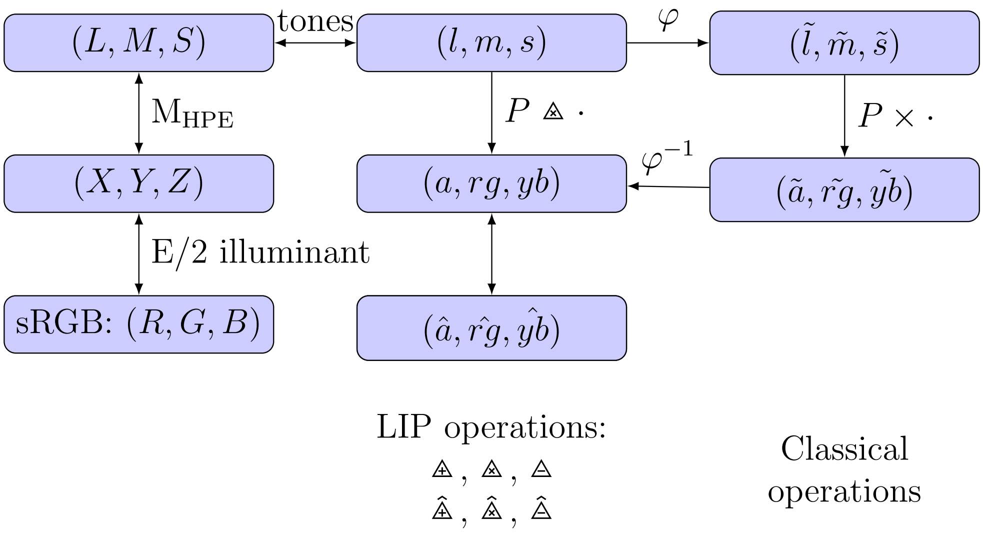
Tutorial: Color Logarithmic Image Processing (CoLIP)

Note

The objective of this tutorial is to have an overview of the Color Logarithmic Image Processing (CoLIP) framework [3, 4, 1, 2]. The CoLIP is a mathematical framework for the representation and processing of color images. It is psychophysically well justified since it is consistent with several human visual perception laws and characteristics. It allows to consider color images as vectors in an abstract linear space, contrary to the classical color spaces (e.g., RGB and $L^*a^*b^*$). The purpose of this tutorial is to present the mathematical fundamentals of the CoLIP by manipulating the color matching functions and the chromaticity diagram.

1 Definitions

This diagram summarizes the transitions between the classical RGB space and the CoLIP space. The transfer matrices are presented in the following.



1.1 RGB to XYZ

Here, we choose to keep the conventions of the CIE 1931, i.e. a 2° 1931 observer, with the equal energy illuminant E and the sRGB space. Depending on the illuminant, there exist many conversion matrices.

Informations

Use rgb2xyz MATLAB® function to perform the conversion.

1.2 XYZ to LMS

The matrix M_{HPE} (Hunt, Pointer, Estevez) is defined by:

$$\begin{pmatrix} L \\ M \\ S \end{pmatrix} = \mathrm{M_{HPE}} \times \begin{pmatrix} X \\ Y \\ Z \end{pmatrix}, \tag{1}$$

with

$$\mathrm{M_{HPE}} = \begin{pmatrix} 0.38971 & 0.68898 & -0.07868 \\ -0.22981 & 1.18340 & 0.04641 \\ 0.00000 & 0.00000 & 1.00000 \end{pmatrix}. \tag{2}$$

1.3 LMS to lms

$$\forall c \in \{l, m, s\}, C \in \{L, M, S\}, c = M_0 \left(1 - \frac{C}{C_0}\right), \tag{3}$$

with C_0 is the maximal transmitted intensity value. M_0 is arbitrarily chosen at normalized value 100. Notice that $C \in]0; C_0]$ and $c \in [0; M_0[$.

