Scene Color Interchange using Histogram Rescaling

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Abstract

This paper proposes an image-dependent approach to interchange a color between different objects in different scenes. An unpleasant scene color is automatically corrected to match to that of reference pleasant scene. The paper introduces a "scene-to-scene color transfer model", based on Histogram Rescaling between color gamuts. The Histogram Rescaling method can easily adapt an image gamut to an objective target image gamut by simply setting the lowest and highest source values corresponding to the end points of the destination. First the lightness rescaling is performed and next the chroma is rescaled. After the histogram rescaling of lightness L, the chroma components are divided into 16 segments by ΔH at hue angle H. Where source and target image center points on the CIELAB color space are separately set. Then source image's chroma C of each segment is expand or compressed by histogram rescaling referencing target image's chroma. Finally a center of source image is transferred into a center of target image and scene color interchange is performed. Proposed system is applied to preferred color reproduction, scene simulation, industrial design, etc. Experiments on total scene color transfer and local object color interchange are presented, where a color atmosphere is transferred from one scene to another.

Introduction

Now digital imaging technology plays a leading role in visual communication. One of the most common tasks in image processing is to alter an image's color. Recently, E. Reinhard et al[1] tried to transfer the scene color from one image to another using vision-based $l\alpha\beta$ color space and M. Zhang et al[2] applied it to correct the color imbalance between the right and left image in a panoramic scene. Although $l\alpha\beta$ is a de-correlated color space, its axes don't always match to the principal axes in the real image and doesn't always work in stable. On the other hand, H. Kotera et al[3,,4,5] introduced a scene color transfer model by region-based principal component (PC) matching in color clusters of CIELAB color space. This model presented two basic scene color interchange models of "Total" and "Segment" based on *PC matching*. The "Segment" PC matching model was reported very well, but optimum automatic classification is very hard.

This paper presents our approach to a color interchange between different objects in different scenes, based on *histogram rescaling* between color gamuts. We introduced a generalized *histogram rescaling* method for a versatile GMA through automatic gamut comparison using the GBD of the image and device[6,7]. The *histogram rescaling* method can easily adapt an image gamut to an objective target device gamut by simply setting the lowest and highest source values corresponding to the end points of the destination.

Scene Interchange Models

Color Transfer by lαβ Model

Figure 1 summarizes the $l\alpha\beta$ scene color transfer model proposed by *Reinhard*. It's composed of two stages. In the 1st stage, a source *RGB* color is converted into vision-based $l\alpha\beta$ space whose axes are assumed to be visually de-correlated. Next, each $l\alpha\beta$ vector is scaled up/down by the ratio of standard deviation around the mean vector.

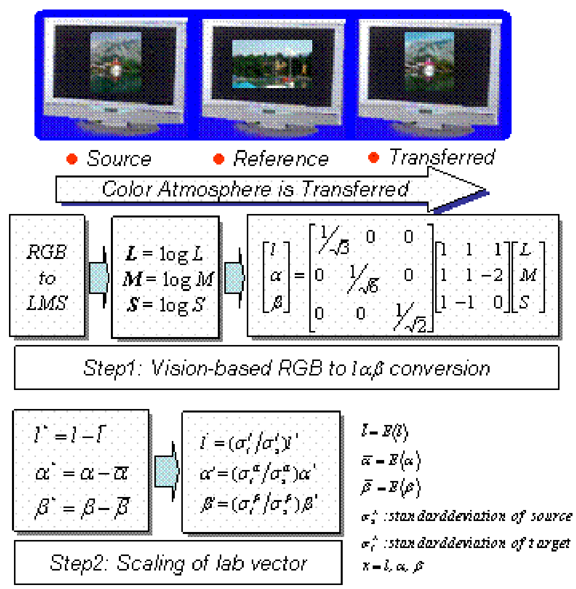


***Figure 1**. lαβ scene color interchange model*

PC Color Matching Model

Figure 2 shows object-to-object color matching algorithm to transfer the scene colors in *PC* space.

