

Quick Gamut mapping for simplified color correction

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ABSTRACT

This paper presents an alternative simplified method to convert color spaces more quickly than using the traditional gamut mapping. The conversion is carried out in the two-dimensional xy chromaticity diagram, through an affine transformation, which remaps the color chromaticity only. The affine transformation applies to the colors of the original image the values obtained by solving two linear systems of three equations using the coordinates of the input and output color spaces. Then, these values are applied to each xy coordinate of the image color obtained from its RGB values.

Purpose of this alternative method is not the colorimetric accuracy, but testing is an oversimplified version can lead to acceptable results. In image and video editing, the steps of color correction and color grading are often performed by the expert's eye using various image editing tools and software. This approach overshadows the colorimetric aspect, focusing just on the aesthetic enhancement. The proposed alternative gamut mapping method, named Quick Gamut, will be presented through application examples.

KEYWORDS (Gamut mapping, Color correction, Image processing, Digital image, Colorimetry)

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1. Introduction

When talking about color reproduction in digital systems it is fundamental to define the concept of color gamut. A color gamut is the set of colors that can be reproduced by a specific device (e.g., monitor, printer, photographic film). Each device or media has a different color gamut, so the colors that we see in a monitor cannot be reproduced by a printer or by a different kind of monitor. A common way to compare different color gamut is through the x y coordinates of the CIE 1931 chromaticity diagram. As defined in (Ramanath, 2014):

"Gamut Mapping refers to the process of translating colors in one device's color space to that of another. This process is performed on colors in images and video so as to create a rendition of a source image (typically in a capture device's color space) in an output device's color space while meeting several rendering intents: absolute and relative colorimetric fidelity, perceptual accuracy, and the problem of saturation – each of which trades off one color property at the expense of another".

Since gamut mapping is a current open issue in computer science and color analysis, through the history different methods and approaches to perform it have been proposed and this issue has been recognized also by CIE (Commission Internationale de l'Éclairage), which set up the Technical Committee 8-03 on Gamut Mapping.

The state of the art on gamut mapping is really wide and complex, therefore in this work we will not report a survey or a technical comparison among gamut mapping methods, anyway we suggest the works proposed in (Morovič, 2001) and (Morovič, 2008) for a detailed survey on gamut mapping techniques.

In general, the traditional methods of automatic color spaces conversion and gamut mapping from a device to another are colorimetrically accurate, but in some cases the result is not perceptually satisfactory, and it needs to be edited manually. In this paper, we present an alternative method that implement an oversimplification of the classic gamut mapping approach.

In contrast to traditional gamut mapping, the proposed method applies a geometric simplification, which consists in mapping the colors only in the two-dimensional CIE xy chromaticity diagram and applying an affine transformation that remaps colors chromaticity (Wolf, 1961). In this paper, we propose some preliminary experiments and applications of this method, called Quick Gamut on some images, to assess if the decrease of computational complexity (which becomes linear) could provide satisfactory results.

2.1 Affine transformation

Quick Gamut uses an affine transformation based on the following formula (Weisstein, 2002):

$$\begin{cases} X = ax + by + e \\ Y = cx + dy + f \end{cases} \quad (1)$$

Where, X and Y are the coordinates of the new color space (output) and x and y are the old coordinates (input). Before applying the transformation, it is necessary to know a, b, e, c, d and f values. These values can be obtained by solving two linear systems of three equations, one for x and the other for y, using the coordinates of the three fundamental components of the input and the output color spaces.

$$\begin{cases} X_r = ax_r + by_r + e \\ X_g = ax_g + by_g + e \\ X_b = ax_b + by_b + e \end{cases} \quad (2)$$

$$\begin{cases} Y_r = cx_r + dy_r + f \\ Y_g = cx_g + dy_g + f \\ Y_b = cx_b + dy_b + f \end{cases} \quad (3)$$

After the values computation from the previous systems, it is possible to map each pixel of the image from the original color space to the output color space by applying Formula 1.

2.2 Quick Gamut mapping

In order to map the colors of the original image in the new color space, it is necessary, at first to convert the input RGB values into x and y chromaticity coordinates then, apply the affine transformation and at the end convert the new x y coordinates into RGB values.

