

An Efficient Color Transferring Interface with 3-Dimensional Transformation

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Abstract: We propose a user interface for color transferring with 3D computer graphics techniques. Proposing user interface can plot points describing color information of images in an arbitrary color space, such as RGB, HSI, and CIELAB ($L^*a^*b^*$). These colors form three-dimensional distributions in the color spaces. Users can facilitate some operations, such as transformation, rotation and scaling, to these shapes representing color distribution in 3D space without altering visual appearance of original images. This type of interactive color transferring makes control very intuitive.

1. Introduction

The technique for image processing becomes so popular that many users can easily edit or improve their photographs or graphics with various types of advanced photo retouch tools. Color transferring is one of the most important processes to enhance the quality of images[1,2]. RGB (*Red, Green, Blue*) color system is applied to display digital color images and many other color system, such as HSI, CMYK, or YIQ, has been improved for effective color processing. Color transferring or color correction of images is very popular in the ordinary photo retouch tools. So, users can turn up the brightness of the images or enhance the colors of them in order to give various effects to the images. However, in the many tools, colors are shown with 2-dimensional space such as histograms or hue circles. This function often prevents users to figure out distribution of colors and find how to correct the coloring in the image. So users require knowledge for color scheme, technique of color processing, and experience equivalent to experts when users operate color processing for editing their photographs[3,4].

In this paper, we propose an interactive user interface for color transferring using the technique of 3D computer graphics. Proposing interface can display points describing color information of images in an arbitrary color space, such as RGB, HSI, and CIELAB ($L^*a^*b^*$). These colors form three-dimensional distributions in the color spaces. FFD (Free-Form Deformation) is applied to transform these color distribution and the transformation is reflected to the images. FFD is one of the most popular methods to transform shapes in computer graphics techniques[3,4,5] and it can provide powerful transform function. Users can facilitate some operations, such as transformation, rotation and scaling, to these shapes representing color distribution in 3D space without altering visual appearance of original images. This type of interactive color transferring makes control very intuitive. This interface can provide more powerful transferring functions than any other ones. Users

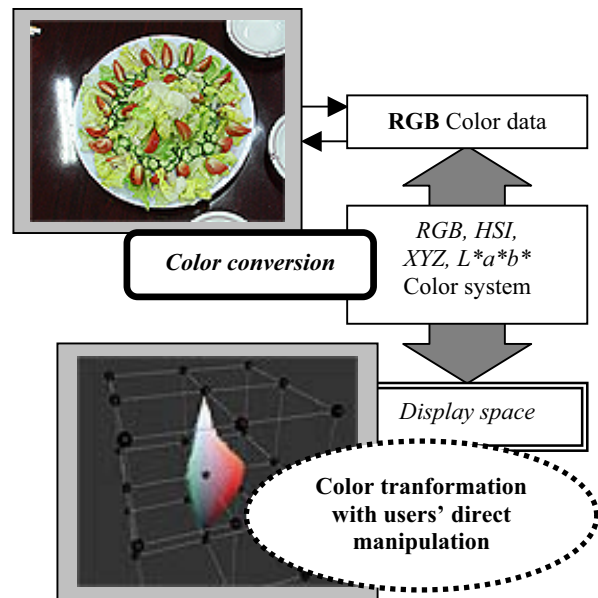


Figure 1. An overview of our interface. All color data included in the image are extracted as RGB color. These color data are converted to the arbitrary color system users requires and normalized to display as color shapes

can achieve interactive and intuitive color transferring even they are novice for image processing with graphic tools.

2. Color transferring

2.1 Color transferring

Figure 1 shows an overview of proposing interface. At first in this interface, RGB data is extracted from each pixel in a 24bit bitmap color image. Their values are normalized to [0.0, 1.0] and converted to HSI and CIELAB color. All the color data are normalized to display them in 3D space.

Color shape consists of all plotted points concerned to values of these color data. The property of color in the image is explained as spatial feature, so users can easily explore color features of the image and transform this color shape directly through this interface. Free-form deformation is applied for transformation. The interface converts the color data in reverse direction to original RGB color interactively. Thus the results of users' direct manipulation are always reflected to the original image immediately.

2.2 Free-form deformations

FFD, free-form deformations, involves implementing a user interface that allows users to modify 3D shapes by moving previously arranged control points in the virtual space[5,6].