1.4 CoLIP homeomorphisme

$$\forall f \in S,\ \varphi(f) = -M_0 \mathrm{ln} \left(1 - \frac{f}{M_0}\right).$$

The logarithmic response of the cones, as in the LIP theory, is modeled through the isomorphism φ:

$$\text{for } c \in \{l, m, s\},\ \tilde{c} = \varphi(c) = -M_0 \ln \left(1 - \frac{c}{M_0}\right), \tag{4}$$

where $(\tilde{l}, \tilde{m}, \tilde{s})$ are called the logarithmic chromatic tones.

1.5 Opponent process

$$\begin{pmatrix} \tilde{a} \\ \tilde{rg} \\ \tilde{yb} \end{pmatrix} = P \times \begin{pmatrix} \tilde{l} \\ \tilde{m} \\ \tilde{s} \end{pmatrix}, \tag{5}$$

with

$$P = \begin{pmatrix} 40/61 & 20/61 & 1/61 \\ 1 & -12/11 & 1/11 \\ 1/9 & 1/9 & -2/9 \end{pmatrix}. \tag{6}$$

1.6 Bounded vector space

Three channels $\hat{f} = (\hat{a}, \hat{rg}, \hat{yb})$ are defined by:

$$\hat{a} = a \tag{7}$$

$$\hat{rg} = \begin{cases} rg & \text{if} \quad rg \geq 0 \\ -\triangle\, rg & \text{if} \quad rg < 0 \end{cases} \tag{8}$$

$$\hat{yb} = \begin{cases} yb & \text{if} \quad yb \geq 0 \\ -\triangle\, yb & \text{if} \quad yb < 0 \end{cases} \tag{9}$$

2 Applications

2.1 CMF

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Represent the classical chromaticity by using the color matching functions.

Informations

The color matching functions in the different spaces, as well as the wavelength and the purple line, are provided in the matrix 'cmf.mat'.

2.2 CoLIP chromaticity diagram

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Represent the chromaticity diagram in the plane $(\hat{rg}, \hat{yb})$ as well as the Maxwell triangle of the RGB colors, as in Fig.1.

References

[1] Yann Gavet, Johan Debayle, and Jean-Charles Pinoli. The color logarithmic image processing (colip) antagonist space. In *Color Image and Video Enhancement*, pages 155–182. Springer International Publishing, 2015. 1

[2] Yann Gavet, Johan Debayle, and Jean-Charles Pinoli. The color logarithmic image processing (colip) antagonist space and chromaticity diagram. In *International Workshop on Computational Color Imaging*, pages 131–138. Springer International Publishing, 2015. 1

[3] Hélène Gouinaud. *Traitement logarithmique dimages couleur*. PhD thesis, Ecole Nationale Supérieure des Mines de Saint-Etienne, 2013. 1

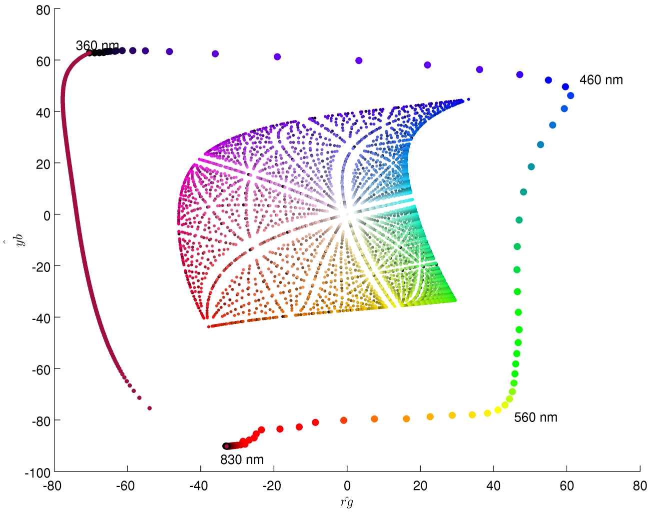

Figure 1: Chromaticity diagram in the plane $(\hat{rg}, \hat{yb})$.

[4] Hélène Gouinaud, Yann Gavet, Johan Debayle, and Jean-Charles Pinoli. Color correction in the framework of color logarithmic image processing. In *Image and Signal Processing and Analysis (ISPA), 2011 7th International Symposium on*, pages 129–133. IEEE, 2011. 1