# A Facial Skin Changing System

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***Abstract*—This paper presents a novel system to remove facial scars and pores for a portrait. The facial skin complexion and color are important attractive factors, and most people consider that a good portrait should be scar free and have smooth facial colors. Currently, most available commercial digital cameras or smart phones all provide facial-skin-beatification functions, but most of them only use simple image processing functions to smooth the taken image for the removal of small-scale unwanted facial scars and pores and these functions cannot remove large and obvious scars or pores from the face as shown in Figure 1. Therefore, the main contribution of this system allows the user to replace the facial skin of a portrait with a beautiful and scar-less skin of another portrait chosen from a database which consists of scar-free and beautiful skin complexion collected from webs.**

## I. Introduction

Beauty have fascinated human beings by instinct so that everyone would like to pursue a nice looking face. Therefore, to have a satisfying facial attractiveness of our own portrait would be pleasing and useful in our daily life. The human facial attractiveness has been extensively studied in [1], [2] and is affected by cultures, ages, genders and other factors but the facial skin complexion and color are two commonly accepted important attractive factors, and most people consider that a perfect portrait should be scar free and have smooth facial colors. Currently, most available commercial digital cameras or smart phones all provide facial-skin-beatification functions, but most of them only use simple image processing functions which can smooth the taken images for removal of small-scale unwanted facial scars and pores but cannot remove large and obvious scars or pores from the face. Therefore, the key insight of the proposed work is that our system allows the user to replace the facial skin of the portrait with a beautiful and scarless skin of another portrait chosen from a database which consists of scar-less and beautiful faces collected from webs.

Fig. 1 shows the overview of our system which comprises five major steps. First, we would collect a set of portraits which have good facial skins. Those promotional photos of famous stars and models are usually good sources. In general, the relative location of the facial features such as the eyes, nose and lips is fixed, and thus, a designed mesh template is used to vectorize all collected portraits. After vectorization of a face, a parametric face is created and saved with a set of bicubic patches and their facial skin saliency. The facial skin saliency is analyzed and extracted with the uniform sampling theorem and used as the color constraints for the vectorization process. The block of beautiful face template in Fig. 1 shows the designed facial mesh template and exemplar faces with their corresponding facial skin saliency. Second, a portrait is acquired for transformation and its features and facial skin saliency is extracted roughly with the active shape modelling algorithm (ASM) [3] and refined by the watershed algorithm [4] and the Grabcut algorithm [5]. The entire extraction process is automatic. According to the location of all these extracted facial features, our algorithm would warp the designed template mesh to fit the contour of input portrait. Since the same template is used to handle both the input portrait and database portrait, we could directly transfer the facial skin saliency from the chosen portrait in our database to the warped input portrait. Then, Thin-Plate Spline (TPS) [6] is applied to reconstruct the new facial skin of the input portrait based on the stored bicubic patches and their facial saliency. Because each portrait in our database is selected and chosen with a face which has smooth skin colors without any scar and pore, the original facial scars, pores and other defects can be removed and transformed to the good facial skin. In this step, we could remove all scars and large pores in the original portrait and a more beautiful and attractive facial skin would be generated by our beautiful template. However, the transformed facial skins may have large color difference to other facial features, and this may create obvious seams and results in annoying artifacts in the final result. Thus, Poisson image blending [7] is chosen to fuse these two parts, and the final portrait would be generated without any obvious scar and big pore. The synthesized faces are subjectively evaluated by groups of human raters and the experimental results indicate that the proposed system has ability to increase the facial attractiveness and provide a useful tool for digital image editing software.

The rest of the paper is organized as follows. Section II investigates the previous published face beautification systems. Section III overviews the main steps of our system. Section IV discusses the details of vectorizing a portrait for fitting into a facial template. Section V discusses the replacement of the skin of a portrait from the chosen portrait. In Section VI, the experimental results demonstrate the superiority of the proposed system. Section VII concludes the paper.

