Facial Skin Beautification using Region-Aware Mask

Lingyu Liang
School of Electronic and Information Engineering
South China University of Technology
Guangzhou, China
lianglysky@gmail.com

Lianwen Jin
School of Electronic and Information Engineering
South China University of Technology
Guangzhou, China
lianwen.jin@gmail.com

***Abstract*—In this paper, we present a facial attractiveness enhancement system for three major skin attributes: homogeneity, lighting, and color. To implement specific facial manipulation, we propose a new region-aware mask generation approach based on the state-of-the-art edit propagation techniques. The region-aware masks allow the user to beautify faces without the tedious and time-consuming region selection.**

In our system, an input portrait is decomposed into smoothness, lighting and color layers by edge-preserving filter. Then, taking the facial landmarks and significant edges as the constraint, layer masks are generated based on the image-guided energy minimization framework. The system could beautify faces automatically using the attractiveness priors of example-sets and psychological knowledge. Experiments illustrate the effectiveness of our method on various face databases, and the comparison with the previous methods indicates the reliability of our region-aware mask.

***Index Terms*—Skin beautification, facial attractiveness, edit propagation, region-aware mask.**

I. Introduction

Face beautification is a fascinating and significant technique. The ever-growing requirement for face retouching has led to many engineering and research problems. Since facial geometric beautification have been studied extensively in the previous works [1], [2], [3], we focus on the specific facial skin beautification in this paper.

Recently, skin beautification has attracted growing research interest. Liu et al. presented an approach for portrait fusion with virtual background based on quantum evolution algorithm and a multi-layer portrait weighted method, and performed skin color editing based on color temperature estimation [4]. Lee et al. presented an automatic skin smoothness enhancement method using Gaussian mixture model and Bayesian segmentation [5]. Chen et al. performed automatic skin color enhancement based on color-temperature-insensitive skin color detection and implemented beautification using bilateral filter and Poisson image cloning [6]. However, most of the previous method only focus on one or two attributes for facial skin enhancement. To achieve better beautification effect, our method covers three major skin properties, including homogeneity (smoothness), lighting and color. To overcome the challenge of region selection and inhomogeneous adjustment, we generate region-aware masks using the state-of-the-art edit propagation technique [7].

(a) Original (b) Our results

Fig. 1. Facial skin beautification for Caucasian. The original images are taken from Caltech face database [22]. The results show that our method not only effectively perform facial beautification, but also well preserve the identity and significant details of the portrait.

Facial makeup is a closely related technique to skin beautification [8], [9]. Our framework is similar to the work of [9], since both of us implement layer decomposition through edge-preserving operators [10]. However, we use region-ware masks for the specific layer manipulations, while Guo and Sim [9] dose not.

In this paper, we propose a unified framework to beautify skin homogeneity, lighting, and color using region-aware mask. First, we use an edge-preserving operator [10] to separate the portrait into three layers with respect to the three skin attributes. Second, in order to automatically generate region-aware masks for specific layer manipulation, we implement an edge-preserving energy method in edit propagation technique [7], which could adaptively propagate the local adjust-

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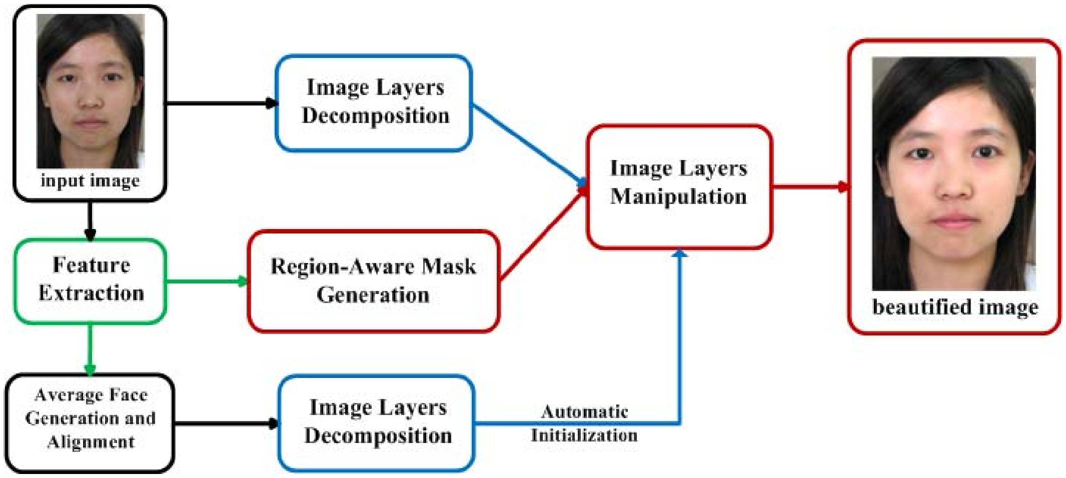


