

Image States and Standard Color Encodings *(RIMM/ROMM RGB)*

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Abstract

Images can be broadly categorized into two types of image states: *unrendered* and *rendered*. Images in an unrendered image state are directly related to the colorimetry of a real or hypothetical original scene. Images in a rendered image state are representations of the colorimetry of an output image, such as a print or a CRT display. Over the years, many device-dependent, and device-independent color encodings have been used to represent images in both of these image states. This has resulted in a host of interoperability problems between various systems. There would be a significant advantage to standardizing on a small number of color encodings for the purposes of storage, interchange, and manipulation of digital images. While the recently agreed upon *sRGB* color encoding is one important piece of this puzzle, there is also a need to define standard color encodings that are not limited by the color gamut of any specific device. This paper will describe a family of new color encodings that have been developed to address this need. A new color encoding specification known as Reference Output Medium Metric RGB (*ROMM RGB*) is defined for representing rendered images, and a companion color encoding specification, known as Reference Input Medium Metric RGB (*RIMM RGB*), is defined for representing unrendered scene image data. These color encodings are both based on the same additive color space, which is defined by a set of imaginary primaries.

Introduction

Digital images are often encoded in terms of color spaces that are tied directly to the characteristics of actual input or output devices. Common examples of such color spaces are scanner RGB, video RGB, and printer CMY(K). However, such spaces generally are *device-dependent* in that their values can be associated with specific colorimetric values only in the context of the characteristics of the particular device on which the image is displayed or captured.

On the other hand, device-independent color spaces are generally meant to represent colorimetric values directly. Most often, these color spaces are based on the system of colorimetry developed by the Commission International de l'Eclairage (CIE). Examples of such color spaces include CIE XYZ and CIELAB. It should be noted that the specification of a color value in a device-independent (or device-dependent) color space does not fully specify color appearance unless the viewing conditions also are known. For example, two patches with identical colorimetric values can have very different color appearance, depending on the conditions under which they are viewed. Thus, the specification of image colorimetry alone does not unambiguously communicate the desired color appearance. It is also necessary to specify the viewing environment in which the image is intended to be viewed.

The fact that images exist in many different color spaces significantly complicates the development of software applications that use and manipulate images. For example, an image-processing algorithm that works in one color space might not have the expected behavior when used in another color space. This has led many people to advocate the use of a standard color encoding (or perhaps a small number of standard color encodings) for the storage, interchange, and manipulation of digital images. Often, these proposals have involved specifying a particular output-device-dependent color space to be a "standard." Examples of such color spaces include *SWOP CMYK*[1] and *sRGB*.[2]

One significant problem with specifying an output-device-dependent color space as the standard is that typically it will limit the encodable color gamut and luminance dynamic range of images according to the capabilities of that specific output device. For example, hardcopy media and CRT displays typically have very different color gamuts. Therefore, using *sRGB* (which is based on a particular CRT model) as a standard color encoding would necessarily involve clipping many colors that could have been produced on a given hardcopy medium.

The International Color Consortium (ICC)[3] has defined a Profile Connection Space (PCS) that comprises a device-independent color encoding specification that can be used to explicitly specify the color of an image with respect to a reference viewing environment. Device profiles can be used in a color management system to relate the device-dependent code values of input images to the corresponding color values in the PCS, and from there to the device-dependent output color values appropriate for a specific output device. It could be argued that the PCS could serve as the standard color encoding we are looking for. However, it was never intended that the PCS be used to directly store or manipulate images. Rather, it was simply intended to be a color space where profiles could be joined to form complete input-to-output color transforms. Neither the CIELAB nor the XYZ color encodings supported for the PCS is particularly well suited for many common kinds of image manipulations. Additionally, quantization errors that would be introduced by encoding images in PCS would be significantly larger than necessary because a large percentage of the code values correspond to unrealizable colors. It is therefore desirable to define standard large-gamut color encodings that can be used for storing, interchanging, and manipulating color images. This paper will describe a new color space known as Reference Output Medium Metric RGB (ROMM RGB). This color encoding is tightly coupled to the ICC PCS and is intended to be used for encoding rendered output images in a device-independent fashion.