## II. Related Work

Due to the importance of the facial attractiveness, various face beautification systems have been developed [8]-[13] in the academic research. Arakawa and Nomoto [8] presented a human face beautification system by using interactive evolutionary computation. To obtain satisfying attracted portrait,

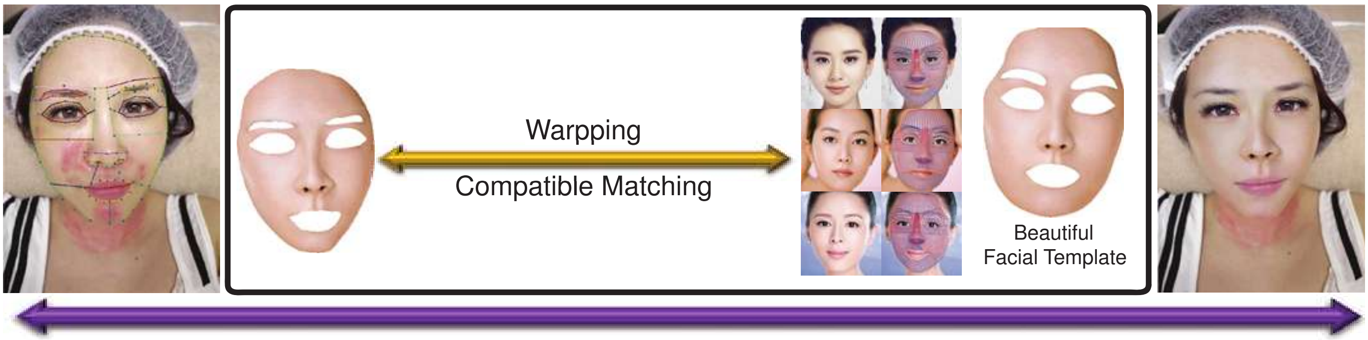



Fig. 1. Flowchart of the proposed human facial skin beautification system.

this system is designed to remove the unpleasant wrinkles and spots from the face images. However, there are too many parameters to adjust in order to get satsified results and the adjustment process is strenuous and requires experiences. Moreover, this system slightly blurs the input face images. Later, Matsui, Arakawa, and Nomoto [9] presented another human face beautification system to beautify the portraits while keeping them sharp. Arakawa and Okada [10] presented a nonlinear filter to eliminate those random noises with a small signal amplitude. This filter can be utilized to remove the wrinkles and blemishes of the face and preserve the natural roughness of the skin for the face beautification system. According to the attractiveness model proposed in [11] which is learned with supervised learning techniques, Leyvand *et al.* [12] presented a method to increase the attractiveness rating of the face by modifying the facial features. The main idea of their algorithm is that the changes of the face are delicate, but the effect is significant and therefore, they adopted two techniques to achieve the goal: one is the K-nearest neighbors search and the other is an the SVR-based beautification, respectively. Lately, Leyvand *et al.* [13] proposed a method to change the face features and enhance the facial attractiveness of human faces in portraits, while preserving the similarity with the original ones.

## III. Overview of the Skin Changing System

The proposed system can be used to replace the facial skin and complexion in order to remove the facial scars, wrinkles, spots, pores and any undesirable defects on faces for beautifying the given portrait and the process of our system is illustrated in Fig. 1. Our system mainly comprises three major steps. First, a set of portraits which have good facial skins is collected and vectorized. After vectorization of the portrait, a parametric face is generated and saved with a set of bicubic patches and their facial skin saliency. The facial skin saliency is extracted with the uniform sampling theorem and used as the color constraints for the vectorization process. Second, a portrait is acquired for transformation and its features and facial skin saliency is extracted roughly with the active shape modelling (ASM) [3] and refined by the watershed algorithm [4] and the Grabcut algorithm [5]. Next, we could directly transfer the facial skin saliency from the chosen portrait in our database to the warped input portrait. Then, Thin-Plate Spline (TPS) [6] is applied to reconstruct the new facial skin of the input portrait based on the stored bicubic patches and their facial saliency and Poisson image blending is chosen to fuse the transformed facial skins and other facial features.

