Gamut Boundary Descriptor (GBD) Using a Modified Convex Hull

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1 Introduction

This document provides a detailed description of the process used to calculate and visualize the Gamut Boundary Descriptor (GBD) in LAB color space using a modified convex hull. The method follows principles from color science, specifically those described in Bala's paper, which proposes a pre-conditioning transformation to better approximate the color gamut's true shape in perceptual color spaces like LAB.

2 Gamut Boundary Descriptor (GBD) Overview

The Gamut Boundary Descriptor (GBD) is a method used to describe the outer boundary of a color gamut in a given color space. In this code, the LAB color space is utilized, where each pixel of the image is transformed into LAB coordinates. The convex hull is then applied to the set of boundary points to determine the extent of the color gamut.

3 Key Steps of the Process

The code performs the following key steps:

3.1 Image Conversion to LAB Space

The input image, which is in RGB color space, is first converted into the LAB color space. The LAB color space is used because it is perceptually uniform and allows for better analysis of color gamuts. The pixels of the image are then flattened into a single array of LAB values.

3.2 Pre-conditioning Transformation

A pre-conditioning transformation is applied to the LAB values to more accurately represent the true boundaries of the color gamut. This transformation modifies the distance of each point from a reference point, typically chosen as $[50, 0, 0]$ in LAB space (representing mid-lightness, neutral in chroma). The transformation inflates points that are close to the reference point and contracts points that are further away. This transformation is controlled by two parameters: α and γ.

- α: Controls the rate of transformation based on distance from the reference point.
- γ: A power factor that adjusts how the distances are scaled.

This transformation helps in capturing concavities in the color gamut, which are often missed by a standard convex hull.

3.3 Segmentation and Maximum Point Selection

The LAB color space is segmented into bins based on spherical coordinates. The spherical coordinates are derived from the LAB values, where:

- r: The radial distance from the reference point.
- α: The azimuth angle in the a^*b^* plane.
- θ: The elevation angle relative to the lightness axis L^*.

The space is divided into bins of size n_α (azimuth bins) and n_θ (elevation bins). For each bin, the point with the maximum radial distance is selected as the segment maxima. These segment maxima represent the outermost points in the LAB space for each angular bin.

3.4 Convex Hull Calculation

After segment maxima points are identified, the convex hull is calculated using these points. The convex hull generates a triangulated surface that encloses the set of segment maxima points. This surface approximates the boundary of the color gamut in the LAB space.

3.5 Inverse Transformation to LAB Space

Once the convex hull is calculated, the inverse of the pre-conditioning transformation is applied to return the points to their original positions in LAB space. This step ensures that the GBD is mapped back into perceptual LAB coordinates while preserving the modified hull.

3.6 Visualization and Gamut Boundary Plotting

The convex hull is visualized in 3D, with the LAB points converted back to RGB for display purposes. The resulting triangles of the convex hull are colored based on their corresponding LAB values, creating a color-mapped 3D surface. The surface is plotted in LAB space, where:

- The L^* axis represents lightness.
- The a^* and b^* axes represent the chromatic dimensions (green-red and blue-yellow, respectively).

4 Parameters and Adjustments

The granularity of the convex hull and the size of the triangles can be controlled by adjusting the number of bins n_α and n_θ. Higher values of these parameters will lead to smaller triangles and a finer mesh for the GBD surface.

4.1 Parameters Used in the Code

- n_α: Number of bins for azimuthal angle segmentation.
- n_θ: Number of bins for elevation angle segmentation.
- α and γ: Parameters controlling the pre-conditioning transformation.
- Reference point: A fixed point in LAB space used for radial distance calculations, typically set as $[50, 0, 0]$.

5 Conclusion

This method provides an accurate approximation of the Gamut Boundary Descriptor (GBD) by using a pre-conditioning transformation and convex hull approach. The pre-conditioning ensures that the concavities in the color gamut are captured, and the LAB color space provides a perceptually uniform representation of the gamut. The final result is a 3D plot of the color gamut boundary in LAB space, where the triangles are colored based on the corresponding LAB values of the boundary points.

6 References

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