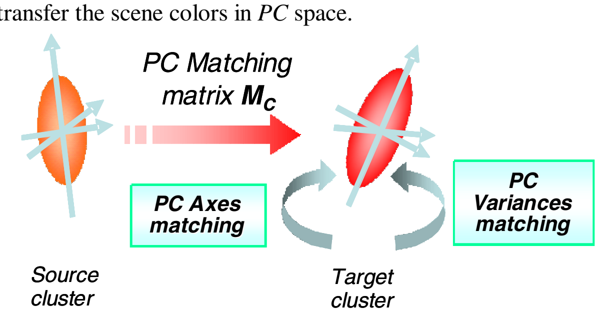


***Figure 2**. PC matching scene color interchange model*

Different from $l\alpha\beta$ model, a *PC* of source color cluster is transformed to match to that of target through the matching matrix $_{jk}\boldsymbol{M}_C$ given by

$$_{jk}\boldsymbol{M}_C = \left({}_k\boldsymbol{A}_{DST}^{-1}\right)\left({}_{jk}S\right)\left({}_j\boldsymbol{A}_{ORG}\right). \quad (1)$$

It has two basic functions, "*Axes matching*" by rotating its cluster along the eigenvectors and "*Variance matching*" by scaling the color distribution along the *PC* axes. $_j\boldsymbol{A}_{ORG}$ and $_k\boldsymbol{A}_{DST}$ denote the eigen matrix for a source cluster *j* and a target cluster *k*. The scaling matrix $_{jk}\boldsymbol{S}$ is a diagonal matrix whose elements are given by the eigen values' ratio in equation (2).

$$_{jk}\boldsymbol{S} = \begin{bmatrix} \sqrt{{}_k\lambda_{1DST}/{}_j\lambda_{1ORG}} & 0 & 0 \\ 0 & \sqrt{{}_k\lambda_{2DST}/{}_j\lambda_{2ORG}} & 0 \\ 0 & 0 & \sqrt{{}_k\lambda_{3DST}/{}_j\lambda_{3ORG}} \end{bmatrix} \quad (2)$$

This model extended a "Segment" PC matching model by image classification using K-means and Bayesian classifier to solve that has hard to handle as a single cluster.

Histogram Rescaling Model

Figure 3 illustrates an explanatory ***histogram rescaling***. In the original histogram $p_1(x)$, lowest value *a* and highest value *b* are flexibly expanded or compressed for adaptation to the histogram of the target gamut using Equation (1) as follows:

$$x' = k(x-a) + a'; \quad k = {(b'-a')}/{(b-a)} \quad (3)$$

Where, *b'* and *a'* denote the highest and lowest end points to be rescaled matching the gamut boundaries of target and *k* means a scaling factor working compression for $0 < k < 1$ or expansion for $k > 1$.

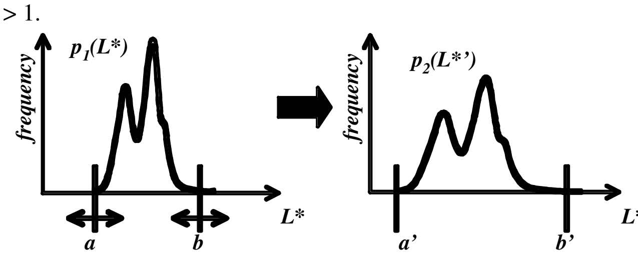


Figure 3. *Schema of histogram rescaling*

Under the conditions of

$$\int_a^b p_1(x)dx = \int_{a'}^{b'} p_2(x')dx' = 1$$
$$p_2(x')dx' = p_1(x)dx; \quad dx' = kdx \quad (4)$$

The histogram $p_2(x')$ after rescaling is given by

$$p_2(x') = k^{-1}p1\{k^{-1}x' + (a - k^{-1}a')\} \quad (5)$$

First the lightness rescaling is performed by assigning the valuables *x'* and *x* to *L* and *L'* before and after, and next the chroma is rescaled by setting *x'* and *x* to *C* and *C'* before and after as well.

Figure 4 shows scene interchange model for chroma by histogram rescaling. After the histogram rescaling of lightness *L*, the chroma components are divided into *m* segments by *ΔH* at hue angle *H*. Then, chroma *C* of each segment is expanded or compressed by *histogram rescaling* as well as *L* without changing the color hue. The hue *H* is segmented to *m* = 16 in this experiment. Where source and target image center points on the CIELAB color space are separately set. Then source image's chroma C of each segment is expand or compressed by histogram rescaling referencing target image's chroma. Finally a center of source image is transferred into a center of target image and scene color interchange is performed.