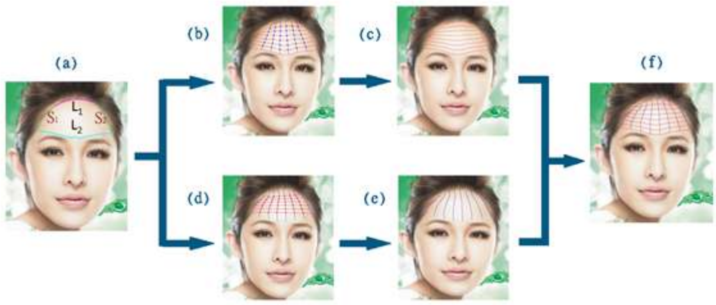


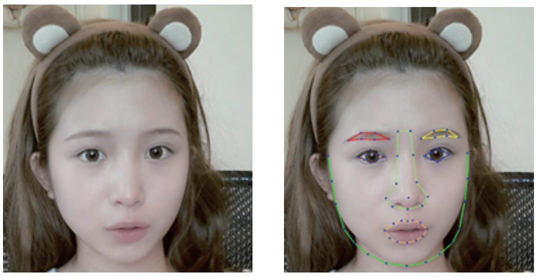

Fig. 2. The bicubic patch is generated by the initial segmentation of a face, and we would save the color information for each node. In the last, we would use this parametric patch to reconstruct the no-defect face via Thin-Plate Spline interpolation.

## IV. Portraits Database Vectorization

In order to replace the facial skin of the input portrait, the user is allowed to choose a favorite facial skin from the database first. Hence, a set of suitable portraits is gathered from webs into our facial database. These portraits have a perfect and no-defect facial skin complexion and facial skin color. Because the contour of the input portrait is usually different from the contour of the chosen portrait, our system choose to represent the chosen portraits with a cubic patch of the chosen portrait in the database and lately, the represented cubic patch can be warped to fit the input portrait for the skin changing procedure. Generally, a portrait can be transformed to a cubic patch in the following four steps: First, the portrait is separated into 19 regions based on the feature points by using the ASM and 14 of these 19 regions are designed to contain the facial skin. Second, the bicubic patch of each region would be generated to segment the facial skin in Fig. 2. Third, the color information and parametric coordinate of the facial skin which are determined by the order of subdivision bicubic patch. In our algorithm, the initial bi-cubic patch would be

(a) (b)

Fig. 3. The feature points of the human face are acquired by ASM.



(a) (b)

Fig. 4. The feature points of the human face are roughly acquired.

subdivided five to seven times to fit the facial color. Finally, the each node of bicubic patch would be the color constraints for the vectorization process. Consequently, a parametric face is created and saved with a set of bicubic patches. The following sections will give more details about how to generate the represented cubic patch.

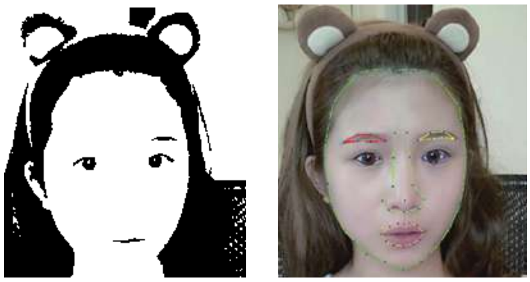
### *A. Acquiring the Feature Points and Facial Skin Saliency of the Input Portrait*

Since the contour of the input portrait and the chosen database portrait are different, the feature points and the facial skin saliency of the input portrait are determined and acquired by using ASM [3]. The feature points of the input portrait is shown in Fig. 3.

