A Simple Algorithm for Equivalent Color Sense Reproduction based on HVS in Photographing Conditions

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Abstract: *Generally, white balance of a conventional camera is set by linear adjustment of RGB channel gains. However, spectral sensitivity of human visual tri-receptor, LMS cone, is nonlinearly changed according to surround chromaticity and luminance level. Therefore, the perceived colors of the image reproduced on a standard display using the output signals of a conventional camera are quite different from the perceived object colors in real photographing place. It is necessary that reproduced colors on a display in standard viewing conditions is perceived as same as the original object colors. In this paper a corresponding color reproduction algorithm based on HVS is proposed. The algorithm transforms the output signals of a conventional camera into the signals to reproduce the same colors as the perceived object colors when human visual system has been adapted chromatically under the various photographing conditions. Experimental results show that the reproduced color using the algorithm is objectively and subjectively better than the conventional method.*

Keywords: HVS, equivalent color sense, chromatic adaptation

1. Introduction

RGB color filters convert tristimuls *XYZ* to *RGB* signal and linear gain control for each channel of *RGB* can make white balance for surroundings in camera system[1]. Reference white is D_{65} in standard camera system. Generally, we make white balance to 3100 K~3200 K at studio, sunrise, and sunset. As mentioned above, when we photograph an object under white balance point of daylight, RGB signals are nearly equal to the signals under D_{65}. However, spectral sensitivity of human visual tri-receptor, LMS cone, is nonlinearly changed according to surround chromaticity and luminance level. Also spectral sensitivity of human visual tri-receptor is different from RGB color filters in camera system. So if surrounding illuminant is not D_{65}, white balance point of human visual system is different from that of camera system.

In this paper, equivalent color sense reproduction algorithm based on HVS (Human visual system) in photographing conditions is proposed. The algorithm transforms the output signals of a conventional camera into the signals to reproduce the same colors as the perceived object colors when human visual system has been adapted chromatically under the various photographing conditions. If we use standard display system whose white balance point is D_{65} under D_{65} illuminant, standard viewing condition[2], the reproduced color using the proposed algorithm is same with the object colors in real photographing place.

2. Color reproduction in conventional camera systems

White balance of a conventional camera is set by linear adjustment of RGB channel gains. So it is not considered characteristics of HVS that is influenced by viewing condition. Namely, output RGB signal of conventional camera under any illuminants is the same signal under D_{65} illuminant. Transformation procedure of tristimulus value, *XYZ*, of object to *RGB* signals in camera system is shown in fig. 1. Output signals of the camera set the white balance point to illuminant in rgb coordinate is shown in fig. 2. We can see the same output signal of conventional camera in spite of illuminant variation in Fig. 2. But the perceived object colors in real photographing place vary as illuminant is changed.

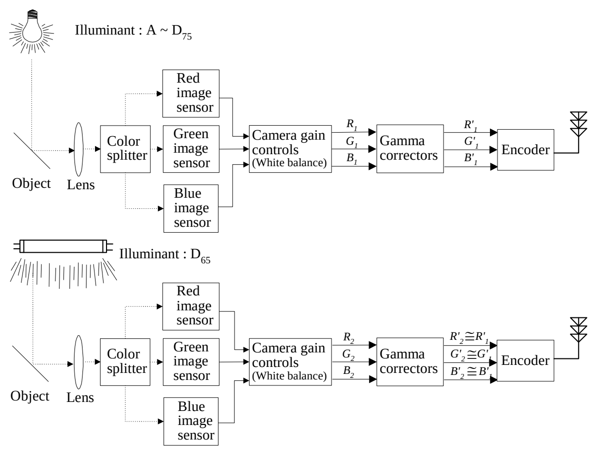


Fig. 1. Transformation procedure of *XYZ* tristimulus of object to *RGB* signal in camera system

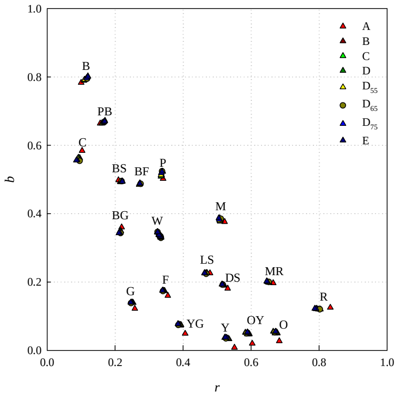


Fig. 2. rgb coordinates of output signal of the camera set the white balance point to surrounding illuminant.

3. Equivalent color sense reproduction based on the HVS in photographing condition

After set the white balance point to illuminant in photographing place, we photograph an object and display the photographed object on standard display system. We can obtain visual stimulus value, $L_1M_1S_1$, of the object on standard display. Also we can obtain visual stimulus value, $L_2M_2S_2$, of the object in photographing place. $L_1M_1S_1$ is different from $L_2M_2S_2$, Because Spectral sensitivity of human visual tri-receptor, LMS cone, is different from that of camera. Also, channel gain of camera changes linearly for physical variation like luminance variation.