Fig. 2. The process of our facial skin beautification method. Step 1: Facial feature extraction; Step 2: Image layers decomposition via edge-preserving smoothing; Step 3: Inhomogeneous region-aware facial mask generation; Step 4: Specific skin layer enhancement with automatic initialization.

ment to the whole image. Third, we perform automatic parameters initialization using both data-driven and knowledge-driven perception principles in psychology studies. Here, we make no claims on the absolute attractiveness enhancement for the beautified faces, although the results could compete with hand-craft manipulation to some extent, as shown in Fig. 1.

II. Facial Skin Beautification Framework

According to the recent psychology studies [11], [12], [13], there are three major factors that influence facial attractiveness: skin homogeneity (smoothness), lightness, and color. Therefore, we present a facial skin beautification framework that provides specific enhancement for each attribute, as illustrated in Fig. 2. There are two key components in our framework: facial mask generation and image layer manipulation. Facial mask generation produces a layer-specific region-aware mask for skin enhancement operations. Image layer manipulation provides interactive enhancement with user-customized adjustments, and automatic initialization based on the related psychological knowledge and average face generated from an example set. The beautification workflow of our system is summarized below:

1) Detect face and locate landmarks on input image.
2) Decompose images into detail, lighting, and color layers.
3) Generate facial masks for the three layers.
4) Perform specific enhancement for skin smoothness, lighting, and color with automatic initialization.

The first two steps are discussed in Section II, step 3 in Section III, and step 4 in Section IV.

A. Feature extraction

To extract facial features, we implement the Viola-Jones face detection [14] on the input image, and use the Active shape model (ASM) [15] to locate 84 landmarks in the major facial feature (likes eyes, nose and mouth). In most cases, our feature extraction method proceeds automatically, but in some cases, when hair or pose obscures the face, user modification may be required.

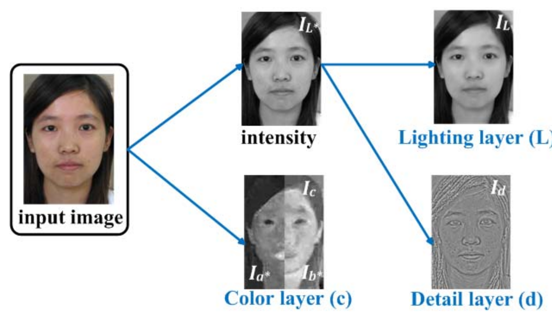


Fig. 3. Image Layers Decomposition: the process to separate the input image into three specific facial layers for skin beautification.

B. Image layers decomposition

In computational photography, images are often decomposed into lightness and color layers through color space transformations. These layers are then passed through edge-preserving filter and decomposed into a piecewise smooth base layer and a detail layer for image editing [10]. We follow this method to separate the input image into detail, lighting, and color layers, as shown in Fig. 3.

First, the input image I is converted into a CIELAB color space, which is commonly used in human perceptual work and facial attractiveness studies in psychology [12], [16]. The converted input image is composed of one lightness channel L^* (I_{L^*}) and two color channels a^* (I_{a^*}) and b^* (I_{b^*}). The two color channels are regarded as the color layer. Second, the edge-preserving smoothing operator is applied to the lightness channel to capture its large-scale variations. The large-scale variations in intensity are regarded as the lighting layer I_L. Finally, the large-scale variations (lighting layer) are subtracted from the logarithm of the lightness channel. The residual is regarded as the detail layer I_d for facial smoothness enhancement.

Here, we choose the edge-preserving smoothing operator based on weighted least squares framework [10] for the lighting and detail layers separation, since it is effective for detail manipulation without introducing the halo artifacts as the explicit filters, like bilateral filter [17] or guided filter [18].

III. Region-Aware Mask Generation

In skin beautification, identity and the significant details of the portrait should be retained, while the unwanted details like wrinkle or spot should be removed. Therefore, different facial regions require different degree of adjustment. To avoid the time-consuming mask writing task, we propose a automatic region-aware mask generation method using the state-of-the-art edit propagation technique, which propagates the facial adjustment in constraint region to the whole portrait.

