high ratings. We analyzed the association between the parameters of the optical phenomena of pearls and the evaluation factors, and determined that influence of blurring on the evaluation factors was the most effective among the optical phenomena of pearls. The results lead to the conclusion that the influence of blurring is a valuable indicator when developing base makeup for pearly skin. In future, we will develop base makeup products that make use of the blurring of pearls and conduct evaluations of these products.

[References]

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