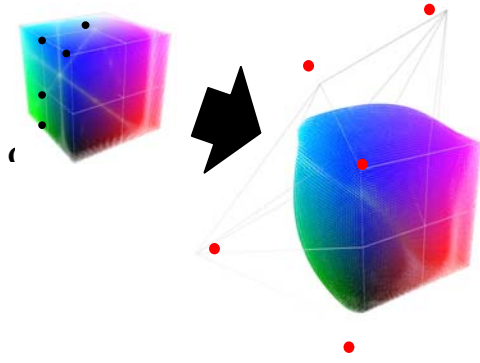


Figure 2. Free-form deformation. RGB color shape (cube) is transformed by FFD. Black and red points are control points

Using splines to calculate the modifications of the mesh will allow for smooth, natural looking deformations.

$P(i,j,k)$ represents coordination of control points. The new transformed points $P(x,y,z)$ are calculated as below:

$$P(x, y, z) = \sum_{i=0}^n \sum_{j=0}^n \sum_{k=0}^n B_{n,i}(x) B_{n,j}(y) B_{n,k}(z) P(i, j, k)$$

n is the number of division, and $B_{p,q}(a)$ express Bernstein basis polynomials as following equation.

$$B_{p,q}(a) = \frac{p!}{q!(p-q)!} (1-a)^{p-q} a^q$$

Figure 2 shows an example of RGB color shape transformed with FFD, in which the number of division $n=3$, so there are $27 (=3^3)$ control points that form a lattice structure. All the color data are normalized in $[0.0,1.0]$. Control points are set on all the vertices and centered points of edges of the cube that comprises the color shapes.

2. 3 Rotation and resizing

The interface allows users to rotate color shapes. Users can move slide bar on the interface to rotate color shape in the space around z -axis. This axis represents intensity and brightness. So users can obtain the image that color is changed without varying intensities. Users can also change scale of the shapes with every axis. Scaling supports adjusting contrast of the image. These transformations can simply be represented as following equation.

$$\begin{pmatrix} x' \\ y' \\ z' \end{pmatrix} = \begin{pmatrix} \cos \theta & \sin \theta & 0 \\ -\sin \theta & \cos \theta & 0 \\ 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} s_x & 0 & 0 \\ 0 & s_y & 0 \\ 0 & 0 & s_z \end{pmatrix} \begin{pmatrix} x \\ y \\ z \end{pmatrix}$$

where θ is angular of rotations, S_x , S_y , and S_z are scaling parameters for each axis.

2. 4 Constraints for transformation

There are some constraints for transferring color shapes to maintain the quality of images. For instance, each color data be within the particular range while transformation. Recently, the value over the range is forced to be either 0.0 or 1.0 automatically and recalculated, so occasionally noises occur in the image. Rotating operations in HSI color

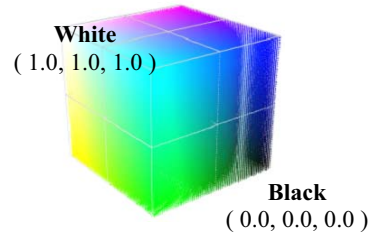


Figure 3. RGB color space forms a cube.

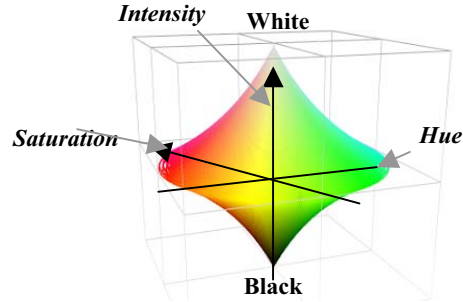


Figure 4. HSI color space forms double cones. Hue is corresponding to angular, Saturation is distance from center of color shape, and Intensity is height.

system have another constraints. Color rotation should be allowed only around z -axis that represents intensity of each pixel because inclined axis cannot assign the points to values. These constraints should be implemented on the interfaces carefully.

3. Color systems

3. 1 RGB color system

Normally, the range of primary values *Red*, *Green*, and *Blue* is set within 0.0 to 1.0. They form the cube in the display space shown in figure 3. It can easily display onto 3D display space and users can easily recognize topological relationship of color position.

3. 2 HSI color system

The HSI color system consists of *Hue*, *Saturation*, and *Intensity*. HSI can be drawn as a double hexcones as show in figure 4. Both RGB and HIS color system are non-linear deformations of the RGB color cube. The two apexes of the cones correspond to black and white. The angular parameter around z -axis corresponds to *Hue*, distance from the z -axis corresponds to *Saturation*, and distance along the black-white axis corresponds to *Intensity*.