Rendered output images should be distinguished from images that are intended to be an encoding of the colors of an original scene. It is well known that the colorimetry of a pleasing rendered image generally does not match the colorimetry of the corresponding scene. Among other things, the tone/color reproduction process that "renders" the colors of a scene to the desired colors of the rendered image must compensate for differences between the scene and rendered image viewing conditions.[4,5] For example, rendered images generally are viewed at luminance levels much lower than those of typical outdoor scenes. As a consequence, an increase in the overall contrast of the rendered image usually is required in order to compensate for perceived losses in reproduced luminance and chrominance. Additional contrast increases in the shadow regions of the image also are needed to compensate for viewing flare associated with rendered-image viewing conditions.

In addition, psychological factors such as color memory and color preference must be considered in image rendering. For example, observers generally remember colors as being of higher purity than they really were, and they typically prefer skies and grass to be more colorful than they were in the original scene. The tone/color reproduction aims of well-designed imaging systems will account for such factors.

Finally, the tone/color reproduction process also must account for the fact that the dynamic range of a rendered image usually is substantially less than that of an original scene. It is therefore necessary to discard and/or compress some of the highlight and shadow information of the scene to fit within the dynamic range of the rendered image.

Because the colorimetry of scenes and their corresponding rendered images are intentionally and necessarily different, it would be ambiguous to try to represent images in both image states using the same color encoding. For example, if someone were to send the CIELAB values for a particular image with no information about whether the color values were scene color values or rendered image color values, the recipient would not know what to do with the image in order to make a print. If the color values were rendered color values, it would simply be necessary to determine the device code values needed to produce the specified color appearance in the output-viewing environment. However, if the color values corresponded to original scene color values, it would be necessary to modify the image colorimetry by applying the appropriate tone/color reproduction aims before printing the image.

Due to these and other factors, color encodings such as sRGB or ROMM RGB that are intended for encoding rendered output images are inappropriate for use in encoding original-scene images. Rather, a color encoding that is directly related to the color of an original scene should be used. Accordingly, a companion to the ROMM RGB color encoding specification, known as Reference Input Medium Metric (RIMM RGB), has also been defined. This encoding is intended to represent original scene color appearance. The RIMM RGB color encoding not only provides extra dynamic range necessary for the encoding of scene information, it is specifically defined to be an encoding of images in a scene image state.

A diagram illustrating how these standard color encodings can be used as the basis for a general imaging system architecture is shown in Fig. 1. RIMM RGB is ideal for the manipulation, storage, and interchange of images from sources such as digital cameras that naturally capture scene-referred image data. Likewise, ROMM RGB serves a similar purpose for images from sources such as print scanners and other devices that produce images in a rendered output-referred image state.

A color negative scanner can be used to produce either scene-state or rendered-state images. The wide dynamic range of color negative film makes it an ideal source of scene-referred image data. It is also possible to produce rendered image data from color negative film by determining the color of a print that could be made from the negative.

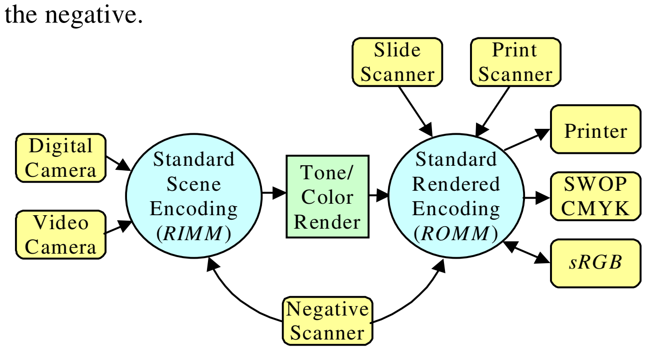

Figure 1. Image state diagram showing standard color encodings.