The steps to apply Quick Gamut mapping are listed below:

1. Normalize the RGB values over [0, 1];
2. Perform the gamma correction (i.e., raise each normalized value to gamma);
3. Multiply the color space transformation matrix by the RGB vector;

The product between the transformation matrix and the RGB vector is shown below:

$$\begin{bmatrix} X \\ Y \\ Z \end{bmatrix} = [M] \begin{bmatrix} R \\ G \\ B \end{bmatrix} \quad (4)$$

Where, M is the transformation matrix given by:

$$\begin{bmatrix} X_r & X_g & X_b \\ Y_r & Y_g & Y_b \\ Z_r & Z_g & Z_b \end{bmatrix} \quad (5)$$

The transformation matrix varies according to the color space (i.e., Adobe RGB (1998), sRGB).

4. The values obtained from the above multiplication have range [0, 1] and are mapped in the XYZ color space.
5. Convert the XYZ values into xyz coordinates with the formulas:

$$x = \frac{X}{X + Y + Z} \quad (6)$$

$$y = \frac{Y}{X + Y + Z} \quad (7)$$

$$z = \frac{Z}{X + Y + Z} \quad (8)$$

In this case, it is enough to know only the x and y coordinates because we are working on a two-dimensional space.

6. Apply the affine transformation to the obtained xyz coordinates (Formula 1);
7. Map all the pixels in the image to the output color space with the affine transformation and convert the new coordinates back to XYZ values using the formulas:

$$X = \frac{x}{y} Y \quad (9)$$

$$Y = Y \quad (10)$$

$$Z = \frac{1 - x - y}{y} Y \quad (11)$$

8. Normalize and clamp the CIE XYZ values in the range [0, 1];
9. Convert CIE XYZ values to RGB color space using the inverse transformation matrix:

$$\begin{bmatrix} R \\ G \\ B \end{bmatrix} = [M^{-1}] \begin{bmatrix} X \\ Y \\ Z \end{bmatrix} \quad (12)$$

10. Apply the gamma factor (rising the RGB values to $1/\gamma$), and multiply the values by 255 to bring them back into range [0, 255];
11. Clamp all the RGB values into the range [0, 255].

2.3 Example of Quick Gamut mapping applications

In the examples that will be shown, the sRGB coordinates are obtained by a linear transform with the matrix reported in Formula 13 and the inverse transformation matrix in Formula 14 (Anderson et al., 2020).

$$M = \begin{bmatrix} 0.4124564 & 0.3575761 & 0.1804375 \\ 0.2126729 & 0.7151522 & 0.0721750 \\ 0.0193339 & 0.1191920 & 0.9503041 \end{bmatrix} \quad (13)$$

$$M^{-1} = \begin{bmatrix} 3.2404542 & -1.5371385 & -0.4985314 \\ -0.9692660 & 1.8760108 & 0.0415560 \\ 0.0556434 & -0.2040259 & 1.0572252 \end{bmatrix} \quad (14)$$

New RGB color space		
	x	y
R	x	0.4
	y	0.35
G	x	0.3
	y	0.4
B	x	0.27
	y	0.24
White	x	0.3093
	y	0.3260

Tab. 1 Color space specifications.

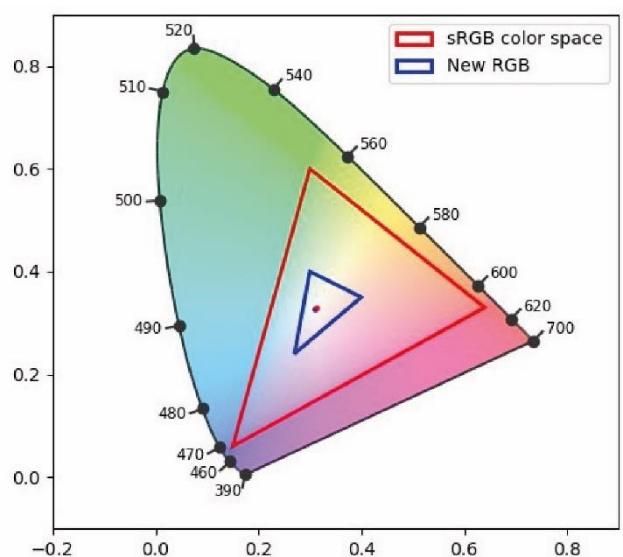


Fig. 1 Input and output RGB color spaces.



Fig. 3 (left) Quick Gamut mapping application, (centre) original image and (right) gamut mapping performed through Photoshop.



Fig. 2 ColorChecker.

In Figure 1 is reported an image of a typical input RGB color space (sRGB) and the destination color space computed using Quick Gamut mapping (see Table 1).

