Visualization of Gamut Boundary in CIELAB Space: Single Slice and Multiple Slices Approaches

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1 Introduction

Understanding the color gamut of an image in the CIELAB color space is essential for various applications in color science, including color reproduction and gamut mapping. This document details two methods for visualizing the gamut boundary: a single slice approach and a multiple slices approach. These methods provide insights into the distribution of colors within the gamut, aiding in the analysis of color reproduction capabilities.

2 CIELAB Color Space Conversion

Both the single slice and multiple slices approaches start by converting the image from the RGB color space to the CIELAB color space. The conversion is crucial as the CIELAB space is designed to be perceptually uniform, making it suitable for analyzing color distributions. The conversion process involves:

1. Converting the RGB values to XYZ tristimulus values.
2. Converting XYZ values to CIELAB using the following standard 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 the function $f(t)$ is defined as:

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

3 Single Slice Visualization of Gamut Boundary

The single slice approach focuses on visualizing the gamut boundary in the a^*b^* plane at a fixed lightness (L^*) level. This method provides a clear view of the color distribution at a specific lightness level, highlighting the boundaries within that slice.

3.1 Gamut Boundary Extraction

To extract the gamut boundary in the a^*b^* plane:

1. The image is converted to the LAB color space.
2. The a^* and b^* channels are extracted for all pixels, corresponding to the color distribution in the plane.
3. A convex hull is computed to define the boundary of the color gamut in this plane. The convex hull represents the smallest convex shape that encloses all points in the a^*b^* plane.

3.2 Visualization

The points in the a^*b^* plane are plotted with their corresponding RGB colors, and the convex hull is drawn to highlight the boundary. This visualization helps to understand the extent and shape of the color distribution at the selected lightness level.

4 Multiple Slices Visualization of Gamut Boundary

The multiple slices approach extends the single slice method by visualizing the gamut boundary across multiple lightness (L^*) levels. This method provides a more comprehensive understanding of the color distribution across the entire lightness spectrum.

4.1 Selection of L^* Slices

To visualize the gamut across multiple lightness levels:

1. Specific L^* values are selected, either provided by the user or chosen automatically.
2. For each selected L^* value, a tolerance is applied to include points close to the desired lightness level.
3. The corresponding a^* and b^* values are extracted, and a convex hull is computed to define the boundary for each slice.

4.2 Visualization

Each L^* slice is plotted in a separate subplot, showing the color distribution and the corresponding gamut boundary in the a^*b^* plane. This multi-slice visualization reveals how the gamut changes with lightness, providing insights into the overall structure of the color gamut.

5 Conclusion

The single slice and multiple slices approaches provide valuable methods for visualizing the color gamut boundary in the CIELAB color space. The single slice approach offers a focused view at a specific lightness level, while the multiple slices approach provides a broader perspective, illustrating how the color gamut varies across different lightness levels. These visualizations are crucial for understanding the color characteristics of an image and can inform decisions in color reproduction and gamut mapping.