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Artistic Illumination Transfer for Portraits

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(a) Reference (b) Input (c) Result

Figure 1: *Artistic illumination Transfer. (a) is the reference artistic painting. (b) is the input portrait. (c) is our transferred result. The illumination in (c) is similar to that of (a).*

Abstract

Relighting a portrait in a single image is still a challenging problem, particularly when only a single artistic reference photograph or painting is provided. In this paper, we propose an artistic illumination transfer system for portraits based on a database of portrait images (photographs and paintings) associated with hand-drawn illumination templates (276) by artists. Users can select a reference portrait image in the database, and the corresponding illumination template is transferred to an input portrait using image warping. Users can also provide reference portrait images those are not in the database. Based on the Face Illumination Descriptor (FID), the system selects from the database the reference image with the closest illumination to that of the user-provided reference image and adjusts the corresponding illumination template to match the contrast of the user-provided reference image. Experiments on not only paintings but also photographs, paper-cuts and sketches demonstrate that convincing illumination transferred results can be rendered by our system.

Keywords: illumination transfer, illumination template, face illumination descriptor and matching, face relighting, face illumination rendering

Categories and Subject Descriptors (according to ACM CCS): J.5 [Computer Applications]: Arts and Humanities—Fine Arts; I.4.9 [Computing Methodologies]: Image Processing and Computer Vision—Applications

1. Introduction

1.1. Motivation

Image based face relighting has wide applications in film production, personal photo enhancement, art design, etc. Good lighting is the key to good portraiture. In practice, artists are required to make very careful observation and learn over the years how to replicate the pattern of light in the image [Hur07]. Both professional portrait photographs and masterpieces of portrait paintings by master painters such as

Leonardo da Vinci and *Rembrandt van Rijn* have artistic illumination effects which make the artwork attracting (Figure 1 (a)). However, with such a single reference portrait image, the task is more challenging. Current face relighting technologies and computer vision algorithms often fail in estimating reliable illumination component from a single artistic portrait image with complex texture and colors.

The goal of this paper is to achieve convenient rendering artistic illumination effects in a single portrait (frontal view, normal lighting: without obvious shadow and light effects), so as to make the illumination effects of the transferred result similar to those of a reference artistic portrait (see Figure 1). Typical artistic illumination effects are often featured by the shapes of the light and shadow areas in the face [JZC*10]. Thus, we do not aim for arbitrary relighting tasks. In the particular case of portrait illumination, only a few lighting setups are commonly used. We acquire the artistic illumination templates by referencing professional portraits with the help of professional artists.

1.2. Related Work

Current automatic face relighting methods are not designed to extract ideal illumination components from masterpiece portrait paintings and professional portrait photographs.

Quotient Image and Morphable Model. Quotient Image based methods [PTMD07, CSHB10] are not suitable to our task because two images are needed to form the quotient image as the illumination component. While in the artistic portraits collected by us, only a single reference image is available. We have tried to capture the quotient images in a photography studio. Since a pair of photos (one with artistic lighting and the other with normal lighting) are required , it is very hard to control the lighting equipment to realize such a fast switch between this two illumination conditions while the model remains still.

Recently, Wang *et al*. [WLH*07] integrate the spherical harmonics representation [BJ03] into the morphable model framework by a 3D spherical harmonic basis morphable model [BV99] (SHBMM). The re-constructed textured 3D faces can be re-rendered under the new illumination conditions. However, the synthesized results seem less realistic if the scanned faces are not similar to the input faces.

Single Image Methods. With a single reference image, the task is more challenging. The high contrast, dark shadow areas, over-light areas, complex face details (such as hair, beard, makeup, etc.) and various colors in masterpieces and professional photos (see Figure 3) may cause some artifacts by using the state-of-the-art single face relighting methods such as *Total Variation Model* [LYD09], *Intrinsic Image Decomposition* [BPD09, SY11, SYJL11], *Edge-Preserving Filters* [CCJZ11], etc.

Guo and Sim [GS09] adopt a gradient-based editing method, which add only large changes in the gradient domain of the reference image to the input image so as to transfer highlight and shading. However, their assumption that large changes are caused by makeup will hold only if the illumination of reference image is approximately uniform. While our reference images are artistic portrait images which contain noticeable shadows commonly.

Artistic Illumination Analysis and Evaluation. Jin *et al.* [JZC*10] have used local lighting contrast features to learn the artistic lighting template from portrait photos. The template is in fact an average template of 350 artistic portraits and is designed for classification and numerical aesthetic quality assessment of portrait photos. Though the templates can not be directly used to render the artistic illumination effects of a single input portrait, which is different from our templates, they can predict an indicative score from 0 to 1 of the artistic lighting usage of a portrait.

