A Three Dimensional Method for Gamut Mapping

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Abstract

It is necessary to ensure that the color reproduction of an original will offer a good correspondence between the original and reproduction gamut. The transformation of the gamut of input device to fit that of output device is called gamut mapping. It is very important to decide the mapping direction considering three attributes of color i.e. hue, lightness and chroma. The mapping directions can be categorized as one, two or three-dimensional. Considering some limitations of one or two-dimensional models, a three-dimensional gamut mapping is suggested in the present study. The experimental results show that the clipping or compression do not have similar effects if the images vary from low-key to high-key ends. The compression method also depends on image quality. In the present study, three-dimensional gamut mapping has been adopted for different image qualities to indicate the preferred method.

Introduction

The gamut mapping has become extremely important nowadays as the color gamut of printers are different from that of the input devices. Hence it is not possible to reproduce all colors of the monitor on a printer. The transformation of the color gamut of one device to fit that of the other is known as gamut mapping. It is necessary to ensure a good correspondence of color appearance between the original and the reproduction.

It has been found in the previous works[3] that the gamut mapping is image-dependent and the gamut mapping method is not determined by the gamut of the image. In a significant number of studies, clipping is preferred over compression. However, the article of Morovic and Luo[3] shows that compression is advantageous when the gamut differences are larger. There are different approaches of gamut mapping.

Much of these studies have been concentrated on chromatic image content overlooking the lightness characteristics.

In most of the earlier works, gamut mapping started with lightness compression. Katoh and Ito[5] have found that lightness compression reduces the image contrast and smallest change is tolerated in the lightness direction.

The main aims of gamut mapping are to preserve the gray axis of the image, to reduce the number of out-of gamut colors, to minimize the hue shift and to increase saturation.[3]

Gamut mapping can be broadly classified as Gamut clipping and Gamut compression. Gamut Clipping are applied to out-of-gamut colors only and maps those colors inside the reproduction gamut. But this method may cause a loss of gradation as some of the colors of the original are mapped to the same point. However, it maintains most of the image saturation.[2]

Gamut Compression are applied to all colors of the original gamut to avoid gamut mismatch across the entire image. Gamut compression are of two types: linear or non-linear. The linear compression maps all the colors of the original gamut linearly. This method can minimize the loss of the gradation of the image but reduces the image saturation. Linear scaling for both lightness and saturation has serious implications on the image quality as it lightens the overall image.[1]

In the present study, different images are chosen for gamut mapping. Clipping and compression, both of the methods are applied for mapping. A three-dimensional compression is applied for each image to study which method is most acceptable.

Parameters of Gamut Mapping

The three attributes of colors are hue, lightness and chroma. In most of the cases, CIELab color spaces are used for gamut mapping as these are device-independent. As explained by Morovic and Luo,[3] it has to be kept in mind that the Lab values are not the perceptual attributes e.g., lightness, hue and chroma, but they are only the predictors of the attributes.

Direction of Gamut Mapping

It is very important to select the lines along which the gamut mapping approaches. The options are

a) lines of constant lightness and hue, constant saturation and hue
b) lines towards single center of gravity
c) lines towards variable center of gravity
d) lines towards the nearest color in the reproduction gamut.

In the present study, compression has been done along the lines where the attributes, lightness or chroma are kept as constant.

In the earlier studies, the most important criteria was to maintain hue and hence mapping was done along the chroma direction. However, this one-dimensional mapping causes objectionable decrease of chroma.[5] Considering these facts, Morovic and Luo[4] and many other workers suggested two-dimensional gamut mapping where lightness and chroma were compressed and hue was maintained.[5] However, it reduces the image contrast and vividness.[5]

Gamut Mapping Method

The gamut compression can be of two types. The colors can be compressed sequentially or simultaneously.[1] Katoh and Ito[5] found that for better mapping, minimum changes in lightness scale and maximum changes in chroma scale were acceptable.

Hence, a* and b* values are first compressed where L* values remain unchanged in the present study. Thus a sequential order is followed.