Due to the accuracy of the ASM, the feature points of the human face are roughly acquired, as shown in Fig. 4. Therefore, the feature points should be refined to fit the contour of the facial features. We detected the contour of each facial features to update the positions of the feature points which are generated by ASM, such as forehead, cheek, eyebrows, eyes, and mouth, respectively.

*1) Forehead Detection:* The gray map of the portrait can be used to detect the contour of the forehead, because the luminance of the face is brighter than the luminance of the hair. Hence, the binarization technique is used to generate the boundary between the forehead and the hair of the portrait, as shown in Fig. 5.

The pixels of the original gray map and the binary map are denoted as $g(x,y)$ and $b(x,y)$, respectively. If the gray value of the pixel of the original image is larger than a threshold ($T_{Bin}$) or equal to $T_{Bin}$, the corresponding pixel of the binary map is a white point, and the gray value of the corresponding pixel is set to $255$. On the contrary, the gray value of the pixel of the binary map is set to $0$, if the gray value of the pixel of the original image is smaller than $T_{Bin}$. The fixed threshold, $T_{Bin}$, is set to $115$, empirically. The following equation is used to transform the original gray map into the binary map.



(a) (b)

Fig. 5. The binarization technique is used to generate the boundary between the forehead and the hair of the portrait.

(a) (b)

Fig. 6. The contour of the face cheek is extract by using the watershed algorithm, and then the feature points are updated according to the contour.

$$b(x,y) = \begin{cases} 255, & g(x,y) >= T_{Bin}; \\ 0, & \text{otherwise}. \end{cases} \tag{1}$$

After obtaining the boundary between the forehead and the hair of the portrait, the feature points of the forehead which are generated by ASM are moved to the nearest pixel of the boundary to make an adjustment of feature points.

*2) Cheek Detection:* As shown in Fig. 6, the watershed algorithm [4] is adopted to extract the contour of the face cheek. The feature points of the cheek which are generated by ASM are moved to the nearest pixel of the contour.

*3) Eyebrows Detection:* In this subsection, the boundary of facial feature, eyebrows, is extract by the watershed algorithm, as shown in Fig. 7. And the feature points of the eyebrows which are generated by ASM are then changed from the original positions to the nearest positions of the contour. In addition, the feature points of the corners of the eyebrows would not be changed to keep the shape of the eyebrows.

*4) Eyes Detection:* We use the grabcut algorithm [5] to find the boundary between the eyes and surroundings skin, as shown in Fig. 8(c) and (g). As mentioned above in the previous subsection, the feature points of the eyes which are generated by ASM are refined according to the detected contour in Fig. 8(d) and (h).

*5) Mouth Detection:* The grabcut algorithm is also used to detect the contour of the mouth. As shown in Fig. 9, the

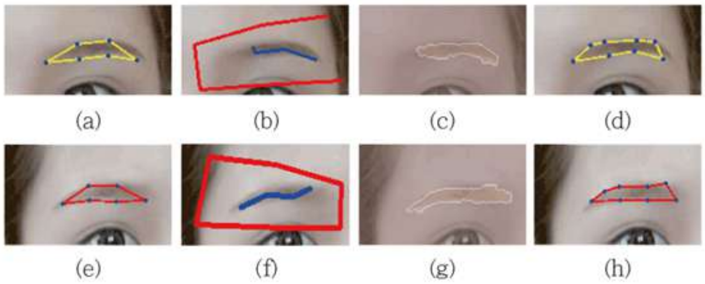



Fig. 7. The contour of the eyebrows is extract by using the watershed algorithm, and then the feature points are changed according to the contour.