As surveyed in Stork [Sto09], current methods of computer analysis of lighting in Masterpiece fall into two general classes: model independent (where one makes no assumption about the three-dimensional shape of the rendered objects) and model dependent (where one does make some assumptions about their three-dimensional shape). However, the surveyed methods mainly analyze the direction and position of the key light sources. Complex multiple light sources with various shapes will be challenging for these methods. In addition, 3D model of the input portrait will be needed when rendering the illumination effects under the analyzed lighting condition.

1.3. Our Approach

The challenge of our task resides in that only a single artistic reference image is provided and the extreme sensitivity of the human perception system towards the appearance of the face of another person [CSHB10]. This paper proposes an artist-assisted method to transfer artistic illumination effects from professional portraits to input portraits. We aim to make the illumination effects of the transferred results as similar as possible to those of the reference artistic portraits rather than be radiometrically accurate, which is not that critical in producing artistic portraits. To the best of our knowledge, no literature has addressed this problem before.

It is observed that professional painters can easily draw light and shadow effects on a portrait under normal lighting by using an off-the-shelf image drawing software. Painters have years of experience of appreciating, perceiving and drawing light and shadow effects. Thus we ask some professional painters to draw light and shadow effects on a portrait under normal illumination condition by referencing an artistic portrait. Then the illumination component of the reference artistic portrait can be conveniently extracted as an illumination template (including separated shadow and light templates as described in Section 2). This template contains

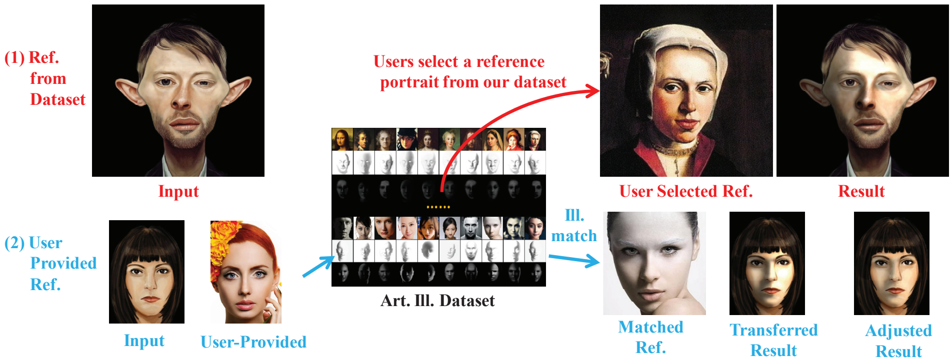


Figure 2: *Overview of our system, which offers 2 main ways of transferring artistic illumination for portraits. (1) Users can select reference illumination from our database (Section 3). (2) Users can provide a custom reference portrait (Section 4).*

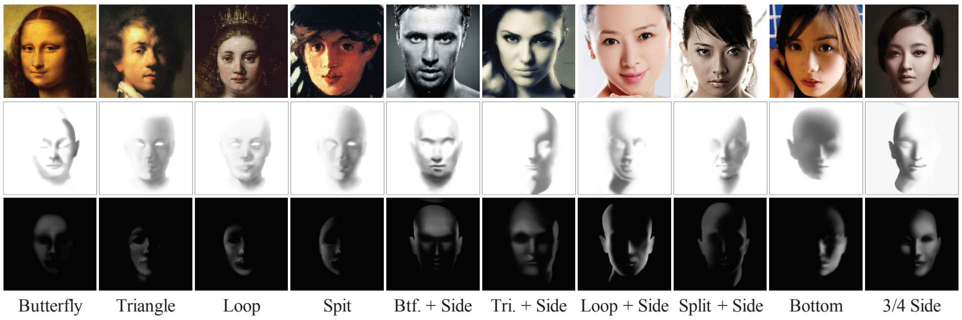


Figure 3: 10 *representative artistic portraits and artistic illumination templates. The* 10 *types are classified by artists from* 500 *artistic photographs and masterpiece paintings. They are featured mainly by the shadow and the light effects. The four basic shadow effects are: Triangle, Butterfly Loop and Split as described in [JZC*10]. With the addition of the side light, four other illumination types are: Butterfly plus Side, Loop plus side, Split plus Side, and Triangle plus Side. The other two types are: Bottom (with the key light from Bottom) and Three-quarters Side (with the key light generating three-quarters of the face in the light side). We collect 276 illumination templates covering these* 10 *artistic illumination types.*

not only the artistic illumination effects of the reference portrait but also the artistic creation of the painters.