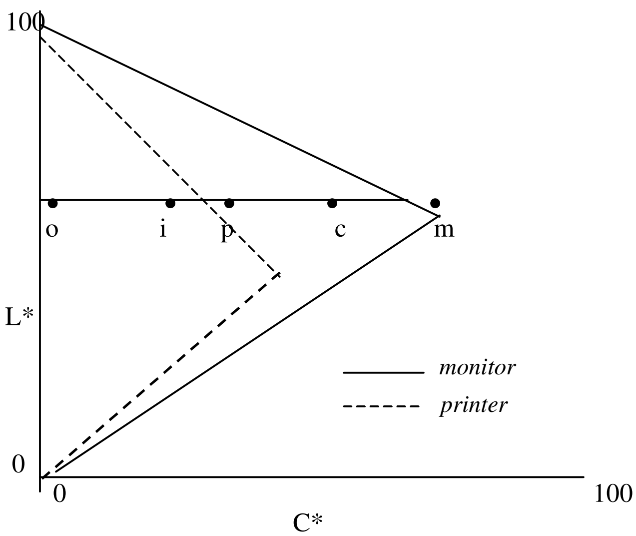

Figure 1. Three-dimensional gamut mapping

Figure 1 states how compression is done along the lines of constant perceptual attributes. The color located at point c which is an out-of-gamut color is compressed to a point i inside the printer gamut where o is the focal point, m and p are the points at the monitor and printer gamut boundaries respectively. The compression is done along the line where L* is kept constant. The linear compression is done by the equation:

$$oi / op = oc / om \tag{1}$$

The equation for non-linear compression is:

$$oi / op = (oc / om)^{\gamma} \tag{2}$$

The value of γ taken for this experiment is the ratio of out-of-gamut colors.

After this compression, then lightness are compressed by plotting L* vs. C* data and compressing L* by the equation (1) and (2).

Experiment

Different images are taken from low-key to high-key range according to the histogram. Two images A and B are low-key, C is average key and D is high-key image. The images were scanned using Umax Astra 4400 scanner and their CIELab values are taken. The prints are taken in HP 930c printer and are further scanned to get the CIELab values of the reproduction.

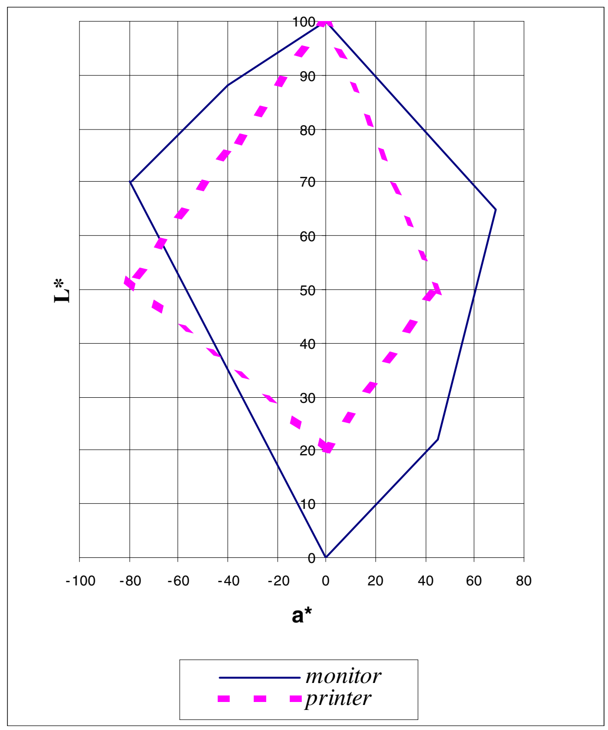

Figure 2. Monitor and printer gamut of average key-image C along a axis*

The three-dimensional gamut polygons are formed for monitor gamut and printer gamut. Figure 2 and Figure 3 show how printer gamut are deviated from monitor gamut for an average key image. The clipping and compression tests are then performed and compared. The color difference formula taken to find minimum color difference is $\Delta E_{94.}$

A psychophysical experiment has been carried out to compare the color appearance of monitor image and printed image after mapping.

