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Space-variant Adjustment Layer

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Abstract: This study describes an approach of color adjustment extending the technology of adjustment layer. Adjustment layer allows to apply color adjustment to layered images using a separate layer, useful in many graphic utilities, but the parameters of color adjustment cannot be different in different parts of the image. To break this constraint and make a more flexible way of color adjustment, the proposed approach introduced three schemes of blending the color values of two layers, focusing on taking the color values of a basic layer as parameters of three types of color adjustment, making a basic layer function as an augmented adjustment layer. As a result, the tedious work of space-variant color adjustment can conveniently be done by assigning the three schemes to one basic layer and deliberately editing this layer.

Key words: Adjustment layer, color adjustment, alpha compositing, transfer mode, blending mode

INTRODUCTION

Objective: Adjustment layer is a common technology in many graphic utilities (such as Adobe Photoshop) (Bartell and Hamburg, 1999). It encapsulates functions of color adjustment into an independent layer, allowing a flexible way of adjusting colors. With masks on it, the user can define the territory he wishes to apply the adjustment.

The constraint of an adjustment layer is that it can only apply the same color adjustment to every pixel included in the mask because the user can only set global parameters of the color adjustment.

Contribution: In this study we show how to apply different color adjustment to different portions of an image, to break the constraint and enable larger flexibility of adjustment layer, making color adjustment on layered images easier and more flexible. The core of our approach is three new transfer modes of alpha compositing. These new transfer modes turn a basic layer to a space-variant adjustment layer and the contents of the basic layer then become the space-variant parameters of the color adjustment.

Related works: The general topic of this study is interactive local color adjustment. Previously, a common way of local color adjustment included two steps: (1) interactive image segmentation (2) color adjustment. In the first step, the user can draw scribbles on the image indicating the intended image segmentation and then an algorithm infers the user's intention and divides the image into segments (Farbman *et al*., 2010; Xu *et al*., 2009; Wen *et al*., 2008; Sapiro, 2005; Lischinski *et al*., 2006; Li *et al*., 2008). In some works, the algorithm can automatically divides the image into different objects according to some criteria (Chen *et al*., 2004; Maslennikova *et al*., 2007) without the user's operation. Then in the second step, the user can adjust the color in these segments by adjusting parameters (Wen *et al*., 2008; Lischinski *et al*., 2006; Li *et al*., 2008), specifying color (Farbman *et al*., 2010; Xu *et al*., 2009; Sapiro, 2005; Chen *et al*., 2004) or transferring color from another image (Maslennikova *et al*., 2007). In fact, most researches focused on the first step and thus their actual contributions are new ways of image segmentation. They haven't made significant improvement on color adjustment techniques.

Different from most previous works, in this study we focused on extending the second step: color adjustment. By examining the previous works, we found that no one has tried to improve the technology of adjustment layer. To augment the technology of adjustment layer, we proposed several tricks, which are several new transfer modes of alpha compositing. By doing this we made a basic layer an augmented adjustment layer which can apply different color adjustment to different locations on the target image.

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TECHNICAL BASIS

Alpha compositing: Alpha compositing, a basis in many graphic utilities, was originally developed by Catmull (1978) and Smith (1995) and Porter and Duff (1984) and has been developed into many modifications (Carlsen *et al*., 2002; Bartell and Hamburg, 1999; Hamburg, 2001; 2002a, b; 2004; Wilensky *et al*., 2009). The fundamental principle of alpha compositing is that an image comprises of a stack of basic layers and every basic layer is represented by color channels and an alpha channel, which represents the color and transparency of the layer, respectively. Thus a basic layer is represented as:

$$L = < C_1, C_2, \ldots C_n, \text{Alpha} > \quad (1)$$

where, C_1, C_2, ..., C_n are the color channels of the layer, that are usually R, G, B representing component colors in RGB color space or H, S, V representing component colors in HSV color space; Alpha is the alpha channel representing the transparency of the layer. As a constitution, the values of color and alpha are bounded in the interval [0, 1]. 0 means entirely dark for color value or entirely transparent for alpha value, 1 means the max value for color value or entirely opaque for alpha value, other values between 0 and 1 mean the intermediate states.