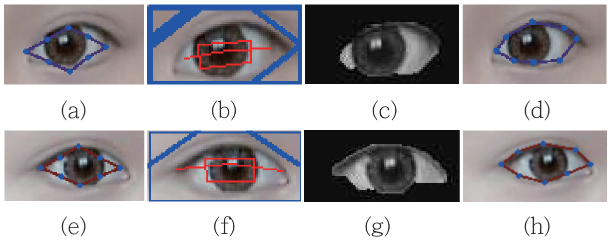



Fig. 8. The contour of the eyes is found by using the grabcut algorithm.

rough boundary are generated by the grabcut algorithm, and then the floodfill algorithm is adopted to refine the boundary of the mouth. And the feature points of the mouth which are generated by ASM are then changed from the original positions to the nearest positions of the contour. It is the same as eyebrows detection, the feature points of the corners of the mouth would not be changed to keep the shape of the eyebrows.

## V. Facial Skin Reconstruction Using Thin Plate Spline

According to the location of all these extracted facial features and the corresponding bicubic patches between the input portrait and the chosen portrait in the database, our system would warp the portrait template to fit the contour of input portrait by using the consistent parametric structure.

The bicubic patch is the curved surface which is constructed by cubic spline. The portrait would be separated into 14 regions which contain the facial skin based on the feature points. Then, each region is segmented by several cubic spline to construct a curved surface which is called the bicubic patch. For example, we want to segment a patch into four parts by two cubic splines, as shown in Fig. 10. The equation of bicubic patch is defined as followed

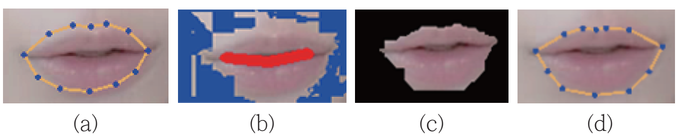



Fig. 9. The feature points of the eyes which are generated by ASM model are refined according to the detected contour.

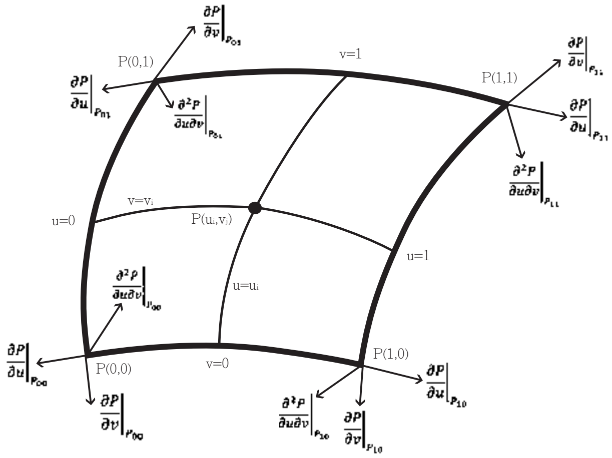



Fig. 10. The patch is segmented into four parts.

$$p(u,v) = \left[\ F_1(u)F_2(u)F_3(u)F_4(u)\ \right] B \begin{bmatrix} F_1(v) \\ F_2(v) \\ F_3(v) \\ F_4(v) \end{bmatrix} \quad (2)$$

where $F_1(s) = 1 - 3s^2 + 2s^3$, $F_2(s) = 3s^2 - 2s^3$, $F_3(s) = s - 2s^2 + s^3$, $F_4(s) = -s^2 + s^3$, and $s = \{u, v\}$.

$$B = \begin{bmatrix} P_{00} & P_{01} & P_{00}^{v} & P_{01}^{v} \\ P_{10} & P_{11} & P_{10}^{v} & P_{11}^{v} \\ P_{00}^{u} & P_{01}^{u} & P_{00}^{uv} & P_{01}^{uv} \\ P_{10}^{u} & P_{11}^{u} & P_{10}^{uv} & P_{11}^{uv} \end{bmatrix} \quad (3)$$

The four corners of bicubic patch are denoted as $P_{00}, P_{01}, P_{10}, P_{11}$. $(P_{00}^u, P_{01}^u, P_{10}^u, P_{11}^u)$ and $(P_{00}^v, P_{01}^v, P_{10}^v, P_{11}^v)$ are first order differential about $u$ and $v$, respectively, and $P_{00}^{uv}, P_{01}^{uv}, P_{10}^{uv}, P_{11}^{uv}$ are $2 \times 2$ zero matrixes. By using (2), the cubic patch with two cubic splines would be generated for wrapping.