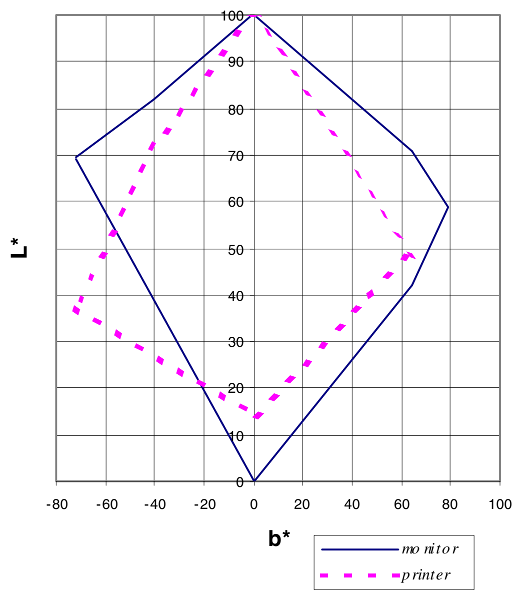

Figure 3. Monitor and printer gamut of average key-image C along b axis*

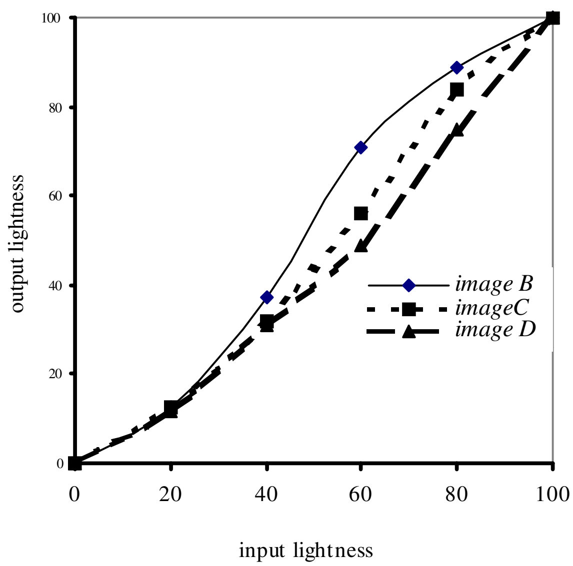

Figure 4. Input and output lightness of different images after three-dimensional non-linear mapping

Result and Discussion

The four images taken are as follows: two low key images A and B, one average key image C and one high key image D. The ratio of out-of-gamut colors for A, B, C and D are 28%, 52%, 44% and 67% respectively.

All of the images are subjected to clipping, linear compression and nonlinear compression.

Different trends are obtained for different images. A and B are low key images. It has been observed that clipping is acceptable for low key image A where the ratio of out-of-gamut colors are not very high. It should be noted that the image A contains mainly low frequency components for which clipping is the better option. For B, compression is better option.

The average key image C and high key image D give better result with three-dimensional compression. Figure 4 shows how the lightness has been mapped for different types of images varying from low key to high key end. It has been seen that for all three images, non-linear compression gives better result than linear compression.

Conclusion

It has been found that the gamut mapping methods depend on image content. Experimental results show that clipping is preferred for the low key image A which has low frequency components more and ratio of out-of-gamut colors less. For other images, compression is better choice where the ratio of out-of-gamut colors vary widely, but most of the out-of-gamut colors have high frequency. It may be concluded that for three-dimensional gamut mapping, where both linear and non-linear options are tried, nonlinear compression gives better result.

References

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Biography

Dr. Swati Bandyopadhyay received her B.E. degree in Chemical Engineering from Jadavpur University at Kolkata, India in 1987 and Ph. D. (Engg.) from the same University in 1995. Since 1990, she has worked as a lecturer of Printing Engineering Department in Jadavpur University. Now, she is working as Reader of the department. Her work is primarily focused on image quality of ink jet printer and color theories. She is a member of IS&T and IIChE.