To show the performances of Quick Gamut applied on an image, in Figure 2 is reported a comparison between an image mapped using Photoshop and an image mapped using our method. Here, it can be seen that Quick Gamut offers a perceptually satisfactory result without loss of details, in contrast to Photoshop that produce images with flat colors.

2.4 Quick Gamut mapping assessment

To evaluate the precision of Quick gamut conversion, we tested this method on a ColorChecker (Figure 3). In Table 2 are reported the CIE L*a*b* values of every patch of the ColorChecker after a gamut mapping performed using Photoshop and using Quick Gamut. The differences between CIE L*a*b* values have been computed using ΔE^* difference (Mokrzycki and Tatol, 2020). Since Quick Gamut provides a strong geometrical simplification to map the color values in a new space, the color difference ΔE^* is high for some patches. Nevertheless, the linearity of the affine transform makes this method particularly easy to compute.

Colore	Photoshop			Quick gamut mapping			Δ			
	L*	a*	b*	L*	a*	b*	ΔL^*	Δa^*	Δb^*	ΔE^*
1	38	8	11	37	4	5	-1	-4	-6	7.28
2	64	11	15	64	8	6	0	-3	-9	9.48
3	53	5	-18	50	3	-6	-3	-2	12	12.53
4	46	-8	14	44	-1	6	-2	7	-8	10.82
5	56	9	-23	55	6	-6	-1	-3	17	17.29
6	74	-17	4	72	-3	-1	-2	14	-5	15.00
7	58	19	22	59	12	17	1	-7	-5	8.66
8	55	13	-27	40	6	-13	-15	-7	14	21.68
9	52	27	11	46	14	6	-6	-13	-5	15.16
10	35	11	-17	30	7	-6	-5	-4	11	12.73
11	82	-11	22	73	-4	16	-9	7	-6	12.88
12	71	5	22	69	8	20	-2	3	-2	4.12
13	49	12	-25	31	5	-12	-18	-7	13	23.28
14	62	-19	16	56	-7	9	-6	12	-7	15.13
15	45	26	17	37	16	9	-8	-10	-8	15.09
16	84	-6	23	80	3	23	-4	9	0	9.85
17	59	22	-12	47	15	-5	-12	-7	7	15.56
18	60	0	-15	53	0	-9	-7	0	6	9.22
19	97	-1	2	97	4	2	0	5	0	5.00
20	81	-1	0	82	5	1	1	6	1	6.16
21	67	0	0	67	4	1	0	4	1	4.12
22	51	0	0	51	3	1	0	3	1	3.16
23	36	0	-1	36	2	0	0	2	1	2.24
24	22	0	-1	22	2	0	0	2	1	2.24

Tab. 2 CIE $L^*a^*b^*$ values obtained from Figure 3. Highlighted in green the values between 0 and 2.99, in yellow the values between 3 and 4.99, in orange the values between 5 and 9.99, in blue the values greater than 10

3. Conclusion

In this work, Quick Gamut, an alternative simplified gamut mapping method has been presented. This method works only on the two-dimensional chromaticity information of the color spaces involved.

The preliminary tests carried out in this work, showed that despite the high color differences between the images obtained with traditional gamut mapping and with this method, the new proposed method can be used to provide a quick transformation for the color correction of images and/or videos.

4. Conflict of Interest

The authors declare no conflict of interest.

5. Declaration of funding sources

The authors received no specific funding for this work.

6. Short biography of the authors

Matteo Cereda – He graduated in Computer Science for digital communication at the University of Milano. As a great passionate of digital videos and photos, during his university experience he chose to deepen the multimedia field. This allowed him to gain skills in video and image processing, image enhancement and color correction.

Alice Plutino – She recently obtained the PhD at the Department of Computer Science, University of Milano. Her research interests are: Colorimetry, Image Processing, Data Digitization and Archiving with a particular interest in applications on Film Restoration. She is author of many scientific works, member of the Organizing Committee of AIC2021 and part of different workshops and conferences.

Alessandro Rizzi – He is Full Professor at the Department of Computer Science at the University of Milano, teaching Multimedia, Colorimetry and Film restoration. He is doing research since 1990 in the field of digital imaging with a particular interest on color, visualization, photography, HDR, VR and on the perceptual issues related to digital imaging, interfaces,

and lighting. He is co-chair of the IS&T Conference "Color Imaging: Displaying, Processing, Hardcopy and Applications", Topical Editor for "Applied Color Science" of the Journal of Optical Society of America A, Associate Editor of Journal of Electronic Imaging, member of several program committees of conferences related to color and digital imaging, and author of about 400 scientific works.

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