In this paper, we use the edge-preserving energy minimization method presented by Lischinski et al. [7] to generate the facial masks. For clarity of presentation, we denote the input constraint of the model as R, the output region-aware mask as M, and the guided image as $L, (L = logI_L)$. Then, we achieve the goal by minimizing the following quadratic functional:

$$M = \underset{M}{\operatorname{argmin}} \left\{ \sum_{\mathbf{x}} w(\mathbf{x}) \left(M(\mathbf{x}) - R(\mathbf{x})\right)^2 + \sum_{\mathbf{x}} h(\nabla M, \nabla L) \right\} \quad (1)$$

where,

$$h(\nabla M, \nabla L) = \lambda \left(\frac{|M_x|^2}{|L_x|^{\alpha} + \varepsilon} + \frac{|M_y|^2}{|L_y|^{\alpha} + \varepsilon} \right) \quad (2)$$

The first term in Eq. (1) is the data term, which ensures the mask M satisfies the facial constraint R. The weight w is between 0 and 1, which is used to indicate the constrained pixel. The larger weight value is, the more similar value between M and R would be obtained. In mask generation, the constrained region is determined by the facial components (like eyes or mouth) and the significant edges (like hair).

The second term is the smoothing term, responsible for keeping the gradients of the layer mask M as small as possible, except across the significant gradients in L. Here, α controls the sensitivity to the gradients of L, and ε is a small constant to prevent division by zero. Parameter λ is used to balances the relative weight of the two terms. We use the typical values $\varepsilon = 0.0001$ in our implementation. For α and λ, different combination is used for the specific layer.

Lighting Mask. We assume that user are desired to perform facial beautification only in skin region, while maintain the background unchanged. For lighting enhancement, the face and neck regions are effectively segmented by our method, as shown in Fig. 4a.

Smoothness Mask. For smoothness enhancement, we should not only remove the unwanted wrinkle or spots, but also preserve the details in facial components like eyes and mouth or some significant details like 'edges' caused by the facial expression. To achieve the objective, we take the skin region from the lighting mask, generate facial component regions based on the landmarks, and detect the significant edges in the lighting layer (I_L). Then, the input constraint of smoothness mask is obtained by combining all these information, and the region-aware mask is generated, as shown in Fig. 4b.

(a) lighting layer (b) smoothness layer (c) color layer

Fig. 4. The input constraint and output facial mask for lighting, smoothness and color layer.

Color Mask. The process of color mask generation is similar to smoothness mask, although the constraint regions are taken as eyebrows, eyes, and background, as shown in Fig. 4c.

IV. Image Layers Manipulation

Our system provides three specific facial skin manipulation, which aim at skin smoothness, lighting, and color enhancement. The system provide two complementary schemes for beautification: automatic and interactive. The automatic enhancement makes our system convenient for the user, especially for the non-professional, and the interactive manipulation enables fine-tuning since there is high diversity of facial styles.

A. Interactive layers Enhancement

Suppose the detail, lighting and color layer of the input image are denoted I_d, I_L and I_c; corresponding facial masks M_d, M_L and M_c; manipulation outputs O_d, O_L and O_c. Layers enhancement is implemented as follows.

In skin smoothness manipulation, we lower down the input detail according to the facial mask M_d:

$$O_d(\mathbf{x}) = (1 - M_d(\mathbf{x}))I_d(\mathbf{x}) \quad (3)$$

Similar to smoothness manipulation, lighting and color enhancement are implemented as:

$$\begin{cases} O_L(\mathbf{x}) = (1 + w_L M_L(\mathbf{x}))I_L(\mathbf{x}) \\ O_c(\mathbf{x}) = (1 + w_c M_c(\mathbf{x}))I_c(\mathbf{x}) \end{cases} \quad (4)$$

where w_L and w_c are scalar value, which would be initialized automatically by system or adjusted interactively by user.

Fig. 5. Facial skin beautification for faces of different gender and age. Top row: input portraits; Bottom row: our results. All faces were taken from Lifespan database [21].

In our system, altering the scalar value can perform region-ware adjustment, since it is weighted by the layer mask. In special cases, homogeneous adjustment is also implemented when the layer mask is set to an constant (typically equals to one).

B. Automatic layers Enhancement

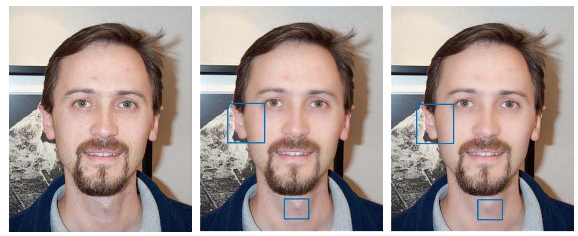
In our framework, the average face is regarded as the beauty prototype for computer automatic beautification. The initial average face is generated from a off-line collected database, which is grouped into different genders and races. After the feature extraction, the average face is aligned to the input face through affine transformation and multilevel free-form deformation [19].