The core idea of alpha compositing is that two layers can be blended pixel by pixel using a function. Then the stack of layers can be blended one by one, into one blended image. Alpha compositing can be represented as the following general formula (Hamburg, 2002a, b):

$$c_D = \alpha \cdot T(c_U, c_L) + (1-\alpha) \cdot c_L \quad (2)$$

where, c_U and c_L are colors from the upper layer and the lower layer, respectively, α is the alpha value from the upper layer, c_D is the composited color of c_U and c_L, T( ) is called transfer mode, that is a function blending c_U and c_L into a color value.

Commercial graphic utilities, like Adobe Photoshop, provide many alterative transfer modes, enabling various blending effects, but do not provide any transfer mode that allows subtly adjusting the color from lower layers.

Adjustment layer: Adjustment layer applies a color adjustment to the lower layers (Bartell and Hamburg, 1999), supplementary to basic layers and the general alpha compositing. The function of adjustment layer can be represented as:

$$c_D = m \cdot f(c_L, p_1, p_2, \ldots, p_n) + (1-m) \cdot c \quad (3)$$

where, c_L is the color value from the lower layer, function f() adjusts c_L using the user-defined parameters $p_1, p_2, \ldots, p_n$; m is the masking value, that is specified by the mask of the adjustment layer; c_D is the adjusted color.

Commercial graphic utilities provide many alternatives of function f( ), which allows various color adjustment. The masking value determines the degree that the color adjustment affects the color value. If the masking value is one for a pixel, then the pixel is entirely adjusted by the color adjustment. If the masking value is zero for a pixel, then the adjustment does not affect the pixel at all. The user can partly apply the color adjustment to lower layers by specifying a mask as a grayscale image.

The limitation of adjustment layer is that it cannot apply different adjustments to different parts of the lower layer. A simple example is that the user can not brighten the left half of the lower layer while darken the right half of it using one adjustment layer, although he can achieve this by applying multiple adjustment layers.

OUR APPROACH

Three new transfer modes: Comparing Eq. 2 and 3, we realized that the transfer mode T( ) in (2) can function as color adjustment similar to the function f( ) in (3), while the parameters of such color adjustment are the color values of the upper layer and thus these parameters can be space-variant throughout the upper layer. It implied that we can build new transfer modes that function as color adjustment; these new transfer modes allow convenient way of editing the color adjustment: shifting color along the hue circle, saturating/desaturating color and brightening/darkening color using common graphic manipulating tools. Based on this idea, we built three new transfer modes: "CIRCLE", "GAMMA" and "SCALE".

CIRCLE: The transfer mode "CIRCLE" is represented as:

$$c_T = T_{CIRCLE}(c_U, c_L) = \begin{cases} c'_U + c_L + 1, & \text{if} \quad c'_U + c_L < 0 \\ c'_U + c_L, & \text{if} \quad 0 < c'_U + c_L < 1 \\ c'_U + c_L - 1, & \text{if} \quad c'_U + c_L > 1_L \end{cases} \quad (4)$$

where, c_L, c_U have the same meaning in (3); c_T is the blended color of c_L and c_U; c'_u is transformed from cu by: $c'_u = c_u - 0.5$

Using this formula, c_L increases if c_U is greater than 0.5 or decreases if c_U is smaller than 0.5, then the value "circles" to be within the bounds [0,1].

GAMMA: The transfer mode "GAMMA" is derived from gamma adjustment and is represented as:

$$C_T = T_{GAMMA}(C_U, C_L) = C_L^{\frac{1-C_U}{C_U}} \tag{5}$$

where, c_L, c_U have the same meaning in (3), gamma( ) nonlinearly maps the bounds [0,1] to [0, +8]. Using this formula, c_L increases if c_U is greater than 0.5 or decreases if c_U is smaller than 0.5.