We perceive different color of the object under other physical condition, because sensitivity of human visual tri-receptor, LMS cone, works nonlinearly. Thus we reproduce corresponding color to photographing place in order to perceive the same object color on standard display under D_{65} illuminant.

Several models about prediction of corresponding colors were proposed. And these models were considered chromatic adaptation of human visual system. Corresponding color reproduction models are classified into linear models and nonlinear models. The von Kries model is linear model. And the Bartleson, the Breneman, the Fairchild[3], and the Modified von Kries model[4] are nonlinear model.

In this paper we use the modified von Kries model that has the smallest errors and is used nonlinear transformation.

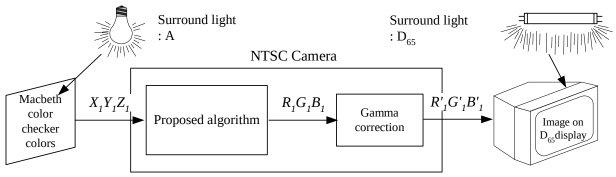
The modified von Kries model is

$$\begin{bmatrix} L \\ M \\ S \end{bmatrix} = \boldsymbol{M} \begin{bmatrix} X \\ Y \\ Z \end{bmatrix}, \ \boldsymbol{M} = \begin{bmatrix} 0.4002 & 0.7076 & -0.0808 \\ -0.2263 & 1.1653 & 0.0457 \\ 0 & 0 & 0.9182 \end{bmatrix} \quad (1)$$

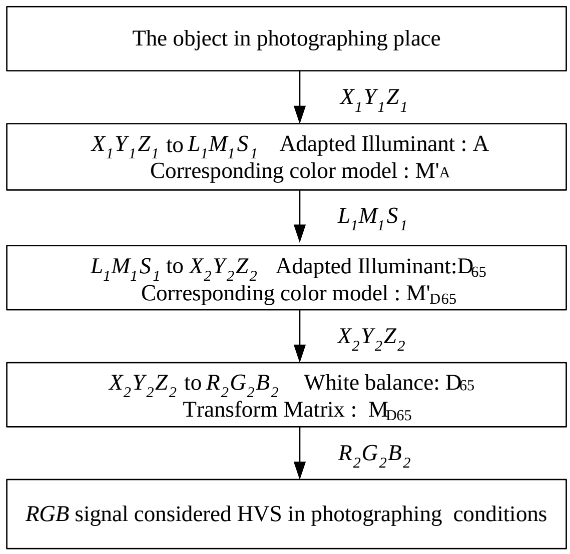
$$k_1 = \frac{L_{\max 2}}{L_{\max 1}}, \ k_2 = \frac{M_{\max 2}}{M_{\max 1}}, \ k_3 = \left(\frac{S_{\max 2}}{S_{\max 1}} \right)^p \quad (2)$$

$$\begin{bmatrix} X_2 \\ Y_2 \\ Z_2 \end{bmatrix} = \boldsymbol{M}^{-1} \begin{bmatrix} k_1 & 0 & 0 \\ 0 & k_2 & 0 \\ 0 & 0 & k_3 \end{bmatrix} \boldsymbol{M} \begin{bmatrix} X_1 \\ Y_1 \\ Z_1 \end{bmatrix} \quad (3)$$

It is shown in fig. 3. that represent proposed equivalent color sense reproduction algorithm considering the HVS under photographing condition.



(a)



(b)

Fig. 3. Flowchart of corresponding color reproduction algorithm considering the HVS: (a) application to camera, (b) Block diagram of proposed algorithm

Procedure of stimulus level transformation is as follows. We can obtain the visual stimulus level, *LMS*, about tristimulus, $X_1Y_1Z_1$, from the original object in photographing place using Modified von Kries model. Then we derive tristimulus, $X_2Y_2Z_2$, that make us to perceive the same visual stimulus, *LMS*, under D_{65} illuminant. Using the characteristic matrix of camera that is set the white balance point to D_{65}, we transform tristimulus, $X_2Y_2Z_2$, to output signal, *RGB*. If this algorithm is applied to signal processing part of camera, we get the output signals that make us to perceive the same color on standard display under D_{65} illuminant as photographing place.

4. Experiments and Results

First, we set the white balance point of camera to surrounding illuminant. The object is Macbeth colorchecker. And we obtain the visual stimulus level,

$L_1M_1S_1$, from standard display that is displayed RGB output signal of the camera under D_{65} illuminant. In order to compare visual stimulus level, $L_1M_1S_1$, and visual stimulus level, $L_2M_2S_2$, in photographing place, we represent stimulus of Macbeth colorchecker to lms coordinates.

Experimental condition is as follows. Surrounding illuminant is varied illuminant A to D_{75} and luminance level is 350 cd/m^2. We make simulation program with visual C++ for experiment. The simulation program is considered kind of illuminant, surrounding luminance, phosphor coordinate of test display, and gamma.

Signal transformation procedure of simulation program is as follows. It is almost equal RGB signal from camera set the white balance point to any illuminant and RGB signal from camera set the white balance point to D_{65} illuminant.

