Reference Input Medium Metric RGB Color Encoding (RIMM RGB) White Paper

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Abstract

A new color encoding known as *Reference Input Medium Metric RGB* (*RIMM RGB*) is defined. This color encoding is intended to be used for manipulating images that exist in a device-independent *unrendered image state*. This color encoding was chosen to provide a large enough color gamut to encompass most common input devices, and is defined to be suitable as an input space to the ICC profile connection space (PCS). Examples of manipulations that might be applied in this color encoding include scene balance algorithms, manual color/density/contrast/ tone scale adjustments, red-eye correction, and dust/scratch removal. The color encoding is also appropriate for archiving and/or interchanging unrendered images. 8-bit, 12-bit and 16-bit versions of this color encoding are defined.

I. Introduction

Many imaging chains require that provision be made for the manipulation of images to correct for deficiencies, or to provide for customization. To facilitate the development of such image processing algorithms, as well as their associated user interfaces, it is beneficial to define a small number of standard color encodings for manipulation of the images. Multiple standard color encodings are required due to the fact that there are several distinct populations of images in practice. The distinct image information attributes of each image population define the *image state* of that image population. At the most general level, there are two basic image states of interest: the *unrendered (scene) image state* and the *rendered image state.*

Scene Image State

Examples of images that exist in the *unrendered* (*scene) image state* include images that are captured by digital cameras (when in raw camera RGB codevalues) and those that are stored in the *Kodak PhotoYCC* Color Space. In these cases, the color values of the image can be directly related to the colors of a real, or hypothetical, scene. Images in these color encodings are generally not intended to be displayed on an output device without some sort of manipulation to "render" the image appropriately. Proper storage of images in an unrendered image state will generally maximize the re-purpose-ability of those images.

Rendered Image State

Other images exist in a *rendered image state* that is directly tied to the colors of a desired *rendered image*. Examples of images in this population include scanned reflection prints, *ROMM RGB* images[1], CMYK images, and images stored in *sRGB* (which is a standard monitor RGB space). In these cases, the color values do not correspond to the colors of an original scene, but rather to the colors of an associated image that has been rendered for an output display medium. Rendered images are produced from unrendered images by applying the tone/color reproduction characteristics and aims of an imaging system. Generally this rendering process will result in an increase in the contrast and chroma of an image relative to the original scene colors, and it will necessarily reduce the large dynamic range of a scene to the smaller dynamic range of an output medium. In general, color management systems provide a means of managing this process by using an input profile to define the relationship between an unrendered scene space and the colorimetry of a rendered image. For example, the *Profile Connection Space (PCS)* specified by the *International Color Consortium (ICC)* is defined to be an encoding of the color that is desired for a *rendered image* viewed in a reference viewing environment.[2,3]

Proposed Color Encodings

The *ROMM RGB* color encoding has been proposed in the "Reference Output Medium Metric RGB Color Space (*ROMM RGB*) White Paper," a prior Eastman Kodak Company publication.[1] The *ROMM RGB* color encoding is intended for manipulation of images that exist in a *rendered image state*. *ROMM RGB* was chosen to provide a large enough color gamut to encompass most common output devices, and is defined in a way that is tightly linked to the ICC profile connection space (PCS).

An associated Reference Input Medium Metric RGB Color Encoding (*RIMM RGB*) is herein provided as an example unrendered (scene) color encoding. *RIMM RGB* is defined simply by a matrix relating scene/image *CIE XYZ* tristimulus values to linear RGB values, together with a specified non-linear encoding. The matrix is uniquely defined by the chromaticities of the primaries and the white point for equal RGB values. The *RIMM RGB* primaries are chosen to be the same as the *ROMM RGB* primaries, to simplify the relationship between these companion color encodings. (Refer to the "Reference Output Medium Metric RGB Color Space (*ROMM RGB*) White Paper" for a discussion regarding the primary selection.) Since the two color encodings use the same primaries, it is generally possible to transform from a *RIMM RGB* unrendered image representation to a *ROMM RGB* rendered image representation using a set of simple one-dimensional LUTs.

