Example-Based Contrast Enhancement for Portrait Photograph

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Abstract

This paper proposes an approach whereby the regional contrasts in snap-shot style portrait photographs are enhanced using pre-modern portrait paintings as aesthetic exemplars. The reference portrait painting is selected based on a comparison of the existing contrast properties of the painting and the photograph. The contrast style in the selected reference painting is transferred to the photograph by mapping the inter-and intra-regional contrast of the regions, such as the face and skin area, reminder part of figure, and non-figure region. A novel two-part partial contrast stretching method is proposed to achieve the contrast mapping. Finally, the transition boundary between regions is smoothed and the non-figure region is blurred. The experiment results demonstrate the effectiveness of the proposed method.

1 Introduction

Traditional portrait paintings follow reasonably consistent formal rules of construction. The figures, being of high pictorial value, are placed somewhere in the foreground of the painting. The figure (FG) in the portrait painting Figure 1(a) is darker than the outdoor background (non-figure, BG). In the painting Figure 1(b), the outdoor BG is darker than the figure. These differences between regions are inter-contrast. In all the cases, the figure is of a higher lightness and saturation contrast than the BG. These are contrast differences within regions (intra-contrast). Despite the differences in strategies that have been employed, the artist has maintained in all paintings a visual emphasis on the figure. The face and skin areas are usually the lightest parts of the figure and have a high contrast with the reminder part of the figure and BG regions. In contrast, in snap-shot style photographs which are more casually framed ('point and shoot'), the lighting and the regional contrast are not well organized (e.g the two photographs in Figure 1(c)(d)).

(a) Painting (b) Painting (c) Photograph (d) Photograph

Figure 1: Examples. (d) is from the database in [1].

In the paper, we explore a method by which the high-level contrast organization of paintings can be transferred to photographs. This is done with respect to the contrast values of the face and skin (FS), the reminder part of figure (FO), and the non-figure regions. These values are considered both inter and intra regionally. The framework of the contrast enhancement is shown in the Figure 2.

Figure 2: Framework of contrast enhancement.

The contrast organization in paintings is very far from being absolute. So, we propose an example-based approach for contrast enhancement. First, the example paintings are culled based on existing contrast values that they hold in common with those of the target photograph. Then, the portrait photograph is rendered region by region based on the user-selected one of top ranked reference paintings. Finally, the transition boundary between regions is smoothed and BG details are blurred.
The FG/BG can be segmented using depth as in [8]. The segmentation is not the focus of the paper, so in our experiments, the FG/BG was segmented manually.

2 Previous Works

The proposed contrast enhancement method can be viewed as an object-based local contrast enhancement method. Existing local contrast adjustment techniques [7][2] only optimize the contrast of local areas, and don’t aim to visually emphasize the figure object. Interactive local contrast adjustment methods [6][3] can change the contrast of interest regions or objects by drawing brush strokes. These interactive adjustments need time and skill to master. In 2011, Bychkovsky et al. [1] proposed learning photographic tonal adjustment from photographers to personalize the tone adjustment of an image. This method needs a lot of example input-output pairs for training. Zhang et al. considered the contrast difference in different depth layers and achieved contrast mapping across depth layers between landscape photographs and paintings [9]. Applying similar consideration, we conduct contrast enhancement separately on the three regions FS, FO and BG in portrait photographs based on reference painting.

3 Reference Selection

As the principle of contrast enhancement is to retain the natural relationship of FG and BG and only enhance its perceptual contrast, so the reference paintings should be selected on the basis of having a similar natural property to the target photographs. For example, a dark figure with a light BG should be rendered referring to a painting that also has a dark figure and light BG. This natural property can be measured by inter- and intra-contrasts of the FG and BG. The similarity of two portrait images are calculated by inter- and intra- contrast features and ranked by descending similarity. More details of the calculation of the features and similarity can be found in [8]. For each portrait photograph, portrait paintings having top \( n \) similarity values with the photograph are recommended as the references. The user can choose one of them as the example template with which the photograph portrait is rendered.

4 Contrast Enhancement

The features used in the contrast enhancement are the lightness and saturation contrasts within and between FS, FO and BG in LCH color space. The L channel best matches the human perception of the lightness of colors and the Chroma is indicative of saturation. The face and skin areas are detected based on the skin color in the figure using the method in [4] with our morphology post-processing.

4.1 Contrast Mapping

Based on Weber’s law, the intra-contrast of one region can be defined as \( \frac{I_{\text{max}} - I_{\text{min}}}{I_{\text{mean}}} \). Inspired by this definition, adjusting the spread range and mean value can change the perceptual intra-contrast. Meanwhile, adjusting the mean value of each region changes the inter-contrast of regions. More formally this means that we could transfer the mean and spread range of regions between painting and photograph to enhance contrast.