SCALE: The transfer mode "SCALE" is represented as:

$$c_T = T_{SCALE}(c_U, c_L) = \begin{cases} c_L + p(1-c_L) & \text{if} \quad p > 0 \\ c_L & \text{if} \quad p = 0 \\ c_L - pc_L & \text{if} \quad p < 0 \end{cases} \tag{6}$$

where c_L, c_U have the same meaning in (3), p is calculated by: $p = 2c_u\text{-}1$.

Using this formula, c_L is pushed toward 1 if c_U is greater than 0.5 or toward 0 if c_U is smaller than 0.5.

Adjustment layer with compound transfer mode: In a general way, a basic layer is comprised out of three color channels and one alpha channel, being represented as $L = [C_1,C_2,C_3,\text{Alpha}]$. Practically, color channels represent component colors in RGB color space or HSV color space and thus L is represented as [R, G, B, Alpha] or [H, S, V, Alpha]. To make this basic layer an adjustment layer, we can specify the proposed three new transfer modes to this layer. We can assign different transfer modes to different color channels, making a compound transfer mode, e.g., channel C_1, C_2, C, may have the transfer modes "CIRCLE", "GAMMA" and "SCALE" respectively. To represent a compound transfer mode, we use subscripts denoting the transfer mode of every color channel. The subscripts "C","G" and "S" denote "CIRCLE", "GAMMA" and "SCALE" respectively, e.g., $[C_1C,C_2G,C_3S,\text{Alpha}]$ means that channel C_1 has "CIRCLE" transfer mode, C_2 has "GAMMA" transfer mode and C_3 has "SCALE" transfer mode.

RESULTS

Effects of the three transfer modes: To test the effects of the three transfer modes, we applied the three transfer modes to the layered structure that contains only one color channel (Fig.1a). Figure 1 shows the result of compositing the two layers. (a) shows the stack order of the two layers, (b) and (c) are the lower layer and the upper layer respectively, (d)(e)(f) are produced by assigning "CIRCLE", "GAMMA" and "SCALE" to the upper layer and compositing the two layers. The result shows that the effects of the color adjustment are dependent on the local parameters from the upper layer, thus enabling adjusting color locally.

Fig. 1(a-f): Effects of the three transfer modes: (a) two layers with one channel; (b) the lower layer; (c) the upper layer; (d) CIRCLE; (e) GAMMA; (f) SCALE

Space-variant color adjustment using one basic layer: By making use of the three transfer modes, we can make compound color adjustment using only one basic layer. Error! Reference source not found. shows an example of adjusting hue, saturation and brightness using one basic layer, (a) shows the structure of the upper layer and the lower layer, (b) shows that the lower layer contains H, S, V channels that are component colors in HSV color space, the transfer modes of the three channels in the upper layer are set as "CIRCLE", "GAMMA" and "SCALE" respectively, (c) shows the original lower layer, (d) is the result of the color adjustment by the upper layer: the skin color of the girl was shifted along the hue circle, was saturated, desaturated, darkened and brightened locally. In this example, that the result is made by deliberately editing the upper layer using other interactive graphic tools indicates that the color adjustment can be locally edited: one can locally shift the hue and saturate/desaturate/brighten/darken any parts of the lower layer taking advantages of various graphic manipulating tools.

Accordingly, the main advantage of our approach is that it enables an easy way of space-variant color adjustment using only one basic layer. Although in previous graphic utilities, one can make space-variant adjustment by applying multiple adjustment layers and masks, but this task is very tedious.

CONCLUSION

The proposed three transfer modes make a basic layer a compound adjustment layer, allowing deliberate control of space-variant color adjustment by editing this basic layer. Besides, the proposed transfer modes can easily be implemented since they only require arithmetical computation.

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