Based on the collected database of artistic illumination templates, we proposed a system to transfer illumination, which offers 2 main ways of transferring artistic illumination for portraits (see Figure 2), i.e. (1) choosing reference illumination from our database; (2) using user-provided reference portraits. To achieve the second way, we adopt a *Face Illumination Descriptor* (FID) based on a modified version of the local lighting contrast features [JZC*10] to describe the illumination effects of a portrait. The system selects from the database the reference image with the closest illumination to that of the user-provided reference image and adjusts the corresponding illumination template to match the contrast of the user-provided reference image. This FID can be used for illumination matching and illumination template adjusting (Section 4). The results demonstrate that our approach can convincingly transfer artistic illumination effects to the input portraits.

Our main contribution is developing the first system by using a database of illumination templates to transfer artistic illumination from professional portraits to normal lighting portraits. We make an exploration of building a bridge between the experiences and knowledge of artists and reusable and computable dataset for image based illumination rendering.

2. Artistic Illumination Database

The overview of the our system is illustrated in Figure 2, which offers 2 main ways of transferring artistic illumination for portraits. The theoretical portrait image model and the database of artistic illumination templates (see Figure 3) are described in this section.

Theoretical Portrait Image Model. Professional artists often use lighting from some directions to make appropriate light and shadow effects in the face. We thus assume that in the photography studio, the artistic photos with the artistic illumination effects can be derived from the photos taken under a normal illumination condition by shutting down or moving further some of the light sources to reduce the intensity of the face in some regions and by adding or moving closely some other light sources to increase the intensity. In portrait paintings, the way is similar, although the light and shadow effects are drawn by painters. The color of the light sources is assumed to be white, which is common in studios. Theoretically, with the above assumptions, the observed color of a portrait image under the artistic illumination condition c at a pixel in each channel of the RGB color space is:

$$P(c) = P(U) * T_I(c) = P(U) * T_s(c) * T_l(c) \qquad (1)$$

where $P(U)$ is the portrait image under a relatively uniform illumination condition U(i.e. normal illumination condition, without obvious shadow and light effects in the face). $T_I(c)$, $T_s(c)$ and $T_l(c)$ refer to the *illumination template*, the *shadow template* and the *light template*. In studios, light sources are often with large areas of softbox or windows and are easy to light the face uniformly. In practice, the illumination in the input portraits need not to be that uniform. Our experimental results show that, with the illumination templates drawn by the painters, the input portraits without obvious light or shadow effects can be used to render artistic illumination effects well.

Database of Artistic Illumination Templates. Artists often use the *light side* to represent the light and the specular highlight areas which are directly facing the light sources. They use the *dark side* to indicate both the cast shadow and form (attached) shadow areas of an object. In practice, they consider and draw the *light side* and the *dark side* separately. The *illumination template* $T_I(c)$ contains the *shadow template* $T_s(c)$ and the *light template* $T_l(c)$, which indicates where and how to reduce and increase the pixel intensity, respectively. The *illumination template* $T_I(c)$ can be considered as the transformation from the uniform illumination condition U to the illumination condition c. The range of $T_s(c)$ is between 0 and 1, and $T_l(c)$ is greater than 1. The only difference between our portrait image model and the quotient image or the intrinsic image is that the illumination component is separated into the shadow component and the light component. The shadow component and the light component are from the so-called *dark side* and the *light side* of the portraits by artists. We make such a design of the portrait photo model not only because artists draw shadow and light separately but also because that in some applications, the shadow and light templates can be treated in different manners conveniently. For common use, the shadow and the light templates can be multiplied together.

The invited professional painters draw the illumination effects of the reference portraits in a *standard* face which contains few light and shadow effects. For female and male, we select the *average face* of 64 female and 32 male face photos generated by the *Beauty Check* project as the *standard* face image to record the illumination effects of the reference portraits, respectively. The drawing procedure of artists to get the shadow and the light templates are shown in Figure 4. A description of our artistic illumination template database is in Figure 3. According to our statistics, nearly one hour is enough for a professional artist to create a illumination template.

3. Reference from Database

Face Alignment and Warping. In order to warp one face according to the shape of another face so as to transfer the illumination template to the input portrait, we adopt an extended Active Shape Model (ASM) [MN08] to localize the facial feature points, which are taken as the inputs of the Multilevel Free-Form Deformation (MFFD) technique [LWyCS96]. We denote the face warping procedure as:

$$F_s^W = \mathrm{Warp}(F_s, F_d) \qquad (2)$$

where the face F_s is warped into F_s^w according to the facial feature points of the face F_d. When drawing the shadow and the light templates, the painters are more familiar with the gray images. Due to various changes of different faces under various illuminations, current ASM methods tend to fail to locate the accurate feature points, therefore we get a initial feature points by using ASM, and then refine their accurate position in an interactive way. In our experiments, one minute is enough to fix the feature points accurately. The corrected results are shown in Figure 4 (g) and (h).