To display in 3D display space, they are transformed as below and normalized to $[0.0,1.0]$.

$$\begin{pmatrix} x \\ y \\ z \end{pmatrix} = \begin{pmatrix} S \times \cos(H) \\ S \times \sin(H) \\ I \end{pmatrix}$$

3. 3 CIELAB ($L^*a^*b^*$) color system

$L^*a^*b^*$ (CIELAB) is the most complete color model used conventionally to describe all the colors visible to the

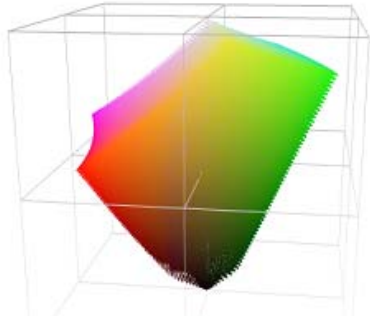


Figure 5. L*a*b* color space. Converted color shape from RGB color cube (figure 2.) into L*a*b* color space. z-axis represent L*.

human eye. It is utilized in many advanced photo retouch or image processing tools. The three parameters in the model represent the lightness of the color (L^*), its position between magenta and green (a^*) and its position between yellow and blue (b^*). To convert between RGB and L*a*b*, for example, it is necessary to determine or assume an absolute color space for the RGB data, such as sRGB or Adobe RGB. For each of these absolute spaces, there are standard techniques for converting to and from the CIEXYZ absolute color space which can be combined with the following transformations to convert them to L*a*b*. (in detail see [7]) First, RGB data is converted to XYZ color space described as below:

$$\begin{pmatrix} X \\ Y \\ Z \end{pmatrix} = \frac{1}{0.17697} \begin{bmatrix} 0.49 & 0.31 & 0.20 \\ 0.17697 & 0.81240 & 0.01063 \\ 0.00 & 0.01 & 0.99 \end{bmatrix} \begin{pmatrix} R \\ G \\ B \end{pmatrix}$$

$$L^* = 116f(Y/Y_n) - 16$$

$$a^* = 500(f(X/X_n) - f(Y/Y_n))$$

$$b^* = 200(f(Y/Y_n) - f(Z/Z_n))$$

$f(t)$ is defined as below:

$$f(t) = \begin{cases} t^{\frac{1}{3}} & t > 0.008856 \\ 7.787t + \frac{16}{116} & \text{otherwise} \end{cases}$$

where X_n , Y_n , and Z_n are values of the reference *white point*, in this method, 95.0429, 100.0, and 108.8900 (D65 white point) respectively.

Figure 5 shows a transformation result from RGB cube show in figure 3. L^* is transformed to [0.0, 100.0] and a^* , b^* is [-100.0, 100.0] by this conversion. It is necessary to normalize to plot data on display space. L^* , a^* , and b^* is projected to z , x , and y respectively.

4. Examples of transformation

4.1 Color transferring

Figure 6 shows a view of implemented interface. Users can directly move control points represented by black spheres to transform color distribution. These control points are previously defined.

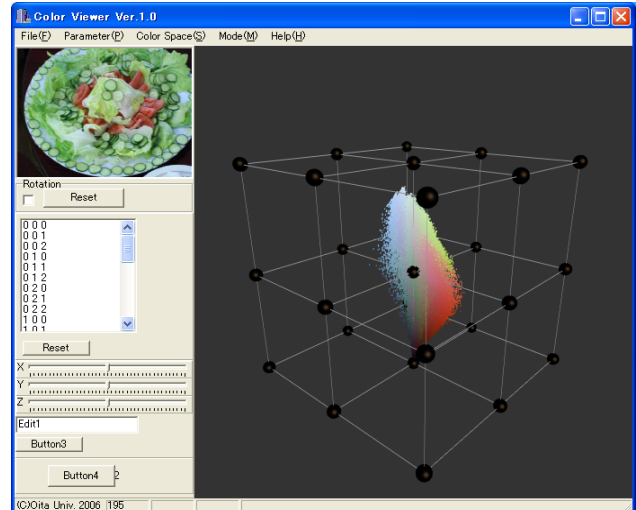
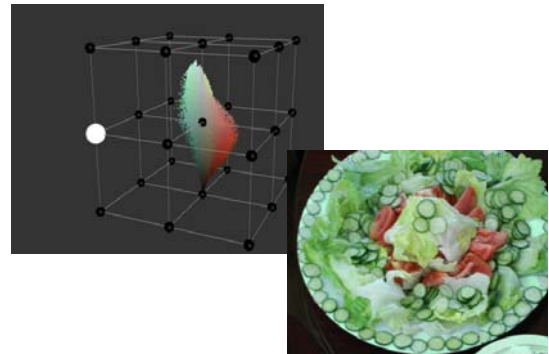
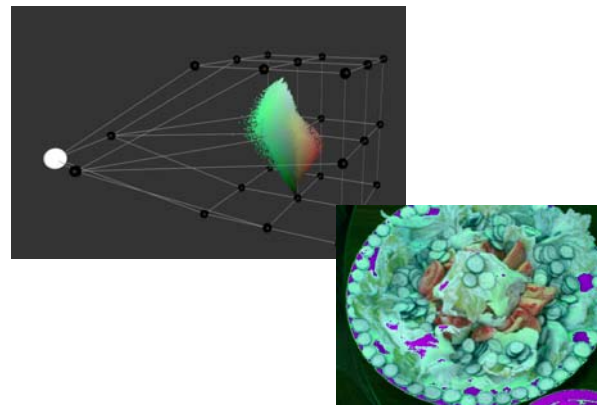


Figure 6. color transferring interface. It displays HSI color data distribution. Black spheres represent control points. User can move these control points and color shape is transformed.