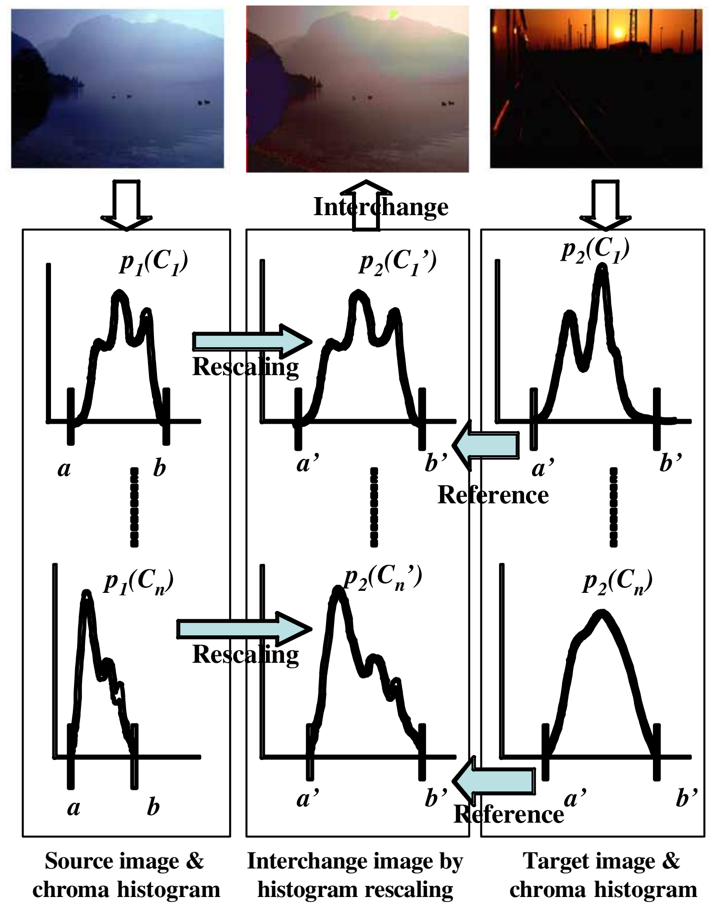
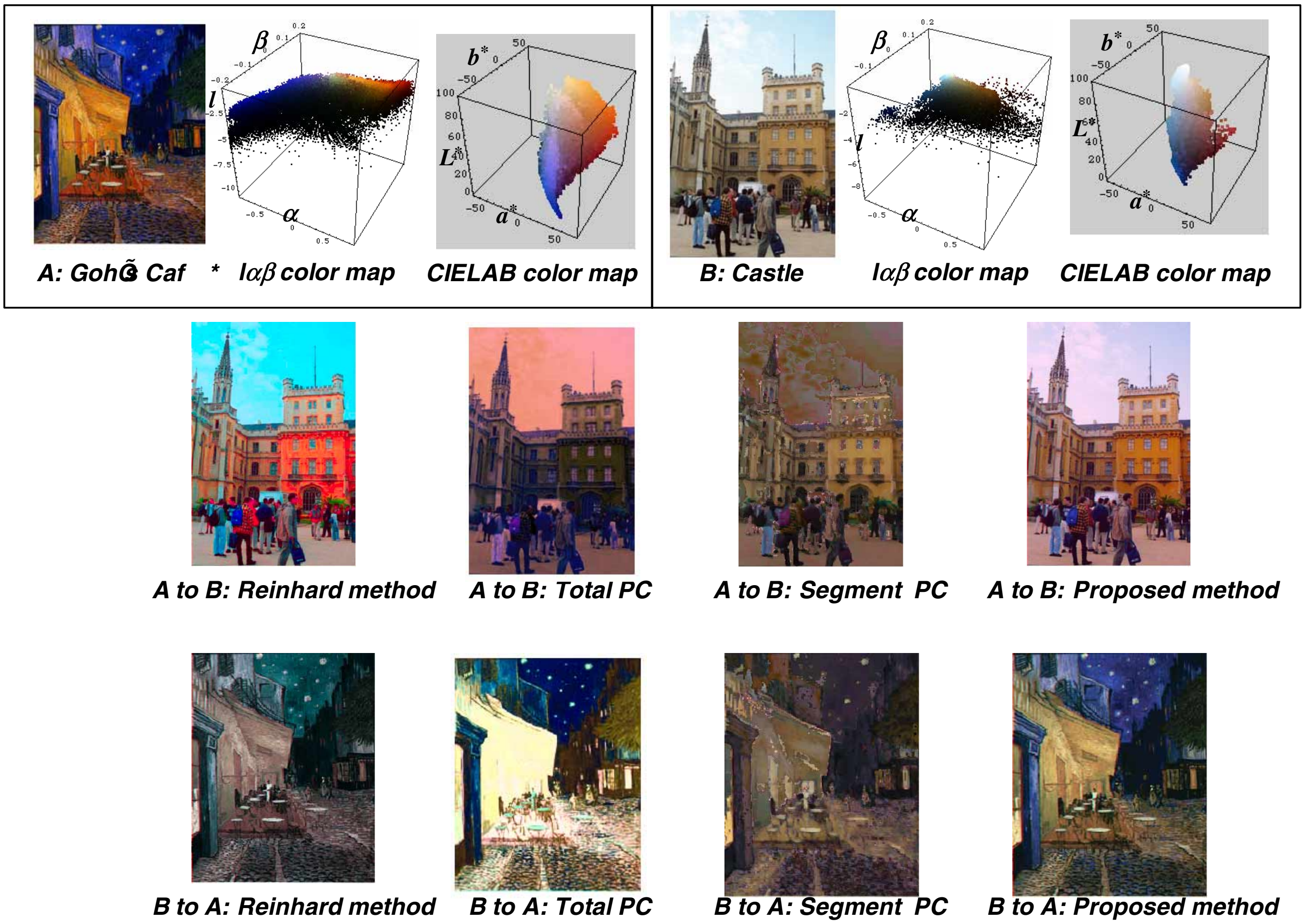