Before sending images to an output device, such as a printer, it generally will be necessary to convert scene-state images to rendered-state images using a tone/color rendering operation. However, in the same way that a negative is much more flexible than a print, an image in a scene-state will be much more flexible than one in a rendered-state. Therefore, it will be desirable in many imaging systems to delay any conversion to a rendered-state until the time when an output image is generated. For example, consider the case where a color negative contains a scene with a brightly-lit background, and a dimly lit foreground. The negative generally will contain information in both of these regions, and that information can be used to make a print that is properly exposed for either one region or the other. In order to make a rendered-state image from this negative, it is necessary to make a choice about which part of the image is important. (In a conventional photographic system, this is done when the negative is printed optically.) However, scene-state images can retain all of the information on the negative, which allows the delay of any decision as to how the scene is to be rendered. This retains the maximum amount of flexibility in the system.

Selection of Color Space

It is desirable that the *RIMM RGB* and *ROMM RGB* color encoding specifications be defined such that they are as similar as possible to one another. Doing so simplifies the development of image-manipulation algorithms across the two color encodings. It also simplifies the rendering process in which a rendered *ROMM RGB* image is created from an original scene image encoded in *RIMM RGB*. This is best achieved by basing the two encodings on the same color space. The criteria that were used to select this color space include the following:

- Direct relationship to the color appearance of the scene/image
- Color gamut large enough to encompass most real-world surface colors
- Efficient encoding of the color information to minimize quantization artifacts
- Simple transformation to/from ICC PCS
- Simple transformation to/from video RGB (e.g., *sRGB*)
- Well-suited for application of common image manipulations such as tone scale modifications, color-balance adjustments, sharpening, etc.
- Compatible with established imaging workflows

An additive RGB color space with an appropriately selected set of "big RGB" primaries is ideal for satisfying all of these criteria. When images are encoded using any such set of primaries, there is a direct and simple relationship to scene/image colorimetry because the primaries are linear transformations of the CIE XYZ primaries. Big RGB color spaces have the additional advantage that simple LUT-matrix-LUT transformations can be used to convert to/from additive color spaces such as PCS XYZ, video RGB (sRGB), and digital camera RGB.

Two of the criteria that affect the selection of particular RGB primaries are somewhat conflicting. First, their chromaticities should define a color gamut sufficiently large to encompass colors likely to be found in real scenes/images. At the same time, their use should result in efficient digital encodings that minimize quantization errors.

Increasing the gamut to encompass more colors can only be achieved by trading off against correspondingly larger quantization errors. If the chromaticities of the primaries are chosen to include the maximum possible color gamut (for example, choosing the XYZ primaries would encompass the entire spectrum locus), a significant fraction of the color space would correspond to imaginary colors and to colors that would not be commonly encountered in real images. Therefore, in any encoding using such a color space, there would be large numbers of "wasted" code value combinations that would never be used in practice. This would lead to larger quantization errors in the usable part of the color space than would be obtained with different primaries defining a smaller chromaticity gamut. It is therefore desirable to choose primaries with a gamut that is "big enough" but not "too big."

Figure 2 shows the primaries selected for RIMM/ROMM RGB. These primaries encompass the gamut of real world surface colors, without devoting a lot of space to non-realizable colors outside the spectrum locus. Also shown for comparison are the sRGB primaries. It can be seen that the area defined by the sRGB chromaticity boundaries is inadequate to cover significant portions of the real world surface color gamut. In particular, it excludes many important high-chroma colors near the yellow-to-red boundary of the spectrum locus.

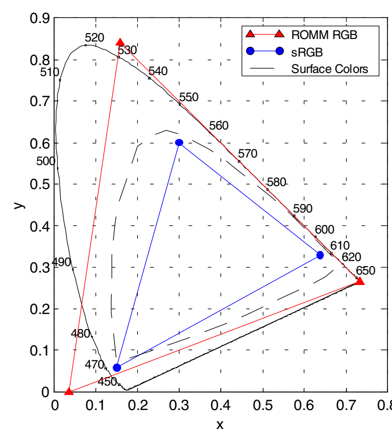

Figure 2. Comparison of primaries in x-y chromaticity coordinates

Another important requirement for the RIMM and ROMM RGB color encodings is that they be well suited for application of common image manipulations. Many types of common image manipulations include the step of applying nonlinear transformations to each of the channels of an RGB image (e.g., tone scale modifications, color balance adjustments, etc.). The process of forming a rendered image from a scene is one important application of this type. One way to accomplish the rendering operation is by means of applying a nonlinear tone scale transformation to the individual channels of an RGB image in a scene image state. A well-designed transformation of this type will produce several desirable characteristics:

