A method for nearest neighbour gamut clipping

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1 Introduction

A method is presented that performs gamut clipping of an RGB image into a specified CMYK gamut, using the Fogra39 dataset. The gamut clipping process is done by mapping colors in the image that lie outside the CMYK gamut boundary to their nearest point within the CMYK gamut.

2 Mathematical Background

2.1 LAB and LCH Color Spaces

The CIE LAB color space is a color-opponent space with dimensions L, a, and b, which approximate human vision. The LAB values are derived from the XYZ color space via non-linear transformations. LAB separates luminance (L), chroma (C), and hue (H) components, which are more perceptually uniform.

The transformation from LAB to LCH can be described mathematically as:

$$C = \sqrt{a^2 + b^2}$$

$$H = \arctan\left(\frac{b}{a}\right)$$

Where:

- C represents *Chroma* (the distance from the neutral axis).
- H represents *Hue* (the angle in the LAB plane).
- L represents *Lightness*, which is unchanged in this transformation.

The inverse transformation from LCH to LAB is:

$$a = C \cdot \cos(H)$$

$$b = C \cdot \sin(H)$$

These transformations allow us to convert from LAB to LCH and vice versa in the code.

2.2 Convex Hull and Gamut Clipping

A convex hull is the smallest convex shape that contains all the points in a dataset. In the code, the convex hull is used to compute the boundary of both the RGB image gamut and the CMYK (Fogra39) gamut.

Given a set of points in the LAB or LCH color space, the convex hull is computed using the *ConvexHull* function. Mathematically, a convex hull of a set P is the smallest convex set S such that $P \subseteq S$.

Gamut clipping is done by checking if a point p lies outside the CMYK convex hull. This is mathematically represented as checking if the point satisfies the half-space equations of the convex hull. If a point lies outside, it is mapped to the nearest point on the convex hull boundary. The nearest point is found by minimizing the Euclidean distance between the point and the points on the boundary of the CMYK convex hull.

2.3 Color Conversion

Once all the points in the RGB image are mapped into the CMYK gamut, they are converted back to LAB and then to RGB. The transformation from LAB to RGB is done using the *skimage.color.lab2rgb* function.

3 Code Explanation

The code performs the following steps:

1. **Load the RGB Image:** The input image is loaded and converted from RGB to the LAB color space.

2. **Convert LAB to LCH:** Using the formulas provided earlier, the LAB values of the image are converted to LCH values. This separates the Lightness (L), Chroma (C), and Hue (H) components.

3. **Load Fogra39 Data:** The CMYK gamut is defined by the Fogra39 dataset, which contains LAB values. These are also converted to LCH for further processing.

4. **Convex Hull Calculation:** The convex hulls for both the image and the Fogra39 dataset are computed in the L-C space, which represents the Lightness-Chroma plane.

5. **Gamut Mapping:** For each point in the image, the code checks whether the point lies inside the CMYK gamut. If it is outside, the point is mapped to the nearest point on the convex hull boundary. This ensures that the final colors lie within the CMYK gamut.

6. **Clipping and Reconstruction:** Once all points are mapped inside the CMYK gamut, the LCH values are converted back to LAB and then to RGB. The clipped RGB values are used to recreate the image.

7. **Display the Images:** The original and clipped images are displayed side by side for comparison.

4 Observation

The original RGB image on the left shows colors that are vibrant and may not be reproducible in the CMYK color space.The clipped image on the right has slightly desaturated colors, especially in areas where bright or highly saturated colors were present. This is expected since those colors were mapped to the nearest available colors in the CMYK gamut. The differences are subtle in this case, but they highlight the limitations of CMYK printing and the necessity of gamut mapping for print compatibility.