Simulating Makeup through Physics-based Manipulation of Intrinsic Image Layers

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A common way to alter or improve one's facial appearance is through the application of makeup. Several techniques have been proposed for simulating the appearance of makeup in an image of the user. These techniques either synthesize makeup effects through computer graphics rendering which requires detailed data such as the user's face geometry and skin reflectance, or by transferring the appearance of makeup in a reference image to the user's face. Although directly transferring makeup is more convenient to apply than rendering-based techniques, it requires restrictive assumptions such as similar lighting conditions in both the reference and target images, and may transfer undesired personal features such as wrinkles and blemishes.

In this work, we present a technique that overcomes these limitations without requiring heavy computation or detailed user data. Our method accomplishes this through decomposing the target image into reflectance layers that can be efficiently transformed into their makeup equivalents using proposed adaptations of physically-based reflectance models. For each of the intrinsic layers, we present transformations which alter them in a way that preserves the identity of the user while conveying the appearance of makeup based on its optical properties. Figure 1 illustrates the schematic flow of our method.

In modeling the effects of cosmetics, we decompose both the barefaced image I_B without makeup and the face image I_M with makeup into three intrinsic image components, namely albedo A, diffuse shading D and specular highlights S:

$$I_B = A_B \cdot D_B + S_B, \quad I_M = A_M \cdot D_M + S_M. \tag{1}$$

Albedo change For a coating of cosmetics, the Kubelka-Munk model is used to express its reflected color R and transmitted color T. As light scatters within the cosmetic layer c, it is transformed by color R_c, and as it passes through layer c, it is transformed by color T_c. The final color from the sum of these light paths can be formulated as a sum of a geometric series [1]:

$$A_M = R_c + T_c R_B T_c + T_c R_B R_c R_B T_c + \cdots \tag{2}$$

$$= R_c + \frac{T_c^2 R_B}{1 - R_c R_B}, \tag{3}$$

where $R_B = A_B$.

Diffuse shading change Bare skin is translucent with considerable subsurface scattering of light. By contrast, cosmetics like foundation are relatively opaque and reduce translucency. We make use of the subsurface scattering approximation proposed in [2] to model the change:

$$D_M * G(\sigma) = D_B, \tag{4}$$

where σ is the Gaussian blur kernel defined by the subsurface scattering. To solve for D_M in Eq. (4), we compute a deconvolution by optimizing the following energy function:

$$\operatorname*{argmin}_{D_M} \|GD_M - D_B\|^2 + \lambda \|\Delta D_M\|^2, \tag{5}$$

where D_M and D_B are represented in vector format, each row of matrix G contains the convolution coefficients of $G(\sigma)$, Δ is the Laplacian operator, and λ balances the deconvolution and smoothness terms.

Specular highlights change An important visual effect of cosmetics is in changing the appearance of specular highlights. We turn to the Torrance-Sparrow model for surface reflectance:

$$f_s = \frac{1}{\pi} \frac{UP}{(N \cdot \omega_i)(N \cdot \omega_o)} F_r(\omega_i \cdot H, \eta) \tag{6}$$

This work was done while Chen Li was an intern at Microsoft Research. This is an extended abstract. The full paper is available at the Computer Vision Foundation webpage.

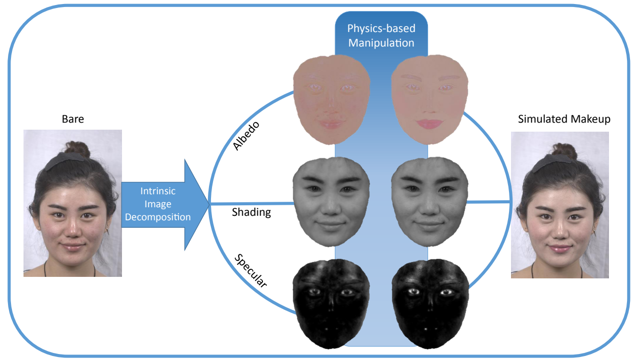

Figure 1: Schematic flow of the proposed makeup simulation method.

(a) (b) (c) (d) (e)

Figure 2: Different makeup styles. (a) Without makeup. (b/d) Our result for makeup style 1/2. (c/e) Real makeup reference for makeup style 1/2.

where U is a geometry term that represents shadowing and masking effects among microfacets, P is the Beckmann microfacet distribution, F_r is the reflective Fresnel term. The free variables are the material roughness m (encoded in P) and refractive index η. We approximatively represent the ratio between the specular reflectance of skin $f_s(m_b, \eta_b)$ and cosmetics $f_s(m_c, \eta_c)$ as $\frac{f_s(m_b,\eta_b)}{f_s(m_c,\eta_c)} \approx \frac{m_c^2}{m_b^2}$. Both specular highlight from the cosmetics layer and skin layer contribute to the final specular highlight layer S_M as

$$S_M = T_c^2 \cdot S_B + \frac{m_b^2}{m_c^2} S_B. \tag{7}$$

To digitally apply a certain cosmetic product c, we recover the material parameters using two images captured of the same face, without makeup (I_B) and with the cosmetic (I_M). The parameters Θ and cosmetic thickness field t are estimated by minimizing the following objective function via L-BFGS:

$$\operatorname*{argmin}_{\Theta,t} \lambda_A E_A + \lambda_D E_D + \lambda_S E_S + E_t \tag{8}$$

where λ_A, λ_D, λ_S balance SSD constraints on the albedo layer E_A (Eq. (3)), diffuse shading layer E_D (Eq. (4)), specular highlight layer E_S (Eq. (7)), and the thickness smoothness energy E_t.

After recovering the cosmetic parameters Θ, the effects can be easily transferred layer by layer to any barefaced image with a user-defined cosmetic thickness map according to Eq. (3), Eq. (5) and Eq. (7). The three layers are then composed by Eq. (1) to obtain the final result. Figure 2 shows one example of our results with two different makeup styles on same subject.

[1] Cheng-Guo Huang, Wen-Chieh Lin, Tsung-Shian Huang, and Jung-Hong Chuang. Physically-based cosmetic rendering. In *Proceedings of the ACM SIGGRAPH Symposium on Interactive 3D Graphics and Games*, I3D '13, 2013.

[2] Jorge Jimenez, Veronica Sundstedt, and Diego Gutierrez. Screen-space perceptual rendering of human skin. *ACM Trans. Appl. Percept.*, 6(4): 23:1–23:15, October 2009.