- Increasing luminance and color contrast in mid-tones and compressing contrast of highlights and shadows.
- Increasing the chroma of in-gamut colors.
- Gamut mapping out-of-gamut colors in a simple but visually pleasing way.

If an input scene is represented using the *RIMM RGB* color encoding, the result of applying such rendering transforms will be a rendered image in the *ROMM RGB* color encoding.

Nonlinear channel-independent transforms will, in general, modify the relative ratios of the red, green, and blue channel data. This can lead to hue shifts, particularly for high chroma colors. Hue shifts are particularly problematic when they occur in a natural chroma gradient, having constant hue and saturation, within an image. Such gradients tend to occur when rounded surfaces are illuminated by a moderately directional light source. In such situations, chroma increases with distance from the specular highlight and then decreases again as the shadows deepen.

Such hue shifts can never be completely eliminated, so the objective when optimizing the location of the primaries was to eliminate or minimize objectionable hue shifts at the expense of less noticeable or less likely hue shifts. Hue shifts for a particular color can be eliminated when the color lies on one of the straight lines passing through the primaries and the white point on a chromaticity diagram.

Hue shifts introduced by the application of nonlinear transformations were studied using a chroma series for eight color patches from the Macbeth Color Checker™. These patches included red, yellow, green, cyan, blue, magenta, light flesh, and dark flesh. Hue shifts in flesh tones and yellows, particularly in the direction of green, are considered to be the most objectionable. These hue shifts are most strongly affected by the location of the blue primary. Other colors that were considered to be particularly important during the optimization process were blues and reds.

There is a tradeoff between the color gamut of the primaries, quantization artifacts, and the extent of the hue shifts that occur during rendering. If the primaries are moved out to increase the color gamut, quantization artifacts will increase, and the hue shifts introduced during the application of a nonlinear transformation generally will decrease. This results from the fact that the RGB values will be clustered over a smaller range, thereby reducing the impact of nonlinear transformations. If the color gamut is decreased by moving the primaries closer together, quantization artifacts diminish but hue shifts are generally larger and color gamut is sacrificed.

Finally, a basic requirement for any commercially useful color encoding is that it be compatible with typical commercial imaging workflows. In many cases, Adobe Photoshop software is an important component in such imaging chains. Conveniently, the latest version of Adobe Photoshop software has incorporated the concept of a "working color space," which is different from the monitor preview color space. This is very consistent with the notion of storing/manipulating images in a "big RGB" color space. Adobe has placed a constraint on the definition of valid working color spaces that requires the primaries to have all positive x-y-z chromaticity values. This condition is satisfied for the ROMM RGB primaries.† (Since the Photoshop software operates within a rendered-image paradigm, it is inappropriate to use RIMM RGB as a Photoshop software working color space.)

During the selection of the RIMM/ROMM RGB primaries, an extensive optimization process was used to determine the best overall solution to satisfy all of these criteria. The hue shifts associated with the selected RIMM/ROMM RGB primaries are shown in Fig. 3. This plot shows a series of line segments connecting the a*, b* values before and after a nonlinear tone scale was applied to a chroma series in each of the eight color directions. It can be seen that only relatively small hue shifts are introduced for the highest chroma colors in the blue and cyan directions, and the hue shifts elsewhere are virtually negligible. Overall, these hue shifts are very small compared to those associated with many other sets of primaries.

