Implementing a Vividness and Depth Preserved Gamut Compression

Shankhya Debnath

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1 Introduction

Vividness Preserved (VP) and Depth Preserved (DP) are two approaches for gamut compression designed to fit colors within a target gamut, such as AdobeRGB, while maintaining specific perceptual qualities. This document explains the mathematical background and implementation of the VP and DP compression algorithms, along with an analysis of the results obtained from compressing the color gamut of an input image.

2 Mathematical Background

The VP and DP algorithms compress the color gamut by adjusting the lightness and chroma of colors. The process can be summarized as follows:

2.1 Lightness and Chroma

In the CIELAB color space, a color is represented by the triplet (L^*, a^*, b^*), where L^* denotes lightness, and a^* and b^* represent the color-opponent dimensions. The chroma C^* and hue angle h are defined as:

$$C^* = \sqrt{a^{*2} + b^{*2}} \tag{1}$$

$$h = \arctan\left(\frac{b^*}{a^*}\right) \tag{2}$$

2.2 Vividness Preserved (VP) Compression

The VP method aims to preserve the vividness of colors by scaling both lightness and chroma by a compression factor, α, towards the black point:

$$L_m^* = L^* \times \alpha \tag{3}$$

$$C_m^* = C^* \times \alpha \tag{4}$$

The compressed LAB values are then calculated using the original hue angle h:

$$a^*_m = C^*_m \times \cos(h) \tag{5}$$

$$b^*_m = C^*_m \times \sin(h) \tag{6}$$

Thus, the compressed color (L^*_m, a^*_m, b^*_m) is obtained.

2.3 Depth Preserved (DP) Compression

The DP method focuses on preserving the depth of colors by scaling chroma while adjusting lightness towards the cusp lightness:

$$L^*_m = L^* + (L^*_{cusp} - L^*) \times (1 - \alpha) \tag{7}$$

$$L^*_m = \min(L^*_m, L^*_{cusp}) \tag{8}$$

$$C^*_m = C^* \times \alpha \tag{9}$$

The compressed LAB values are then calculated using the original hue angle h:

$$a^*_m = C^*_m \times \cos(h) \tag{10}$$

$$b^*_m = C^*_m \times \sin(h) \tag{11}$$

3 Implementation

The Python code implements both VP and DP compression algorithms to compress the gamut of an input image. The code follows these steps:

1. Generate LAB points for the target AdobeRGB gamut using the ICC profile.
2. Generate a Gamut Boundary Descriptor (GBD) using the Convex Hull method.
3. Estimate the cusp lightness, L^*_{cusp}, from the GBD.
4. For each pixel in the input image:
   - Apply the VP or DP method to adjust lightness and chroma.
   - Recalculate the a^* and b^* components based on the compressed chroma and original hue angle.
5. Convert the compressed LAB image back to the RGB color space.
6. Plot and compare the original and compressed gamuts in the L/C plane for both methods.
7. Display the original, VP, and DP compressed images side by side.

4 Observations

The vividness-preserved (VP) compressed image maintains much of the original vibrancy but with slightly subdued colors. The compression results in a noticeable reduction in saturation, particularly in areas with high chroma values such as the greens of the fields and the blue regions of the sky. The overall image still retains a natural appearance, though there is a subtle shift towards less intense colors. The compression appears to be effective in maintaining the general tonal range without causing significant color distortion.

The depth-preserved (DP) compressed image shows a more significant reduction in color saturation compared to the VP method. The colors appear more muted, with a less vibrant representation of the greens and blues. This suggests that the DP method compresses the gamut more aggressively, especially in terms of reducing chroma while attempting to maintain the relative depth of colors. The image has a more flattened appearance, which may be desirable in some applications where preserving the perceived depth or luminance contrast is more critical than maintaining vividness.

The VP gamut plot shows a compressed version of the original gamut, particularly noticeable in the reduction of maximum chroma values. The compression is more evident in regions with higher chroma, where the color points have been shifted inward towards lower chroma values. However, the overall structure of the gamut remains relatively intact, with the points maintaining their general distribution along the lightness axis (L^*), suggesting that the method effectively preserves the perceived vividness while compressing the colors.

The DP gamut plot exhibits a more pronounced compression along the chroma axis, with a significant reduction in chroma values across the entire lightness range. The result is a more compact and less vibrant gamut. The distribution along the lightness axis suggests that while chroma has been significantly compressed, the method preserves the relative lightness of colors, which could be beneficial in applications where maintaining luminance contrast is crucial.

5 References

1. Xu, L., Zhao, B., & Luo, M. R. (2018). Colour gamut mapping between small and large colour gamuts: Part I. gamut compression. Optics express, 26(9), 11481-11495.

2. Morovic, J. (2003). Guidelines for the evaluation of gamut mapping algorithms. PUBLICATIONS-COMMISSION INTERNATIONALE DE L ECLAIRAGE CIE, 153, D8-6.