Rendering with Artistic Illumination Template. The illumination template is drawn on the *average face*. Therefore, the shape of the illumination template is the same as that of the *average face*. Based on Eq. 1, the transferred result $P(c)$ of the input portrait P by referencing the artistic portrait $P^r(c)$ under the artistic illumination condition c is described in Eq. 3. An example is shown in Figure 4.

$$P(c) = P * T_s^{rW}(c) * T_l^{rW}(c) \qquad (3)$$

where $T_s^{rW}(c)$ and $T_l^{rW}(c)$ are the warped result of the shadow template $T_s^r(c)$ and the light template $T_l^r(c)$, respectively. They are all warped according to the face shape of the input portrait face.

4. User-provided Reference

To extend the ability of our template database, for the user-provided reference artistic portrait out of our database, the

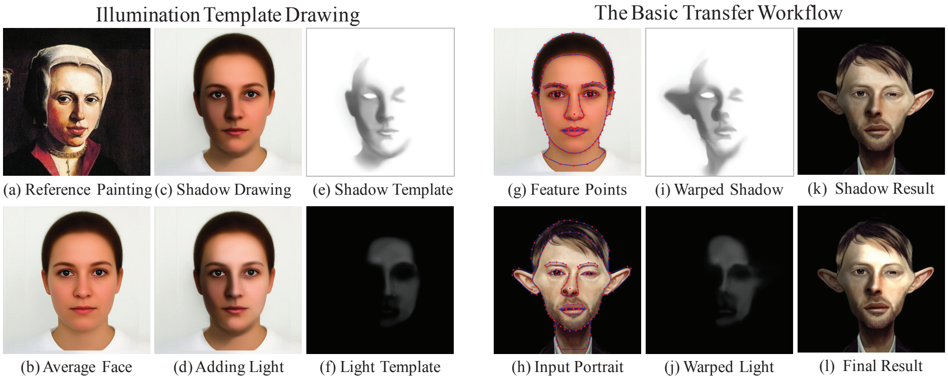


Figure 4: *Artistic Illumination Template and the basic transfer workflow (choosing reference from our database). (a) is a reference artistic portrait:* Mme Moitessier *of the great French artist* Jean Auguste Dominique Ingres*; (b) is the average female face of* 64 *female face photos generated by the Beauty Check project; (c) is the shadow effects drawn by one painter; (d): light effects are added to (c). According to Eq. 1, (e) and (f) are considered as the shadow template and the light template, respectively. The light template is linearly transformed for visualization. In our basic transfer workflow, the input face is aligned firstly. (g) and (h): 160 feature points in the average face and input portrait; (i) and (j) are the warped results of the shadow template (e) and light template (f), respectively. (k) is the transferred result with only shadow template applied. (l) is the final transferred result with both shadow and light effects.*

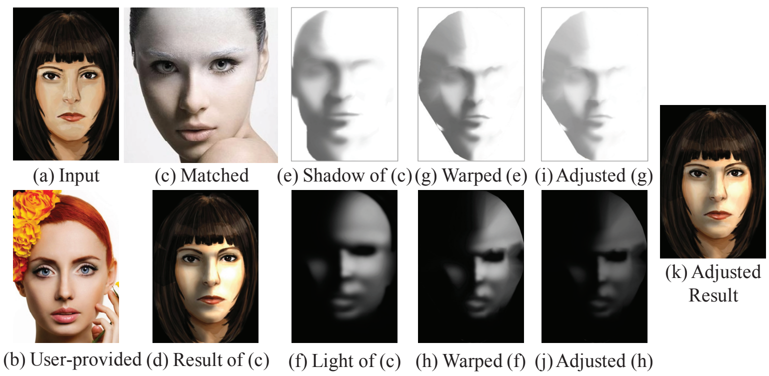


Figure 5: *The extended transfer workflow (User-provided Reference). (a) is the input portrait; (b) is the user-provided reference outside our database; (c) is the matched result obtained by our illumination matching method; (d) is the transferred result by referencing (c); (e) and (f) is the shadow template and the light template of (c); (g) and (h) are the warped templates from (e) and (f); (i) and (j) are the automatic adjusted templates from (g) and (h); (k) are the adjusted result of (d). Illumination in (k) is more similar to that of (b) than that of (c).*

one with the most similar illumination to that of the reference one is selected from our database. Then we make some adjustment of the corresponding illumination template to make the illumination of the results more similar to that of the user-provided reference one (see Figure 5). We design a *Face Illumination Descriptor* (FID) to describe the illumination effects of a portrait, which can be used for both illumination matching and illumination template adjusting.