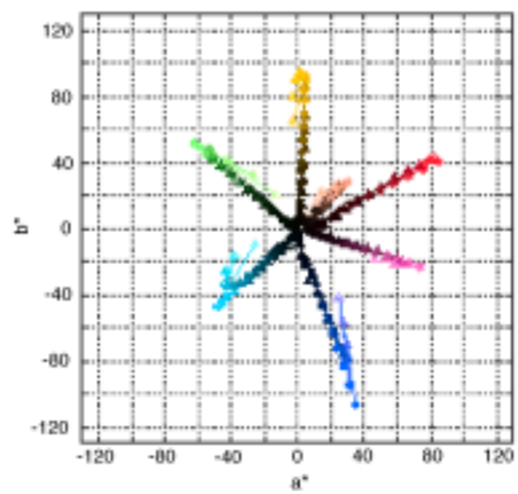

Figure 3. Hue shifts for the RIMM/ROMM RGB color encoding resulting from a typical nonlinear rendering transform. The hue shifts for the most important colors are virtually negligible.

Definition of *ROMM RGB*

In addition to defining a color space, it is also necessary to specify an intended viewing environment in order to unambiguously define an encoding of color-appearance. One of the requirements for *ROMM RGB* is that it be tightly coupled to the ICC Profile Connection Space (PCS).

† For more information about using *ROMM RGB* as a Photoshop software working space, see the white paper posted at www.Kodak.com (search on "ROMM").

Color values in the PCS represent the CIE colorimetry of a defined reference medium that will produce the desired color appearance when viewed in a reference viewing environment. The reference viewing environment for ROMM RGB was based on that defined in the latest ICC draft specification,[6] and is defined to have the following characteristics:

- Luminance level for observer adaptive white is 160 cd/m^2.
- The observer adaptive white point has the chromaticity values of CIE Standard Illuminant D_{50} ($x = 0.3457$, $y = 0.3585$).
- 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 0.75% viewing flare, referenced to the observer adaptive white.
- The image color values are assumed to be encoded using flareless (or flare corrected) colorimetric measurements based on the CIE 1931 Standard Colorimetric Observer.

The *ROMM RGB* color encoding is defined in the context of a reference imaging medium associated with a hypothetical additive color device having the following characteristics:

- Reference primaries defined by the CIE chromaticities given in Table 1.
- Equal amounts of the reference primaries produce a neutral with the chromaticity of D_{50}. ($x = 0.3457$, $y = 0.3585$)
- The capability of producing a white with a luminance factor of F_W = 0.89, and a black with a luminance factor of F_K = 0.0030911

Table 1. Primaries/white point for reference imaging medium.

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

The conversion of the PCS XYZ tristimulus values to ROMM RGB values can be performed by a matrix operation, followed by a set of 1-D functions. This is equivalent to the operations associated with a basic CRT profile. This means that ROMM RGB can be used conveniently in a system employing ICC profiles using an appropriately designed monitor profile.

Most current implementations of the ICC PCS incorporate the concept of a reference medium where the black point of the reference medium is mapped to YPCS = 0, and the white point of the reference medium is mapped to YPCS = 1.0.[7] Therefore, to relate actual CIE image colorimetry to PCS XYZ values, an appropriate normalizing transformation is required:

$$
\begin{aligned}
X_{PCS} &= \frac{(X - X_K)}{(X_W - X_K)} \frac{X_W}{Y_W} \\
Y_{PCS} &= \frac{(Y - Y_K)}{(Y_W - Y_K)} \quad , \\
Z_{PCS} &= \frac{(Z - Z_K)}{(Z_W - Z_K)} \frac{Z_W}{Y_W}
\end{aligned}
\tag{1}
$$

where X, Y and Z are the CIE image tristimulus values, X_{PCS}, Y_{PCS} and Z_{PCS} are the PCS tristimulus values, X_W , Y_W and Z_W are the tristimulus value of the reference medium white point ($X_W = F_W X_0 = 85.81$, $Y_W = F_W Y_0 = 89.00$ and $Z_W = F_W Z_0 = 73.42$, where $X_0 = 96.42$, $Y_0 = 100.00$ and $Z_0 = 82.49$), and X_K , Y_K and Z_K are the tristimulus value of the reference medium black point ($X_K = F_K X_0 = 0.2980$, $Y_K = F_K Y_0 = 0.3091$ and $Z_K = F_K Z_0 = 0.2550$)