Contrast stretching is commonly used to change the spread range to enhance contrast when avoiding artifacts. The spread range can be expressed as \( \text{maxima - minima} \). Therefore we can map the maxima and minima values instead of mapping the spread range directly. For our application, we propose to use partial contrast stretching separately on the lower value part and upper value part separated by the mean value as the graph shown in Figure 3(a). First, the lower and upper value parts are linearly scaled separately by \( \eta_1, \eta_2 \).

\[
I' = \begin{cases} 
(I - m_s) \cdot \eta_1 + m_s & \text{if} \ I < m_s \\
(I - m_s) \cdot \eta_2 + m_s & \text{if} \ I \geq m_s
\end{cases}
\]

(1)

\[
\eta_1 = 1 - \beta + \beta \cdot \frac{I_{\text{max}} - m_r}{I_{\text{min}} - m_s}
\]

(2)

\[
\eta_2 = 1 - \beta + \beta \cdot \frac{I_{\text{max}} - m_r}{I_{\text{max}} - m_s}
\]

(3)

where \( I \) is the region (FS, FO or BG) of the photograph. \( I_r \) is the corresponding reference region. \( m_s, m_r \) are the mean values of \( I \) and \( I_r \) correspondingly. \( I_{\text{min}}, I_{\text{max}}, I'_{\text{min}}, I'_{\text{max}} \) are the minima and maxima values of \( I \). \( I'_{\text{min}}, I'_{\text{max}} \) are the minima and maxima values of \( I_r \). We use the \( 1^{\text{st}} \) percentile value as the minima value, and \( 99^{\text{th}} \) percentile value as the maxima value. \( \beta \) is a weighting factor in [0-1]. It controls the scaling amount of the spread range which influence the intra-contrast.

Then, the mean value is shifted to that of the reference and the shifting amount is controlled by a weighting factor \( \alpha \) in [0-1].

\[
\hat{I} = I' + \alpha(m_r - m'_s)
\]

(4)

\( m'_s \) is the mean of \( I' \). Using one iteration of the process when \( \alpha=1 \) and \( \beta=1 \), the mean value is shifted to
that of the reference, however, the maxima and minima have a shifting from those of the reference as the curve shown in Figure 3(b). After two iterations, the mean, maxima and minima are mapped exactly to those of the reference, result without BG smoothing, result with BG smoothing can be clearly seen by comparing the results without BG smoothing and with BG smoothing in Figure 4. The details in the BG are faint after BG smoothing whilst keeping the outline visually apparent.

4.2 Background Smoothing

In order to keep the focus on the figure, the details of the BG in the portrait paintings are indistinct so as not to draw attention away from the outline of the figure. Inspired by this, the details of BG in lightness channel is blurred. The final lightness channel \( L_o \) is

\[
L_o = (1 - \Phi) \cdot \bar{L} + \Phi \cdot L^*
\]

where \( L^* \) is the lightness got in equation 8, and \( \bar{L} \) is the smoothed image of \( L^* \) using optimization function (equation 5) applying a constant weight \( w_s = \tau_3 \). Given the distance matrix \( D \) of each pixel to the boundary between FG and BG, the weight matrix \( \Phi \) is

\[
D'(x, y) = \begin{cases} D(x, y) & \text{if } (x, y) \in FG \\ -D(x, y) & \text{otherwise} \end{cases}
\]

\[
V = (1 + e^{\sigma D'})^{-1}
\]

\[
\Phi(x, y) = \begin{cases} 1 & \text{if } V(x, y) > 0.5 \\ V(x, y) & \text{otherwise} \end{cases}
\]

\[
\tau_1 > \tau_2 \text{ for smoothing the boundary area.}
\]

In our implementation, we use the parameters \( \theta = 1.2, \varepsilon = 0.001, \tau_3 = 0.3 \) and \( \tau_2 = 0.05 \). The minimization of the energy cost function \( E \) can be achieved using standard or weighted least-squares techniques like the conjugate-gradient method. The result after smoothing is

\[
F^* = F + f
\]

5 Experiments and Discussion

Portrait paintings collected for the references are chosen from artists: Thomas Gainsborough, Francisco Goya, Edouard Manet, and Jean-Auguste-Dominique Ingres. These artists are all maintain a high dynamic range in their paintings which is suitable for the purpose of applying to photographs. In total, 140 portrait paintings were collected to constitute the database. The figures in the portrait paintings were outlined manually.

In contrast mapping, we use the same \( \alpha, \beta \) for the three regions FO, FS, and BG. Parameters of lightness are expressed as \( \alpha_l, \beta_l \), and for saturation \( \alpha_s, \beta_s \). When \( \alpha_l = \alpha_s, \beta_l = \beta_s \), we indicate them as \( \alpha, \beta \). The contrast enhancement results of the photograph in the Figure 1(d) referring to three selected references are shown in Figure 5. Applying the proposed contrast enhancement, more details of the figure, especially on the face, are visible and the results have a similar look and feel with the corresponding references.

Figure 6 shows the influence of the parameters \( \alpha, \beta \). The difference between Figure 6(c)(d) shows the influence of \( \beta \) which controls the intra-contrast. Comparing the results in Figure 6(d)(e), we can see that the change of saturation contrast. When increasing \( \alpha, \beta \), the intra- and inter-contrasts are more close to those of the reference (comparing Figure 6(e)(f)).

A comparison of the proposed method with two local contrast adjustments using Contrast Limited Adaptive Histogram Equalization (CLAHE, matlab function adapthisteq), and Natural Enhancement of Color Image (NECI) [2] are shown in Figure 7. CLAHE produces clear artifacts (Figure 7(b)) whereas the contrast is enhanced and without artifacts using NECI (Figure 7(c)). However, the expression of the figure in the result using the proposed method in Figure 7(d) is more clearly highlighted without artifacts. The comparison...
shows the advantage of the proposed method. Some more results are shown in Figure 8.

6 Conclusions

This paper proposed an example-based portrait contrast enhancement method. The contrast mapping was conducted by a pairwise weighted partial spread range scaling and weighted mean value shifting on the lightness and saturation channels. The mappings on face/skin, the reminder part of the FG and BG were achieved separately. The experiment results demonstrated the effectiveness of the proposed method.

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References