II. Definition of *RIMM RGB* Color Encoding

Scene color appearance

The *RIMM RGB* color encoding is intended to be an encoding of the scene color appearance. Since color appearance is very much a function of the viewing conditions, the color appearance associated with a particular scene color value can only be known when the conditions under which it is viewed are specified. Therefore, in order to unambiguously encode the color appearance, the scene color values must be standardized to CIE colorimetry as viewed within a particular reference scene viewing environment. This does not imply that the images need to be captured in that reference environment, but rather that the *RIMM RGB* color values associated with an image should correspond to color stimuli having the desired color appearance in that reference viewing environment.

The reference scene viewing conditions used to encode the scene color values are typical of outdoor environments, and are defined as follows:

- The scene luminance level is >1,600 cd/m^2.
- The viewing surround is average. In other words, the overall luminance level and chrominance of the surround is assumed to be similar to that of the scene.
- There is no viewing flare for the scene.
- The adaptive white-point is specified by a chromaticity value of x = 0.3457 and y = 0.3585. (Although this is the chromaticity associated with the D50 illuminant, this does not imply that this particular illuminant must be used. This

specification simply implies that an object having this chromaticity will appear to be neutral to an observer adapted to the reference viewing environment.)
- The scene color values are encoded using flareless (or flare corrected) colorimetric measurements based on the CIE 1931 Standard Colorimetric Observer.

Scene color encoding

In addition to the issue of specifying the reference viewing environment associated with the scene color values, it is also necessary to define an appropriate color encoding method. For *RIMM RGB*, the color values are encoded with respect to the primaries of a "reference input medium".

The reference input medium is defined to be a hypothetical additive color device having the following characteristics:

- Reference primaries defined by the CIE chromaticity values given in Table 1.
- Equal amounts of the reference primaries produce a neutral with the chromaticity of D50.
- The capability of producing a black with L* = 0.
- No cross-talk among the color channels (i.e., red output is affected only by red input, green output is affected only by green input, and blue output is affected only by blue input).

Table 1. Primaries/white point for reference input medium

color	*x*	*y*
Red	0.7347	0.2653
Green	0.1596	0.8404
Blue	0.0366	0.0001
White	0.3457	0.3585

II.A. *RIMM RGB* Conversion Matrix

Given the defining primaries and white point shown in Table 1, the following matrix can be derived to compute linear Reference Input Medium Metric values (*linear RIMM RGB*) from the scene tristimulus values:

$$\begin{bmatrix} R_{RIMM} \\ G_{RIMM} \\ B_{RIMM} \end{bmatrix} = \begin{bmatrix} 1.3460 & -0.2556 & -0.0511 \\ -0.5446 & 1.5082 & 0.0205 \\ 0.0000 & 0.0000 & 1.2123 \end{bmatrix} \begin{bmatrix} X_{D50} \\ Y_{D50} \\ Z_{D50} \end{bmatrix} . \quad (1)$$

As required by the definition of the Reference Input Medium, scene tristimulus values with the chromaticity of D50 will map to equal *RIMM RGB* values. It should be noted that the XYZ_{D50} tristimulus values should be normalized so that the Y_{D50} value for a 100% perfect white diffuser would equal 1.0. (Corresponding to *absolute colorimetry*.) If the tristimulus values are normalized differently, they should be scaled before applying Eq. (1). For example, if color-matching functions having an area normalized to 100 are used to compute the tristimulus values, the tristimulus values would need to be scaled down by a factor of 100.

II.B. Nonlinear Encoding for *RIMM RGB*

A nonlinear quantization scheme must be specified in order to store the *RIMM RGB* values in an integer form. The *RIMM RGB* nonlinearity is based on that specified by Recommendation ITU-R BT.709 (Rec. 709).[4] (This recommendation was formerly known as CCIR 709.) This is the same nonlinearity used in the *PhotoYCC* Color Space encoding implemented in the *Kodak Photo CD* System:

$$X'_{RIMM} = \begin{cases} 0; & X_{RIMM} < 0.0 \\ \left(\dfrac{I_{max}}{V_{clip}}\right) 4.5\, X_{RIMM}; & 0.0 \le X_{RIMM} < 0.018 \\ \left(\dfrac{I_{max}}{V_{clip}}\right)\left(1.099\, X_{RIMM}^{0.45} - 0.099\right); & 0.018 \le X_{RIMM} < E_{clip} \\ I_{max} & X_{RIMM} \ge E_{clip} \end{cases}, \qquad (2)$$

where X is either R, G, or B; I_{max} is the maximum integer value used for the nonlinear encoding; E_{clip} is the exposure level that is mapped to I_{max}; and

$$V_{clip} = 1.099 E_{clip}^{0.45} - 0.099 \quad . \qquad (3)$$

For the baseline 8-bit *RIMM RGB* configuration, I_{max} is 255 and E_{clip} is 2.00, which corresponds to the maximum exposure level associated with 8-bit/channel encoding in the *PhotoYCC* Color Space. In this case, the corresponding value of V_{clip} would be 1.402. In some applications, it may be desirable to use a higher bit precision version of *RIMM RGB* to minimize any quantization errors. A 12- and a 16-bit version of *RIMM RGB* are also defined. The only difference is that the value of I_{max} is set to 4095 or 65535, respectively. In cases in which it is necessary to identify a specific precision level, the notation *RIMM8 RGB*, *RIMM12 RGB* and *RIMM16 RGB* is used.

II.C. Inverse Encoding for *RIMM RGB*

It is frequently necessary to convert from *RIMM RGB* back to the corresponding scene colorimetry. To do this, it is simply necessary to invert the nonlinear encoding given in Eq. (2) and apply the inverse of the matrix transformation given in Eq. (1). The inverse nonlinear encoding is given by

$$X_{RIMM} = \begin{cases} \left(\dfrac{V_{clip}}{I_{max}}\right)\left(\dfrac{X'_{RIMM}}{4.5}\right) & 0 \le X'_{RIMM} < 0.081\left(\dfrac{I_{max}}{V_{clip}}\right) \\ \left(\dfrac{\left(\dfrac{V_{clip}}{I_{max}}\right) X'_{RIMM} + 0.099}{1.099}\right)^{1/0.45}; & 0.081\left(\dfrac{I_{max}}{V_{clip}}\right) \le X'_{RIMM} < I_{max} \end{cases}, \qquad (4)$$

and the inverse matrix is given by

$$\begin{bmatrix} X_{D50} \\ Y_{D50} \\ Z_{D50} \end{bmatrix} = \begin{bmatrix} 0.7977 & 0.1352 & 0.0313 \\ 0.2880 & 0.7119 & 0.0001 \\ 0.0000 & 0.0000 & 0.8249 \end{bmatrix} \begin{bmatrix} R_{RIMM} \\ G_{RIMM} \\ B_{RIMM} \end{bmatrix} . \tag{5}$$

III. Conclusions

A pair of color encodings known as *Reference Input Medium Metric RGB (RIMM RGB)* and *Reference Output Medium Metric RGB (ROMM RGB)* have been defined. These color encodings are intended to be used for performing image manipulations on images that exist in the *unrendered* (*scene)* and *rendered image states*. Examples of manipulations that might be applied in these color encodings include scene balance algorithms, manual color/density/contrast/tonescale adjustments, and red-eye correction. Because the same set of primaries is used for both of these color encodings, it is expected that the development of algorithms for both color encodings will be greatly simplified. Alternative precision levels of 8-bit, 12-bit and 16-bit for both color encodings are defined.

References

1. Eastman Kodak Company, “Reference Output Medium Metric RGB Color Space (ROMM RGB) White Paper,” Version 2.2 (1999).
2. S. Gregory, R. Poe and D. Walker, “Communicating color appearance with the ICC profile format,” in *IS&T and SID’s 2nd Color Imaging Conference: Color Science, Systems and Applications*, 170-174 (1994).
3. “Interpretation of the PCS,” appendix to “Kodak ICC Profile for CMYK (SWOP) Input,” ANSI CGATS/SC6 N 254, June 3, 1998.
4. “Basic parameter values for the HDTV standard for the studio and for international programme exchange,” Recommendation ITU-R BT.709 (formerly CCIR Recommendation 709).