ROMM RGB Conversion Matrix

Given the defined primaries shown in Table 1, the following matrix can be derived to compute the linear ROMM RGB values from the PCS image tristimulus values:

$$
\begin{bmatrix} R_{ROMM} \\ G_{ROMM} \\ B_{ROMM} \end{bmatrix} = \begin{bmatrix} 1.3460 & -0.2556 & -0.0511 \\ -0.5446 & 1.5082 & 0.0205 \\ 0.0000 & 0.0000 & 1.2123 \end{bmatrix} \begin{bmatrix} X_{PCS} \\ Y_{PCS} \\ Z_{PCS} \end{bmatrix} , \tag{2}
$$

As required by the definition of the *ROMM RGB*, this matrix will map image tristimulus values with the chromaticity of D_{50} to equal *ROMM RGB* values. A neutral with a Y_{PCS} value of 1.0, corresponding to the reference medium white point, will map to linear *ROMM RGB* values of 1.0. Likewise, the reference medium black point will map to linear *ROMM RGB* values of 1.0.

Nonlinear Encoding of *ROMM RGB*

A nonlinear quantization function is used to store the ROMM RGB values in an integer form. A simple gamma function nonlinearity incorporating a slope limit at the dark end of the intensity scale is defined for this purpose:

$$
C'_{ROMM} = \begin{cases} 0; & C_{ROMM} < 0.0 \\ 16\, C_{ROMM}\, I_{\max}; & 0.0 \le C_{ROMM} < E_t \\ (C_{ROMM})^{1/1.8} I_{\max}; & E_t \le C_{ROMM} < 1.0 \\ I_{\max}; & C_{ROMM} \ge 1.0 \end{cases} , \tag{3}
$$

where C is either R, G, or B, $I_{\max}$ is the maximum integer value used for the nonlinear encoding, and

$$
E_t = 16^{1.8/(1-1.8)} = 0.001953 . \tag{4}
$$

For the baseline 8-bit configuration, $I_{\max}$ is equal to 255. The linear segment of the nonlinearity is used to impose a slope limit to minimize reversibility problems because of the infinite slope of the gamma function at the zero point. 12- and 16-bit versions of ROMM RGB are also defined. The only difference is that the value of $I_{\max}$ is set to 4095 or 65535, respectively. In cases where it is necessary to identify a specific precision level, the notation ROMM8 RGB, ROMM12 RGB, and ROMM16 RGB is used.

Definition of *RIMM RGB*

RIMM RGB is a companion color encoding specification to *ROMM RGB* that can be used to encode the colorimetry of an *unrendered scene*. Both encodings utilize the same "big RGB" color space defined by the primaries and white point given in Table 1. The reference viewing conditions used to encode scene color values for *RIMM RGB* are typical of outdoor environments, and are defined as follows:

- Luminance level for observer adaptive white is >1,600 cd/m^2.
- The observer adaptive white point has the chromaticity values of CIE Standard Illuminant D_{50}: $x = 0.3457$, $y = 0.3585$. (In cases where the chromaticity of the observer adaptive white for an actual scene differs from that of the reference conditions, an appropriate chromatic adaptation transformation must be applied to the image data.)
- 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 other than that already included in the scene colorimetric values.
- The scene color values are assumed to be encoded using flareless (or flare corrected) colorimetric measurements based on the CIE 1931 Standard Colorimetric Observer.