Automatic initialization is implemented only for lighting and color enhancement, since smoothness enhancement is only controlled by the layer mask. Take the lighting enhancement as example. First, the non-skin pixels of the input and average face layers are masked, resulting in two vectors that only contain the lighting values in the skin region. Second, the difference of the two vectors is computed into a ten-bins residual histogram. Third, scalar value w_L is obtained by summation of all the bins weighted by their relative frequencies. The color adjustment scalar w_c is initialized in a similar process.

The simple data-driven approach based on average face is valid, but it fails to perform well in many cases. To improve the performance, we truncate the residual at some lower and upper bounds according to psychology studies on facial attractiveness (knowledge-based priors). For lighting manipulation, female faces are found to be more attractive when there is a luminance difference between facial features (eyes and nose), and skin region, while male faces show the opposite trend [12]. For color manipulation, redder and yellower skin are regarded more attractive in both female and male faces [13], [20], [16]. Therefore, all faces are inclined to increase the red and yellow color, while female faces should also increase the lighting contrast, but not for the male faces.

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

Fig. 6. Comparison with the method of Leyvand et al. [2]. (a) Original image. (b) Facial structure beautified result taken from [2]. (c) Skin beautification of our method. (d) Skin beautification of our method with shape enhancement.



(a) Original (b) Lee et al. 2009 (c) Our results

Lee's Ours Lee's Ours

Fig. 7. Comparison with the method of Lee et al. [5]. The zooming patches show that our method could select the manipulation region with more accuracy, and obtain better performance.

(a) Original (b) Chen et al. 2010 (c) Our results

Fig. 8. Comparison with the method of Chen et al. [6]. The result illustrate that our method could generate more pleasant facial color and smoothness effect.

V. Experiment

In order to evaluate the performance of the facial skin beautification method, we experimented using different databases, and compared our results with that produced by the previous methods.

A. Basic Evaluation

We beautified different faces using our method, which were taken from Caltech face database [22] (shown in Fig. 1) or from Lifespan database [21] (shown in Fig. 5). The results demonstrate the effectiveness of our method: the unwanted skin details, like acne or pores, were eliminated; the skin lighting and color appear to be more pleasant after manipulation. Note that the test faces cover different gender (female/male) and age (young/senior), which indicates a good generalization of our beautification framework.

B. Comparison with related methods

Faces beautified by [2] and our method are shown in Fig. 6. We could see that the manipulated faces not only look more pleasant in general, but also maintain high resemblance to the original. Although we make no claims our results are more attractive than those of Leyvand et al. [2], we could see the significant impact of the combination of facial shape and skin beautification in Fig. 6d.

Fig. 7 shows the comparison of our method with that of Lee et al. [5] for facial skin smoothing. We took the test image from Caltech face database [22]. The results indicate that our method not only preserve better details in the facial boundary, but also obtain better smoothing effect in the neck region.

Fig. 8 shows the comparison between our method with that of Chen et al. [6] for facial color enhancement. Our method seems to produce *healthier* looks for the portrait, since we integrated the psychology knowledge of skin attractiveness into our automatic initialization scheme. Further more, our method well preserved the significant details in the neck region, while [6] tend to over-smooth the skin details.

VI. Conclusion

In this paper, we propose a powerful framework of facial beautification for skin smoothness, lighting and color. In the framework, elaborate region-ware facial skin manipulations can be performed without any hand-craft facial mask or even parameters tuning. Benefit from our region-aware facial mask and automatic beautification scheme, our system enables the user to perform a flexible, effective, and convenient facial enhancement.

Currently, our system performs well in frontal faces with little facial occlusion. For the faces with various pose, expression or occlusion, much user modification may be required, since the ASM fails to perform accurate landmark location. Extending the ASM to deal with more general landmark location situation would be beneficial to improve the performance of our system.

Another direction to extend our work is the mask generation scheme. Although the region-ware mask is designed for specific facial skin enhancement in this paper, the mask generation scheme is general for other image manipulation problem. A new specific mask can be generated freely by replacing the feature extraction or edit propagation with other methods.

Finally, although we integrate some human attractiveness perception principles into our manipulation scheme, the performance assessment is still based on the subject visual evaluation of a user. To obtain objective criteria to guide the beautification, we should take the facial attractiveness prediction [1] into account. However, according to the best of our knowledge, there is not such reliable work for specific evaluation of skin beautification, which merits our further investigation.

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