Flexible Sequential Gamut Boundary (FSLGB) Method for Gamut Boundary Calculation

Shankhya Debnath

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1 Introduction

The determination of gamut boundaries is a crucial step in understanding the range of colors present in an image or achievable on a color reproduction medium. This paper details the Flexible Sequential Gamut Boundary (FSLGB) method, an algorithm specifically designed for calculating gamut boundaries in color spaces, with particular emphasis on its application in gamut mapping.

2 CIELAB Color Space Conversion

To calculate the gamut boundary, it is first necessary to convert the image from the RGB color space to the CIELAB color space, as the latter is perceptually uniform and better suited for this purpose. The transformation from RGB to CIELAB is performed in two steps:

1. Convert the RGB values to XYZ tristimulus values using a linear transformation.

2. Convert the XYZ values to CIELAB using the following equations:

$$L^* = 116 \cdot f\left(\frac{Y}{Y_n}\right) - 16, \tag{1}$$

$$a^* = 500 \cdot \left[f\left(\frac{X}{X_n}\right) - f\left(\frac{Y}{Y_n}\right)\right], \tag{2}$$

$$b^* = 200 \cdot \left[f\left(\frac{Y}{Y_n}\right) - f\left(\frac{Z}{Z_n}\right)\right], \tag{3}$$

where

$$f(t) = \begin{cases} t^{1/3} & \text{if } t > \left(\frac{6}{29}\right)^3, \\ \frac{1}{3}\left(\frac{29}{6}\right)^2 t + \frac{4}{29} & \text{otherwise.} \end{cases} \tag{4}$$

Here, X_n, Y_n, and Z_n are the reference white tristimulus values.

3 Gamut Boundary Descriptor (GBD)

The Gamut Boundary Descriptor (GBD) is a critical component of the FSLGB method. It is calculated by segmenting the color space into a predefined number of segments in the spherical coordinates (L^*, a^*, b^*). The goal is to find the most extreme color within each segment, which defines the boundary of the color gamut.

3.1 Segment Maxima Method

The GBD is calculated using the Segment Maxima Method. The steps are as follows:

1. Calculate the spherical coordinates from the CIELAB coordinates using:

$$r = \sqrt{(L^*)^2 + (a^*)^2 + (b^*)^2}, \tag{5}$$

$$u = \arctan 2(b^*, a^*), \tag{6}$$

$$\alpha = \arctan 2\left(L^*, \sqrt{(a^*)^2 + (b^*)^2}\right). \tag{7}$$

2. Segment the (α, u) plane into $n \times n$ segments.

3. For each segment, find the color with the maximum radius r and store its (L^*, a^*, b^*) values.

4 Flexible Sequential Gamut Boundary (FSLGB) Method

The FSLGB method is designed to calculate the intersection of the gamut boundary with lines along which color mapping algorithms operate. The process involves the following steps:

4.1 Intersection Calculation

For a given hue angle, the 2D gamut boundary is found by:

1. Calculating the equation of a constant hue angle plane:

$$f(\alpha) = \text{constant}. \tag{8}$$

2. Finding the pair of neighboring points in the GBD matrix with hue angles straddling the desired hue angle.

3. Calculating the intersection of the line connecting these two GBD points with the plane $f(\alpha)$.

4. Including points where the GBD intersects the lightness axis (L^*).

4.2 Line-Gamut Boundary Intersections

Once the 2D boundary polygon is established for a given hue angle, the intersection with any line in the (L^*, C^*) plane can be found using:

$$P = A + t \cdot u, \tag{9}$$

where P is any point on the line, A is a known point on the line, u is the direction vector, and t is a scalar parameter.

5 Reference

1. Morovič, J., & Luo, M. R. (2000). Calculating medium and image gamut boundaries for gamut mapping. Color Research & Application: Endorsed by Inter-Society Color Council, The Colour Group (Great Britain), Canadian Society for Color, Color Science Association of Japan, Dutch Society for the Study of Color, The Swedish Colour Centre Foundation, Colour Society of Australia, Centre Français de la Couleur, 25(6), 394-401.