If we know the condition of photographing place and the characteristic of camera, we can derive actual tristimulus value, *XYZ*, of the object in photographing place.

Visual stimulus value, *LMS*, about *XYZ* in photographing condition is obtained through Modified von Kries model. We can derive tristimulus value, *XYZ*, that make us to perceive the same visual stimulus value, *LMS*, as *LMS* about the original object. And we make derived *XYZ* to *RGB* signal considering color reproduction characteristic of standard display.

Captured image of Simulation program is shown in Fig. 4. Conditions of image test are shown in Fig. 5. Fig. 6. represents that lms coordinates of visual stimulus value, *LMS*, of Macbeth colorchecker on standard display under D_{65} illuminant. And Fig. 7. represent lms coordinates of visual stimulus value, *LMS*, of the object in photographing place. In lms coordinate system, lms coordinates of Macbeth colorchecker that is seen directly in photographing place is different from lms coordinates of Macbeth colorchecker that is transformed by white balance camera.

Fig. 8. (a) represents reproduction image of Macbeth colorchecker transformed by camera set the white balance point to W_A. And Fig. 8. (b) represents reproduction image using proposed algorithm in order to perceive the equivalent color sense on standard display under D_{65} illuminant to directly viewing color sense under A illuminant.

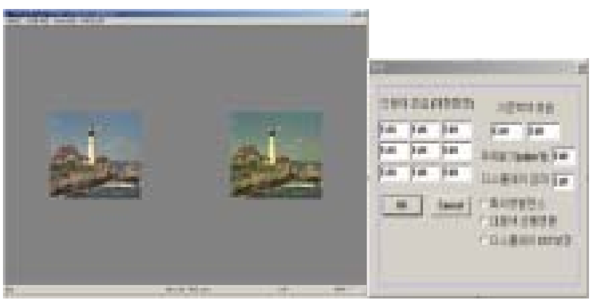


Fig. 4. Captured image of simulation program.

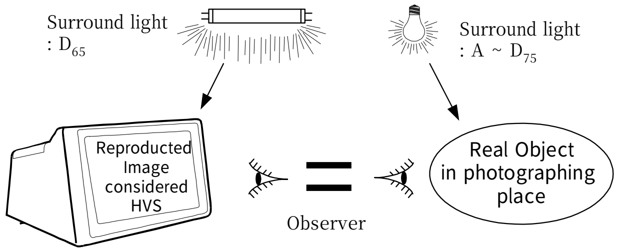


Fig. 5. Conditions of test

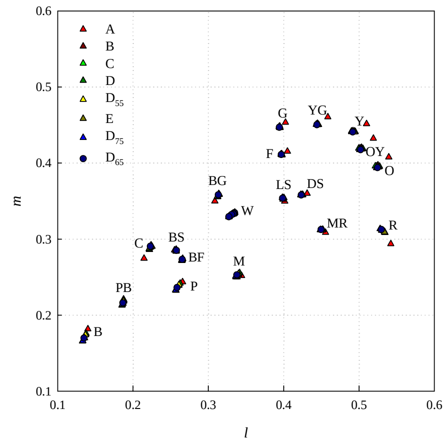


Fig. 6. The lms coordinates of visual stimulus value, *LMS*, of Macbeth colorchecker on standard display under D_{65} illuminant.

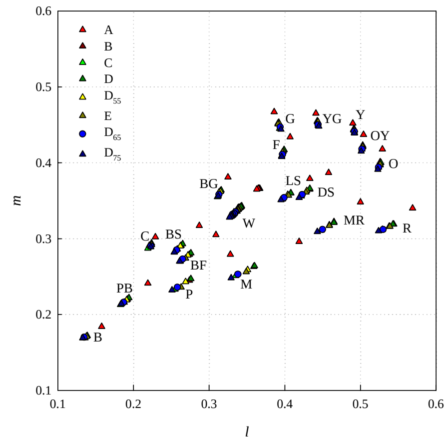
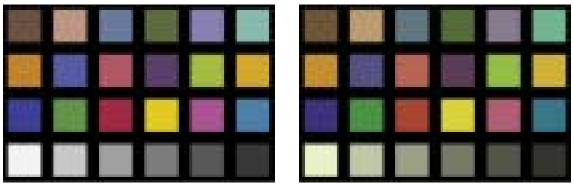


Fig. 7. The lms coordinates of visual stimulus value, LMS, of the object in photographing place.

5 observers judged reproduction image using proposed algorithm. Reproduction image using proposed algorithm is more equivalent color sense than reproduction image by white balanced camera.



(a) (b)

Fig. 8. Comparison (a) reproduction image of Macbeth colorchecker transformed by camera set the white balance point to W_A and (b) reproduction image considering HVS about the object.

5. Conclusion

In this paper, we propose the algorithm that makes us to perceive the equivalent color sense of object on standard display under D_{65} illuminant to directly viewing color sense in photographing place. If we know the condition of photographing place and the characteristic of camera, we can reproduce the image of equivalent color sense to original color sense in photographing place on standard display in standard viewing conditions using proposed algorithm.

Namely, we can make output signal of the camera in order to reproduce equivalent color sense.

References

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