RIMM RGB Conversion Matrix

Since ROMM RGB and RIMM RGB use a common color space, the conversion from the scene tristimulus values to the corresponding linear RIMM RGB values can be accomplished using the same conversion matrix that was given in Eq. (2), except that the input tristimulus values are the scene XYZ values rather than the PCS XYZ values.

$$\begin{bmatrix} R_{RIMM} \\ G_{RIMM} \\ B_{RIMM} \end{bmatrix} = \begin{bmatrix} 1.3460 & -0.2556 & -0.0511 \\ -0.5446 & 1.5082 & 0.0205 \\ 0.0000 & 0.0000 & 1.2123 \end{bmatrix} \begin{bmatrix} X_{D50} \\ Y_{D50} \\ Z_{D50} \end{bmatrix} . \qquad (5)$$

Nonlinear Encoding of *RIMM RGB*

Since the dynamic range of unrendered scenes is generally larger than that of the medium specified for ROMM RGB, a different nonlinear encoding must be used. The RIMM RGB nonlinearity is based on that specified by Recommendation ITU-R BT.709 (Rec. 709).[8] (This recommendation was formerly known as CCIR 709.) This is the same nonlinearity used in the Kodak PhotoYCC Color Interchange Space encoding implemented in the Kodak Photo CD System,[5] and is given by:

$$C'_{RIMM} = \begin{cases} 0; & C_{RIMM} < 0.0 \\ \left(\dfrac{I_{\max}}{V_{clip}}\right) 4.5\, C_{RIMM}; & 0.0 \le C_{RIMM} < 0.018 \\ \left(\dfrac{I_{\max}}{V_{clip}}\right) \left(1.099 C_{RIMM}^{0.45} - 0.099\right); & 0.018 \le C_{RIMM} < E_{clip} \\ I_{\max} & C_{RIMM} \ge E_{clip} \end{cases} , \qquad (6)$$

where C is either R, G, or B; I_{max} is the maximum integer value used for the nonlinear encoding; $E_{clip} = 2.0$ exposure level that is mapped to I_{max}; and

$$V_{clip} = 1.099 E_{clip}^{0.45} - 0.099 = 1.402 \ . \qquad (7)$$

For the baseline 8-bit/channel *RIMM RGB* configuration, I_{max} is 255. In some applications, it may be desirable to use a higher bit precision version of *RIMM RGB* to minimize any quantization errors. 12- and 16-bit/channel versions 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.

ERIMM RGB Color Encoding

The RIMM RGB color space is defined to have a luminance dynamic range that can encode information up to 200% of the exposure value associated with a normally exposed perfect (100%) diffuse white reflector in the scene. This should be adequate for many applications such as digital cameras. However, for some applications, most notably scanned photographic negatives, this luminance dynamic range is insufficient to encode the full range of captured scene information. For these cases, a variation of the RIMM RGB color space is defined, known as Extended Reference Input Medium Metric RGB (ERIMM RGB). For more information on ERIMM RGB, the reader is referred to Ref. 9.

Conclusion

Most images can be classified into one of two different image states: a rendered *output-referred* image state, and a *scene-referred* image state. A family of large-gamut color encoding specifications, based on a "big RGB" color space having optimized color primaries, has been defined for the storage, interchange and manipulation of images in these different image states. *Reference Output Medium Metric RGB (ROMM RGB)* is a large-gamut device-independent color encoding designed to be used for rendered images. It is tightly coupled to the ICC PCS, and it is compatible for use as a Photoshop working color space. *ROMM RGB* is associated with a specified encoding reference viewing environment and imaging medium, thereby enabling unambiguous communication of image color appearance and enhancing interoperability. *Reference Input Medium*

Metric RGB (RIMM RGB) is based on the same color space as *ROMM RGB* and is designed for encoding the color appearance of unrendered scenes. It is associated with a set of encoding reference viewing conditions typical of outdoor scenes. The fact that these color encoding specifications are based on the same big RGB color space facilitates the development of common image-processing algorithms and simplifies the transformations between the different color encodings.

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Biography

Kevin Spaulding received a BS in Imaging Science from Rochester Institute of Technology in 1983, and MS and Ph.D. degrees in Optical Engineering from the University of Rochester in 1988 and 1992, respectively. He has been with Eastman Kodak Company since 1983 where he is currently a Research Associate in the Imaging Science Division, and a member of Kodak's Research Scientific Council. He is also Technical Secretary for the CIE TC8-05 committee, which is tasked with defining standards for the unambiguous communication of color information in images. His research interests include digital color encoding, color reproduction, digital halftoning, image quality metrics, and image processing algorithms for digital camera and printers.