On the other hand, due to the difference of each human face, the facial color information of each portrait should be simplified to store for our proposed system. First, as mentioned above, the portrait would be partitioned into several bicubic patches. Then, the TPS(Thin-Plate Spline) algorithm is adopted to interpolate the color of each region and reconstruct the new facial skin of the input portrait according to the stored bicubic patches, as shown in Fig. 11. The original facial scars, pores and other defects can be removed and replaced by the good facial skin which is chosen from our database.

In our database, we only saved the facial color information on the each nodes of bicubic pathch. In each bicubic patch, given $N$ controlled points of the facial saliency, the position of the controlled points is $(u_i, v_i), i \in N$. The equation $f(u_i, v_i)$ of the TPS algorithm is defined as

$$f(u,v) = \sum_{i=1}^{N} \alpha_i \phi(\|(u_i, v_i) - (u,v)\|) + b_0 + b_1 u + b_2 v. \quad (4)$$

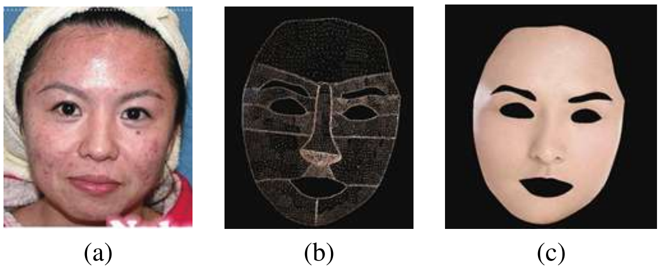



Fig. 11. The image (b) is interpolated from the image (c) by using the TPS algorithm.

where $\sum_{i=1}^{N} \alpha_i = 0$, $\sum_{i=1}^{N} \alpha_i u_i = 0$, $\sum_{i=1}^{N} \alpha_i v_i = 0$.

In (4), the two coefficients, $\alpha$ and $b$, are needed for obtaining the color information of all pixels on the portrait. $h$ is represented as the color information in each bicubic patches, $f(u_i, v_i) = h$. Based on the radial basis function $\phi(s) = s^2 \log s$ and linear $\alpha_i$, the coefficients, $\alpha$ and $b$, can be calculated by

