Additive colour mixing model based on human colour vision

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Introduction

This paper proposes an analytical model of an additive colour mixing widely applied in fields of colour printing and colour imaging, etc.

First, an outline of the proposed model is shown by using both characteristics of human vision and colour signals of sample images. Next, the human characteristics of colour vision are formulated. Finally, the phenomenon of colour mixture is qualitatively discussed by using analytical results of this proposal.

Outline of an Additive colour mixing model

Figure 1 shows the proposed model of an additive colour mixing in the case where red and green are mixed and looked yellow.

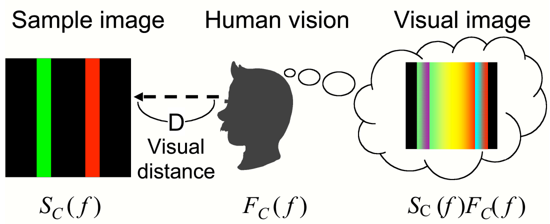


Figure 1. Proposed model of colour mixture based on human colour vision

The proposed model treats the additive colour mixing as the following phenomenon; colour signals of a sample image attenuate because of human colour vision, and overlap with each other.

The colour signals' characteristics of the sample patterns are described as the power spectrum density of the Fourier coefficient $S_C(f)$ of rectangle waves; where f is a spatial frequency [1].

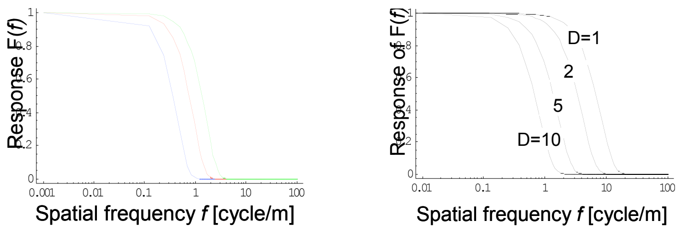
Human visual characteristics of spatial frequency response of colour

The characteristics of human colour vision are considered as spatial frequency responses of colour here. There have been some experimental reports that a low pass filter (LPF) is a reasonable choice for modeling the visual characteristics of the colour spatial frequency. Therefore, the spatial frequency responses of colour vision are expressed as $F(\nu, \nu_C)$ with the Gaussian LPF in this paper. Where, ν is the frequency [cycle/degree] of the colour in the sample pattern according to the viewing angle. The ν_C [cycle/degree] means the frequency of each colour when the amplitude becomes half of the original. The ν_C of red, green, and blue are applied by referring to Kurahashi's report with the following values [2]; $\nu_R = 5.0$, $\nu_G = 8.8$, and $\nu_B = 2.4$.

The original spatial frequency ν [cycles/degree] is converted by using the frequency of the sample surface f [cycle/m] and the visual distance D [m] as parameters [3]. D means the distance between the sample image and the observer. Therefore, the visual characteristics can be expressed as follows;

$$F(f) = \exp\left\{ -\left[\frac{1}{2v_C \cdot \tan^{-1}\left(\frac{1}{2fD}\right)} \right]^2 \right\}. \qquad (1)$$

Figure 2a shows analytical examples of Formula 1 for RGB, and Fig. 2b shows the analytical results for green only. When the visual distance *D* is longer, the characteristics of visual LPF works better.



(a) Each colour (D = 5 m) *(b) Green signal (D = 1, 2, 5, 10 m)*

Figure 2. Analytical examples of visual spatial features with colours and visual distances as parameters.

Analytical results and conclusions

The behavior of the signal is obtained as a multiplication of the signal characteristics $S_C(f)$ and the visual characteristics $FC(f)$ in the frequency domain. The wave shapes of the perceived colour signals in the time domain are calculated by the inverse Fourier transform of $S_C(f) \times FC(f)$. This signal seems to indicate the secondary colour with additive mixing.

Figure 3 shows how the signal behaves under the influence of the human visual LPF. Where, $F^{-1}(x)$ means the inverse Fourier transform of *x*. When the visual distance *D* is longer, the waveform of the colour signal becomes broader in the time domain. It is assumed that when more than 10 % density of both the original signals of red and green overlapped with each other, they are seen as yellow here. These results show that the apparent yellow area increases according to the visual distance.

The proposed model can explain qualitatively the process of an additive colour mixing by using the colour arrangement of samples and the visual distance as parameters. Therefore, it can be said that this model simulation will be useful in the efficient design of colour images, optimal colour displays for many purposes, etc.

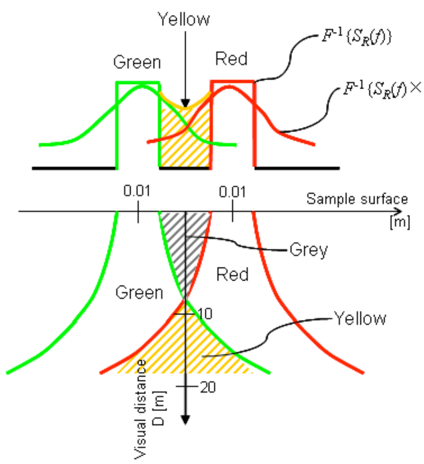


Figure 3. The behavior of colour signals under the influence of human colour vision in the time domain.

References

[1] T. Nonaka, M. Matsuda and T. Hase: Modulation Transfer Function Model of Assimilation Phenomenon Based on Visual Characteristics, *pd. AIC 05*, 983-986, 2005
[2] K. Kurahashi: Visual Color Shifts in Spatial Array of Three Primary Colors, *Journal of the Institute of Television Engineers of Japan*, 40, 5, 392-397, 1986 (in Japanese)
[3] T. Nonaka, M. Matsuda and T. Hase: Two-dimensional Modulation Transfer Function Model of Assimilation Phenomenon, *pd. SMC 2005*, 3035-3042, 2005