(a) Original distributions and image



(b) Transformed distributions and image

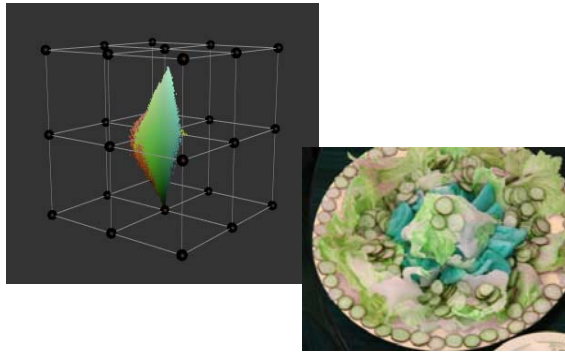


Figure 8. An Example of rotation color transform in HSI color space. color distribution are rotated 180 degree around z-axis.

Figure 7 shows an example of color distributions pulled to a certain direction, in this case "Green" direction in HSI color space. So the whole image takes very greeny.

4. 2 Rotations and scaling

This interface can provide some new color transferring method. One is rotation around z-axis that represents "Intensity" or "Lightness". Users can rotate color shape in the space to change the coloring without varying intensities. Rotation of Intensity, rotation around x-axis, or y-axis, could extremely spoil visual appearance of original images. It is necessary to take these constraints into consideration described in 2.4. Figure 8 shows an example of rotation. It is rotated 180 degree around z-axis in HSI color space. All colors are varied. Figure 9 shows scaling sample. Scale of x and y are about 1.5 times larger than original color. We can find the contrast of the image become strong.

Users can also change scale of the color shape with each axis. Scaling adds effects to adjusting contrast of the image. For example, when users spread with x-axis and y-axis in HSI color space, Hue of all colors is increased so that the appearance of the image can become clear.

5. Conclusion and future works

The interface that users can transfer color distribution to various form is proposed in this paper. We discuss about color control interface with FFD and show some kinds of effect, such as color transferring using our proposing interface. Users can easily find the color feature of the image to edit or correct.

A few users, who are novice for color design, utilized this interface to edit the color of images for evaluation. They give us some comments that 3D display is useful but it is not easy to recognize color "direction" while transforming color shapes. Knowledge and techniques about color scheme design will be required for current interface.

Many works are remained. First, current version of interface is not necessarily intuitive because users occasionally cannot find what to do to add the adequate effect for required image edition. So a relationship between users' manipulation to 3D color shape and added effects

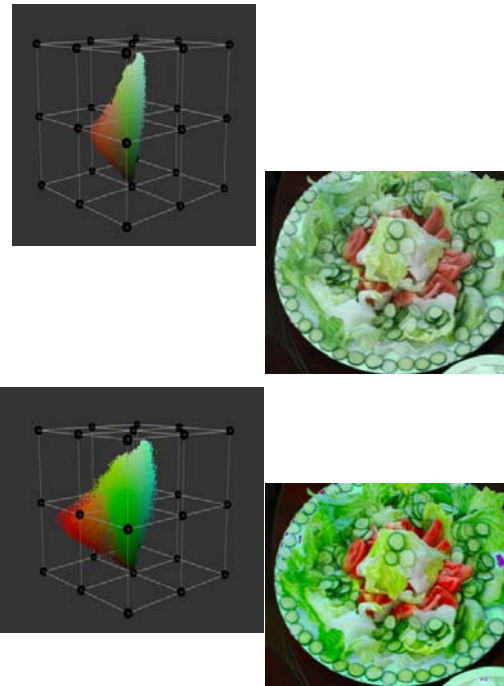


Figure 9. An Example of scaling color transform in L*a*b* color space. Scale of x and y are about 1.5 times larger than original color.

should be clearer to systemize users' operation. Positioning of control points should be improved to enable local transformation. We should also investigate deeply which color space to utilize for a certain effect. Second, constraints described in section 2.4 should be investigated and examined more. We should consider the features of each color space more.

The proposed technique should be evaluated in an actual image processing process practically.

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