Face Illumination Descriptor. We define the the Face Illumination Descriptors(FID) based on the local lighting contrast features introduced in [JZC*10], which are extracted from 16 pre-defined regions in frontal faces. We extend the rectangle region to non-regular region with a mask of each parts such as forehead, nose, eyebrows, mouths, etc. Based on the learned template of [JZC*10], we only extract the local lighting contrast of each region by calculate the difference between the mean pixel values of the 2 subregions on the L channel in "CIE1976($L*, a*, b*$)" color space.

The face illumination descriptor $FID(P)$ of a face portrait image P is a 48d vector, which consists of local lighting contrast values in the 3 directions of the 16 regions in the face:

$$\mathrm{FID}(P) = \{r_i^{lr}, r_i^{tb}, r_i^{cp} | i = 1, 2, ...16\}. \tag{4}$$

where r_i^{lr}, r_i^{tb} and r_i^{cp} are the responses of the local lighting contrast features in the contrast direction left-vs-right, top-vs-bottom and center-vs-periphery computed in the region i, respectively.

Then the difference between 2 face illumination descriptors can be defined by using the *Euclidean distance* as:

$$\mathrm{ED}(fid_1, fid_2) = \sqrt{\Sigma_{i=1}^{16}\Sigma_d (r_{1i}^d - r_{2i}^d)^2} \tag{5}$$

where $d \in \{lr, tb, cp\}$, and r_{1i}^d and r_{2i}^d are the elements in fid_1 and fid_2, respectively.

Face Illumination Matching. For artistic portrait image out of the database, the one with the most similar illumination is selected. We assume that the faces have similar illumination effects under the same illumination condition. We thus use the illumination descriptor to approximate the lighting effects for illumination matching of faces. The one with the minimum difference on the FID under a threshold is considered as the matched result.

Illumination Template Adjusting. The illumination effects of the matched reference portrait still have a little difference from those of the user custom one. Since our database covers most of the lighting directions within each illumination type, the one with similar illumination effects can always be matched. Based on the observations of artistic portrait images and according to the painters, one of the biggest differences within an illumination type is the intensity ratio between the shadow and light regions, which is mainly due to the ratio between the key and the fill light sources in studios. The contrasts between the light and the shadow areas are often with a little difference in the matched portrait and the user-provided one. This can be automatically adjusted based on FID.

During the drawing procedure of the painters, some intermediate light and shadow layers are darker or lighter than those of the reference artistic portrait. Then they adjust the whole light and shadow layer by the "level" tool, which in fact adjusts the input and output graylevel of light and shadow layer pixels. Making the shadow template darker or lighter will influence the ratio. The adjustment of the light template is similar. Then we automatic adjust the matched the input and output graylevel of illumination templates by searching the optimal parameter combination to minimize the distance between the FIDs of the transferred result and the user custom reference. According to the painters, the adjustment of the graylevel is always within a small range. Then the searching is in an exhaustive way because the size of the solution space of the adjusting parameter combination is only around 400. After the illumination template is adjusted, with face alignment, the artistic illumination effects of the user-provided reference artistic portrait, which is out of our database, are transferred to the input portrait. This last step is the same as described in Section 3. More implementation details of the Section 4 are described in the additional multimedia material.

5. Experiments

The proposed system is shown in the multimedia attachments. The 2 main ways of artistic illumination transfer provided by our system are illustrated in this section. Due to the page restriction, a small sample of our results are shown in this section. More experiments have been done to evaluate our system. **Additional results are shown in the multimedia attachments. Please zoom-in to examine all figures.**

5.1. Reference from Database

It is observed that our templates can suit portrait paintings of various styles, such cartoon, watercolor and abstraction. Besides the original portrait paintings drawn by painters, the artistic illumination effects can also be transferred to computer generated paintings (CGP) from photographs. We use current nonphotorealistic rendering technologies to generate paintings from photos, such as flow-based image abstraction [KLC09], Sisley the abstract painter [ZZ10]. Furthermore, we find that some templates can even suit some fine art portrait photographs shot by professional photographers. This is mainly because the fine art photos are similar to portrait paintings to some extents. Our system can make the illumination of the transferred result similar to that of the reference one (paintings, CGP, fine art photos). More transfer results are shown in the multimedia attachments.

One Template, Multiple Inputs. The same illumination template is applied to different input portraits as shown in Figure 6. This indicates the significant re-usability of our approach, i.e., we can transfer only one template drawn by the painter to multiple portraits of other people. In Figure 6, we show the results of a single portrait in different styles. Results of input portraits of different people with different styles are also shown.