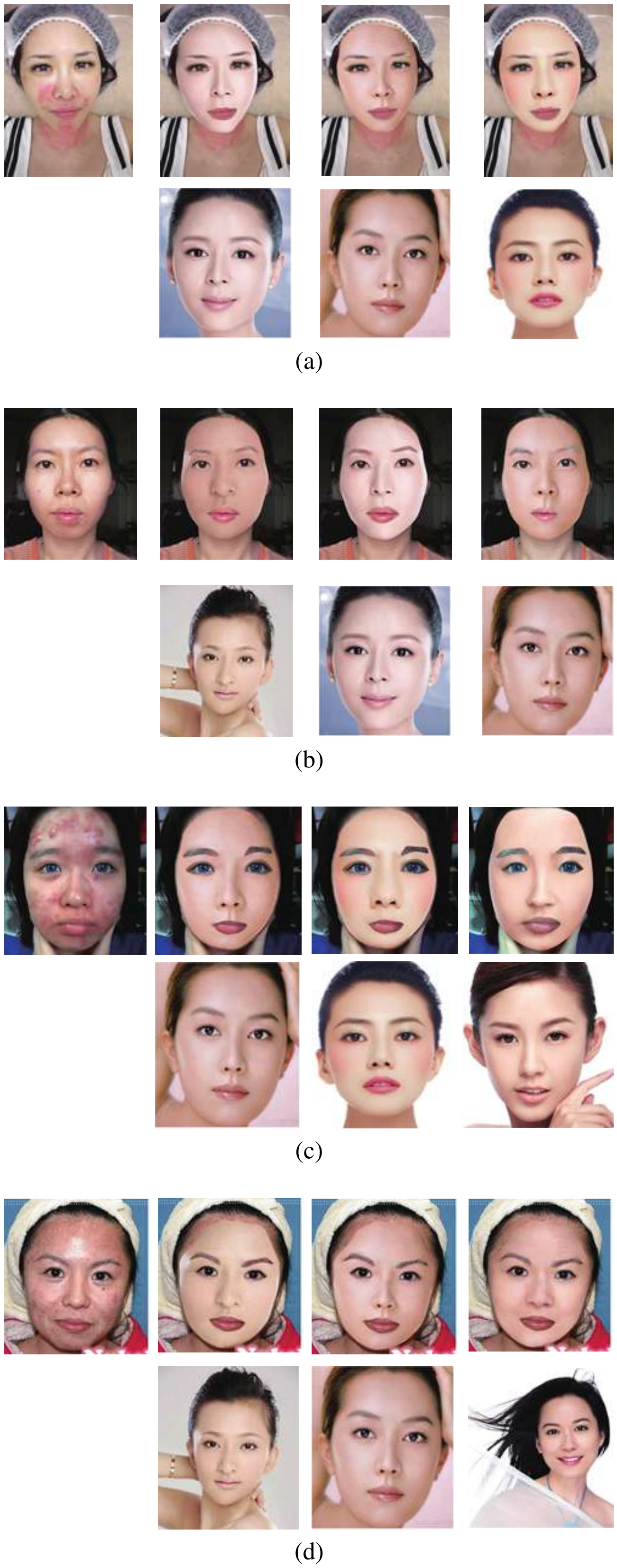
$$\begin{bmatrix} K & P \\ P^T & O \end{bmatrix} \begin{bmatrix} \alpha \\ b \end{bmatrix} = \begin{bmatrix} h \\ o \end{bmatrix} \tag{5}$$

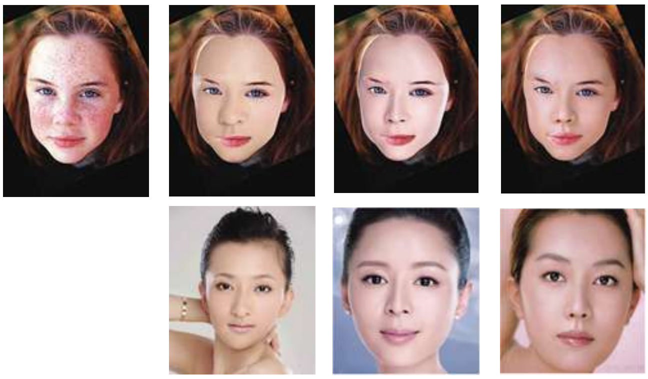
where $\alpha$, $b$,and $h$ are denoted as $[\alpha_1, \alpha_2, \cdots \alpha_N]^T$, $b = [b_0, b_1, b_2]^T$, and $h = [h_0, h_1, h_2]^T$, respectively. Next, matrix $K_{ij} = \phi(\|(u_i, v_i) - (u_j, v_j)\|)$. Each column $i$ of matrix $P$ is denoted as $[1, u_i, v_i]$. Matrix $O$ is a $3 \times 3$ zero matrix. Finally, $o$ is a $3 \times 1$ zero vector. By using the linear system, the two coefficients, $\alpha$ and $b$, can be solved. Then, (4) can be evaluated according the two coefficients, $\alpha$ and $b$ so that the required color information is obtained to remove the facial scars, pores, and other defects for the proposed system.

The transformed facial skins may have large color difference between other facial features, and this may create obvious seams and results in annoying artifacts in the final result. Therefore, Poisson blending method [7] is adopted to fuse the user input portrait with the chosen facial skin of the database. These method is introduced for seamless editing of image regions based on solving Poisson equations. In other words, it allows the user to remove and add objects into the original image seamlessly. Therefore, the chosen facial skin of the database can be blended into the input portrait and replaced the original facial skin for beautifying the portrait.