Figure 4. *Scene color interchange model for chroma by histogram rescaling*

Experimental Results

Figure 5 shows original sample images, their lαβ color maps, their CIELAB color maps in first column, A to B color interchange results in second column and B to A color interchange results in third column. Interchange models were compared with 1) Reinhard's lαβ color space model, 2) Kotera's "Total" PC, 3) "Segment" PC and 4) proposed histogram rescaling model. This figure shows result of each color interchange models in image Vincent van Gogh's "Café-terrace de nuit (Café)" and scene image "castle." Where the pictorial atmosphere of Gogh's "Café" is transferred into real scene "castle." Reinhard model has extremely changed the color of interchange image. "Total" PC and "Segment" PC models also didn't worked very well. On the other hand, proposed model worked best in comfortable color rendition.



*The source: IPA http://www2.edu.ipa.go.jp/gz/

***Figure 5**. Result of each color interchange models in image Gogh's "Café" and "castle"*

Figure 6 shows original sample sRGB image "bride " and "lady" and its color vector from image center in first column. Interchange models were also compared with 1) Reinhard's lαβ color space model, 2) Kotera's "Total" PC, 3) "Segment" PC and 4) proposed histogram rescaling model. This figure shows A to B color interchange results in second column, its color vector in third column, B to A color interchange results in forth column and its color vector in fifth column. Our proposed model worked comfortable color rendition and that was shown in color vector. Reinhard's model "B to A" and "Total" PC "A to B" were insufficient results. Because these images were to manipulate hard for optimum classification, "Segment" PC was failed.

Conclusion

This paper proposed a scene color transfer model by *histogram rescaling* in CIELAB color space. This model was compared with 1) Reinhard's lαβ color space model, 2) Kotera's "Total" PC model and 3) "Segment" PC model. Although lαβ is a de-correlated color space, its axes don't always match to the principal axes in the real image, therefore Reinhard's model doesn't always work in stable. Two types of PC matching model were performed very well in some image types. However, it has hard to handle as a single cluster in "Total" PC and automatic decision of optimum classification in "Segment" PC is very hard. Our model based on *histogram rescaling* worked robust to transfer the total color atmosphere from one scene to another. The *histogram rescaling* method can easily adapt an image gamut. This model was good performance for rescaling by hue segmentation in color space. Many problems are still left in a practical use for every kind of images. But the proposed approach would be a clue to a "*pleasant*" or "*comfortable*" color imaging applicable to scene simulation, industrial design, and/or computer graphics.

References

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Author Biography

Ryoichi Saito received his B.S. degree in 1983 and Doctorate from Chiba University in 2004. Since 1983, he has been working on direct plate making, digital image processing and color reproduction at Chiba University. His current research interest is focused on image gamut description models and their application to 3-D gamut mapping and color appearance matching across multimedia.

***Figure 6**. Result of each color interchange models in image “bride” and “lady”*