One Input, Multiple Template. We transfer different illumination templates to the same input portrait, and the results are shown in Figure 7, which contains typical artistic illumination styles and other ones. It means that people can obtain multiple artistic transferred results with different illumination effects and choose their favourite ones. In Figure 7, we show the results of various input portraits, i.e. paintings and CGP.

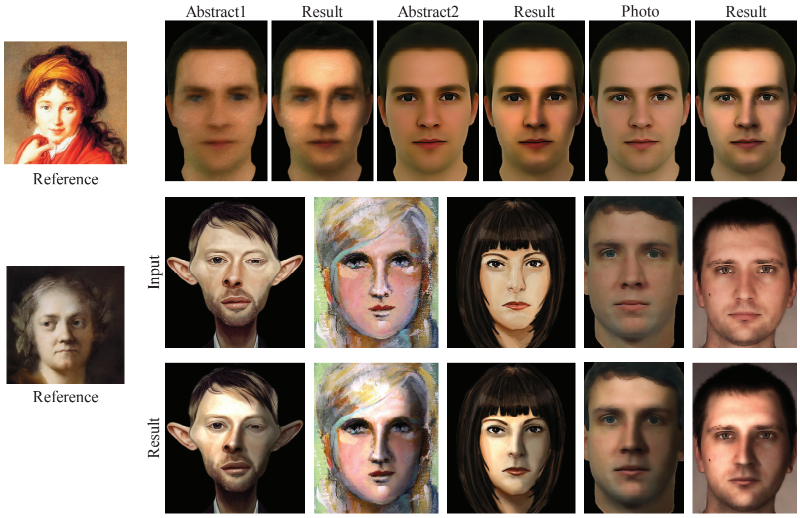


Figure 6: *One Template, Multiple Inputs. With one of the reference portrait in our database, artistic illumination effects can be rendered in multiple styles of paintings, such as abstraction, cartoon, watercolor etc. Two examples are shown here. The input portraits in the first line are a portrait photo and its 2 abstraction styles generated by [ZZ10] (Abstract1) and [KLC09] (Abstract2).*

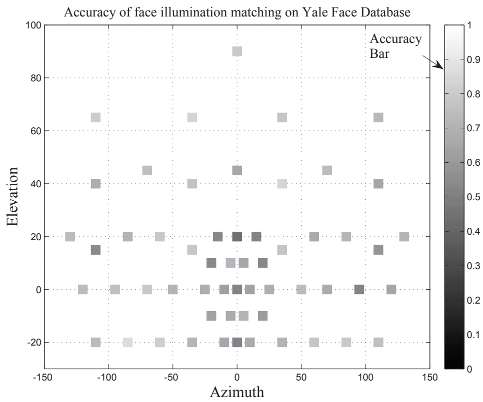


Figure 8: *Accuracy of face illumination matching on Yale Face database. The distribution of all the 64 light sources is shown with each direction as a square. The average accuracy of each direction is shown as a small squares. The whiter the squares are, the more accurate they are considered to be. The light source directions are with respect to the camera axis, which is perpendicular to human faces for frontal view photos. The azimuth is the horizontal angle, while the elevation is the vertical angle.*

Figure 9: *More matched results. Top line: the queried art portrait out of our database. Bottom line: the matched results obtained by our face illumination matching method. The queried art portrait shown in this figure cover most of the artistic illumination types.*

5.2. User-provided Reference

Illumination Matching Results. We test the face illumination matching in the Yale Face database B and the Extension [GBK01], which contain frontal face photos of 38 subjects under the same 64 lighting conditions (64 point light sources in 64 directions). We denote the frontal face database as $\{\Omega^{y_i}|i=1,2,...,38\}, \Omega^{y_i}=\{P_i^j|j=1,2,...,64\}$. For each P_i^j, we run the illumination matching $\mathrm{FIM}(P_i^j,\Omega^{y_k})$ to search the same lighting direction in each Ω^{y_k}, $k=1,2,...,38, k\neq i$. Due to the dense light directions of Yale database, even human can not distinguish the illumination effects of two light directions with small angle. We thus relax the correct matching criterion, and set that if the same lighting condition as that of P_i^j is in the top 3 matched results, we consider it as correct matching. The accuracy rate for each P_i^j is the times of correct matching divided by 37. The average accuracy rate for each lighting condition j is the average over the accuracy rate of $\{P_i^j|i=1,2,...,38\}$.