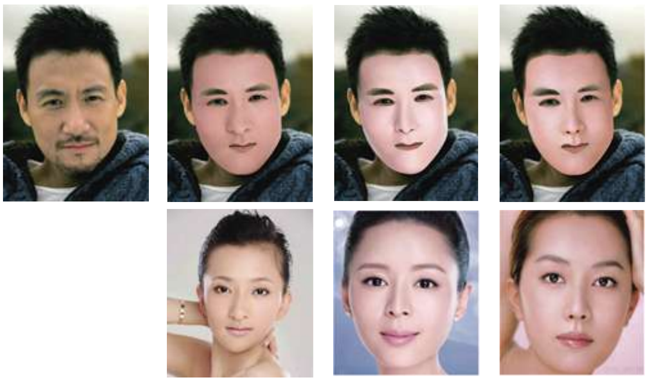
## VI. Experimental Results

After building the entire face skin changing system, we start to collect portraits from the Internet based on the following criteria: first is that the orientation of the face is almost facing forward; second is that the skin complexion and color is attractive based on the author's view point; third is that the facial skin is scar free and smooth. After creating the skin changing database, we uses our system to change the skin of several chosen portraits and the results are shown in Fig. 12. Fig. 12(a) to (f) show six facial skin changing results. The top-left picture is the original portrait and the top-right three pictures are the result portraits which are generated based on the chosen three portraits on the bottom-right three pictures.





(e)



(f)

Fig. 12. The original input portrait and the resultant portraits which are generated by choosing different database portraits.

We can easily note that the scar is quite obviously on the face in Fig. 12(a). Fig. 12(a) illustrate that the proposed system has good scar removal ability. In Fig. 12(b), the portrait looks like she has some undesirable pores on her face. After our system change the facial skin of the portrait, it is observed that she has good facial skin complexion and facial skin color in Fig. 12(b). Next, Fig. 12(c) shows that the girl's face has serious unpleasing defects which may cause some problems in her daily life. Hence, we used our proposed facial skin changing system to replace her facial skin of the portrait by selecting different database portraits. The resultant images are quite satisfied, and the attractiveness of the portrait is increased. Then, Fig. 12(d) demonstrates that our proposed system has a good ability to increase the attractiveness of the portrait by replacing the unwanted spots of the face with a beautiful and scarless skin of database portraits. In Fig. 12(e), we can observe that she has a dark facial skin so that her facial skin is needed to change for a good looking portrait. Our proposed system can easily accomplish this goal of owning a portrait which has satisfying facial attractiveness. Finally, some freckles are appeared on her face in Fig. 12(f). The resultant portraits which are generated by our proposed system have better facial skin and more attractiveness.

Because the human facial attractiveness may be affected by different cultures, ages, gender, and etc, the performance of the proposed system is evaluated by subjective examination. Based on several original input portraits, by visually analyzing the outputs in Fig. 12, it can be observed that the proposed system generates visually pleasing portraits, and the resultant portraits are more attractive than the original ones. Overall, our proposed human facial beautification system is quite useful for beautifying the portrait.

## VII. Conclusions

In this work, we propose a novel algorithm to remove unpleasant wrinkles, scars and pores on the face from a portrait. The key contribution of this work are two-fold. First, the proposed process is entirely automatic. A user could arbitrarily select his/her favorite facial skin color from our database to replace the skin of a portrait. This function is very useful for a doctor to illustrate the result to a patient before really applying a plastic surgery. Second, it is also useful for an artist to save a large amount of tedious work to fix facial scars, pores and any facial defects on the original face when painting a portrait The experimental results show that the beautified portraits are more attractive than the original ones based on the subjective evaluation.

## Acknowledgments

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