# A First Introduction to Metamerism Art

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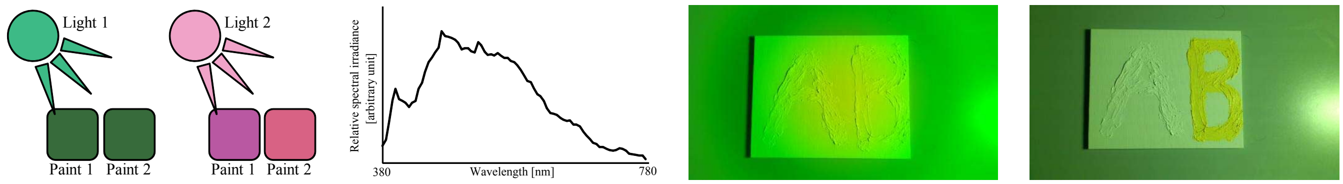


(a) (b) (c) (d)

**Figure 1:** *(a) Metamerism is the capability of the human eye to recognize two colors as the same under a certain light though they are recognized as different colors under other light. (b) One example of the hyperspectral data which is used as the database of our system. (c) Two colors are recognized as same under a certain yellow light. (d) Two colors are recognized as different under another yellow light.*

## 1 Introduction

The human brain recognizes pictures that are first obtained by the photosensitive cells in the retina. Color is a visual perception composed by the stimulus of three kinds of photoreceptors called L, M, and S cones. The human eye often recognizes different spectral distribution as same color since each cone has wide spectral response. This phenomenon is known as metamerism. Our research project aims to innovate a novel form of artistic illusion by fully making use of metamerism. This paper proposes a method which estimates the mixture ratio of paints that can cause metamerism.

## 2 Our Approach

It is quite common that different spectral distribution can be detected as same color by human perception. Such metamerism is a well known phenomena in the field of printing, advertisement, design, photography, and so on. Namely, two patches with same color under a certain illumination can be detected by human vision as different colors, in some cases, under another type of illumination.

Human perception can be represented by three stimuli $X$, $Y$, and $Z$ in the CIE-XYZ color space.

$$(X, Y, Z)^\top = \mathbf{pEDw}. \tag{1}$$

Here, $\mathbf{p}$ is $3 \times N_b$ matrix with CIE-XYZ color matching function.

$$\mathbf{p} = \begin{pmatrix} \bar{x}_1 & \cdots & \bar{x}_{N_b} \\ \bar{y}_1 & \cdots & \bar{y}_{N_b} \\ \bar{z}_1 & \cdots & \bar{z}_{N_b} \end{pmatrix}. \tag{2}$$

Spectral distribution of the illumination $\mathbf{E}$ is represented by $N_b \times N_b$ diagonal matrix.

$$\mathbf{E} = \mathrm{diag}\left(E_1, E_2, \cdots, E_{N_b}\right). \tag{3}$$

Several kinds of paints are blended in order to make intended color. The database of $N_p$ kinds of paints $\mathbf{D}$ is represented by $N_b \times N_p$ matrix. These paints are mixed with the ratio $\mathbf{w}$ represented by $N_p \times 1$ vector.

$$\mathbf{w} = \left(w_1, w_2, \cdots, w_{N_p}\right)^\top, \tag{4}$$

$$\mathbf{D} = \begin{pmatrix} d_{11} & d_{12} & \cdots & d_{1N_p} \\ d_{21} & d_{22} & \cdots & d_{2N_p} \\ \vdots & \vdots & \ddots & \vdots \\ d_{N_b 1} & d_{N_b 2} & \cdots & d_{N_b N_p} \end{pmatrix}. \tag{5}$$

Our purpose is to determine two colors that cause metamerism under two lights.

$$F(\mathbf{p}, \mathbf{E}_1, \mathbf{E}_2, \mathbf{D}, \mathbf{w}_1, \mathbf{w}_2) = \|\mathbf{pE}_1\mathbf{Dw}_1 - \mathbf{pE}_1\mathbf{Dw}_2\|^2 - \|\mathbf{pE}_2\mathbf{Dw}_1 - \mathbf{pE}_2\mathbf{Dw}_2\|^{0.5}, \tag{6}$$

$$\{\mathbf{w}_1, \mathbf{w}_2\} = \underset{\mathbf{w}_1, \mathbf{w}_2}{\mathrm{argmin}}\, F(\mathbf{p}, \mathbf{E}_1, \mathbf{E}_2, \mathbf{D}, \mathbf{w}_1, \mathbf{w}_2), \tag{7}$$

$$\text{s.t.} \quad \sum_{n=1}^{N_p} w_{1n} = 1, \sum_{n=1}^{N_p} w_{2n} = 1,$$
$$0 \le w_{1n} \le 1, 0 \le w_{2n} \le 1, \quad \{n = 1, \cdots, N_p\}.$$

Solving Eq. (7) by simulated annealing method based on Nelder-Mead downhill simplex algorithm produces two paints $\mathbf{Dw}_1$ and $\mathbf{Dw}_2$ which are recognized as same color under light $\mathbf{E}_1$ and as different color under light $\mathbf{E}_2$.

Spectral data within the wavelength 380[nm]–780[nm] is obtained by hyper spectral camera HSC-1700. Through our experiments, we have recognized the metamerism of two oil paintings whose mixture ratios are computed by the proposed method. A next stage of our project is to apply our algorithm to various application including illusion attractions in amusement parks or advertisement signboards which change in appearance between daylight and evening.

## References

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