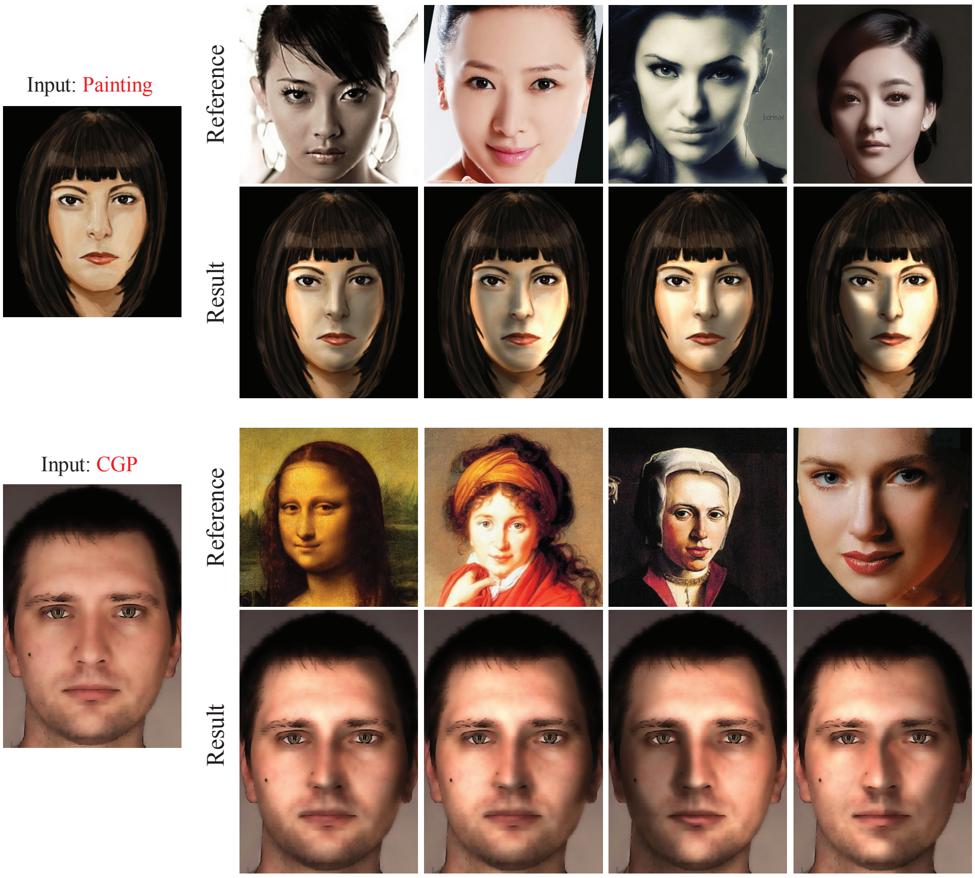
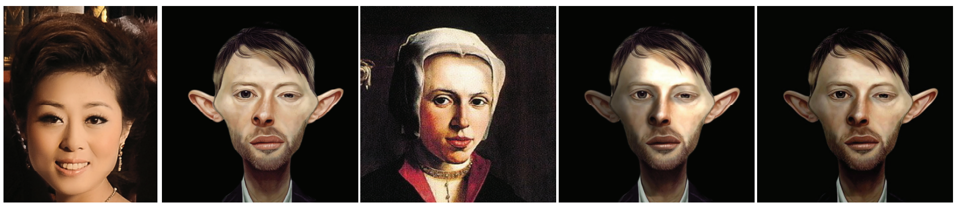


Figure 7: *One Input, Multiple Templates. Multiple illumination effects can be transferred to one input portrait. Two categories of input portraits are show here, i.e. a painting and a computer generated painting(CGP) [KLC09]. The transferred results of fine art photos are shown in the multimedia attachments.*



(a) User-provided (b) Input (c) Ill. Matched (d) Result of (b) (e) Adjusted Result

Figure 10: *Illumination template adjustment. (a) is the user custom reference outside our database; (b) is the input portrait; (c) is the matched result obtained by our illumination matching method; (d) is the transferred result by referencing (b); (e) is the adjusted result of (d). Illumination effects in (e) is more similar to that of (a) than that of (c). More results are shown in the multimedia attachments.*

The accuracy rates are shown in Figure 8. Most lighting conditions achieve above 70% accuracy except the ones with small angle with respect to camera axis, which are really difficult to distinguish even by human. This demonstrates how well the face illumination matching performances in such a strict testing. The query and the matched results returned by our method have the similar illumination effects, which show the performance of the method. More matched results of the real artistic portraits and our database are shown in Figure 9 and the multimedia attachments.

Figure 11: *Comparison with [CCJZ11]. (a) is the masterpiece* Self Portrait *of the German artist Albrecht Durer. (b) is the input abstract portrait generated by [KLC09]. (c) is the result by [CCJZ11]. (d) is our transferred result. The multiple facial details in the artwork influence the transferred result of [CCJZ11].*

Illumination Template Adjusting. Figure 10 shows an example of illumination template adjusting. The user-provided reference portrait is not in our database. Through the illumination matching, the one with the most similar illumination in our database to that of the user-provided reference is matched. By our adjusting method, we obtain the adjusted illumination template that minimizes the distance between the FID of the transferred result and the user-provided artistic portrait.

5.3. Comparison with Automatic Relighting Method

The most recently state-of-the-art automatic method of single image based face relighting is [CCJZ11]. However, even this method can not deal with artistic portraits well. A comparison with [CCJZ11] is illustrated in Figure 11. Chen *et al.* [CCJZ11] have employed edge-preserving filter to transfer the face illumination. They consider the large-scale layer separated by edge-preserving filters as the coarse illumination components and design spatial varying filtering parameters near the edges of the eyes, nose, mouth and the contour of the face. They can deal with relatively high contrast light and shadow well. However, the filtering parameters are designed based on a *clean* face without any face details in the skin areas. Thus, the eyes, lips, hair, bread and other face details cause artitfaces into their transferred results. While our system uses a database of illumination templates by artists for artistic illumination transfer and can record and reuse the experience and creation of human artists. The original test photo is from the FERET database [PWHR98, PMRR00].

5.4. Applications

Numerical Assessment and One-key Transfer. We use the method of [JZC*10] to predict indicative scores from 0 to 1 of the artistic lighting usage of the input and the result portraits by our system. We collect more artistic portrait images and invite professional photographers and painters to do the human study as our training data to predict the indicative scores. Most of the transferred results by our system can achieve higher scores than the input portraits which have no obvious illumination effects. Based on the predict scores, our system can automatically promote the most *appropriate* reference portrait for the input portrait. Artists often design lighting according to the shape of the face and the distribution and shapes of facial parts (eyes, nose, etc.). Thus our system automatically searches a set of faces (10 in our system) with similar shapes and facial part distributions to those of the input portraits from our database. Then the result with the highest score is selected as the proposed appropriate result of the input portrait. More implementation details and results are shown in the multimedia attachments.

Paper-cut and Sketch. In some artistic portrait styles such as paper-cut and sketch, illumination effects are drawn in special effects of two-tone form and hatching form. Thus the styles of our illumination templates should be adapted to the styles of the underlying portrait images. Based on the our separated light and shadow templates, the styles of the illumination templates can be easily adapted to the portraits of paper-cut style (two-tone form) and sketch style (hatching form). The implementation details and the transferred results of paper-cut and sketch styles are shown in the multimedia attachments. The convincing examples of paper-cut and sketch scenarios further demonstrates the feasibility of the proposed system.

6. Conclusion and Discussion

Conclusion. We have presented a system to transfer artistic illumination of portraits based on the painters' experience and knowledge of illumination drawing. A database of artistic illumination templates covering typical artistic illumination effects is developed. The input portraits can be various original paintings, computer generating paintings and fine art photos. This would make composition of an artistic portrait convenient for common people and professional art designers since it only requires a single portrait as the input. The illumination matching and illumination template adjusting methods based on the face illumination descriptor can greatly expand the usability of the proposed system with limited illumination templates. The results show that our system can transfer convincing artistic illumination effects into the input portraits. In addition, the illumination template can be easily adapted to other styles such as paper-cut and sketch. Our work not only can be used for professional artists but also has the potential for personal portrait enhancement.

Discussion and Future Work. The system proposed is based on illumination templates drawn on portraits under a normal illumination without obvious shadow and light effects. Therefore, when the input portraits are with some obvious illumination effects in the face, our transferred results will contain some artifacts. These kinds of input portraits may be firstly treated by some illumination normalization technologies (for example, using the method of [CCJZ11] to transfer a normal illumination effects to a non-normal illumination input portrait). However, to the best of our knowledge, there is not such reliable related work addressing the illumination normalization for artistic illumination transfer for portraits.

The illumination template can also be used to remove illumination by dividing the portraits by the matched template. Careful adjustments are needed to refine the illumination removal results if the illumination template is not the exact same contrast as the real illumination in the face image. This could be our future work.

Our artist-drawn templates referencing masterpiece portraits can produce more convincing results in paintings and fine art portrait photos than in daily personal face photos. In fact, the illumination templates could also be created by CG artists adjusting lighting over the 3D model of a face. For relighting of real face photo, a realistic skin shader could then be used to produce illumination templates with scattering effects. The overall method could remain the same, and this may be our future work.

Besides paper-cut and sketch, with our illumination template, more illumination styles such as stippling [KSL*08] can be conveniently rendered in our future work. Our dataset for training in the artistic illumination evaluation consists only professional photographs and materpiece paintings. Thus, it does not suit evaluating paper-cut and sketch portraits. And illumination matching between two portraits of different modalities (such as between sketch and photos) may also be our future work.

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