Reference Output Medium Metric RGB Color Space (ROMM RGB) White Paper

Eastman Kodak Company

Abstract

A new color space known as *Reference Output Medium Metric RGB* (*ROMM RGB*) is defined. This color space is intended to be used for performing manipulations on images that exist in a *rendered image state*. This color space was chosen to have 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). Examples of manipulations that might be applied in this color space include scene balance algorithms, manual color/density/contrast/ tone scale adjustments, red-eye correction, and dust/scratch removal. The color space is also appropriate for archiving and/or interchanging rendered images. Both an 8-bit version, as well as a 12-bit version of this color space are defined.

I.   Introduction

In digital imaging systems, most images exist in color spaces that are directly tied to the color of a desired output image. Examples of common color spaces that are used include scanner RGB, video RGB, or CMYK. However, these color spaces are *device dependent* in the sense that the color values are associated with an actual perceived color only in the context of the characteristics of the device where the image is displayed or scanned.

On the other hand, *device-independent color spaces* are designed to describe the color that is perceived by a human observer. These color spaces are generally based on the system developed by the Commission International de líEclairage (CIE). Examples of device-independent color spaces include XYZ tristimulus values, and CIELAB. It should be noted that the specification of a color value in a device-independent color space does not fully specify color appearance unless the viewing conditions are known (i.e., two patches with identical tristimulus values can have very different color appearance depending on the conditions under which they are viewed).

The fact that images exist in many device-dependent color spaces significantly complicates the development of software that uses and manipulates images. For example, an algorithm that works in one color space might not have the expected behavior in another color space. This has led many people to advocate the use of a standard color space for the storage and manipulation of digital images. Generally, these proposals have involved specifying some particular device-dependent color space to be a ìstandard.î Examples of these color spaces include *SWOP CMYK* and *sRGB*.

One significant problem with specifying a particular device-dependent color space to be the ìstandardî color space, is that it will necessarily limit the color gamut and dynamic range of an image to that of the specific output device. For example, most color printers have very different color gamuts than CRT video displays. Therefore, using *sRGB* (which is basically a particular video CRT model) as a standard color space would necessarily involve clipping many colors that could be produced on the final output printer to the CRT gamut.

The International Color Consortium (ICC) has defined a Profile Connection Space (PCS) that comprises a device-independent color encoding which 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 some 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 space that 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 color transforms. Neither the CIELAB nor the XYZ color encodings supported for the PCS are particularly well-suited for many common kinds of image manipulations.

It is therefore desirable to define a new standard color space that can be used for the storage and/or manipulation of color images. The color space should have a number of characteristics:

1) It should be tightly coupled to the ICC Profile Connection Space
2) The transform to/from PCS should be relatively simple
3) The transform to/from video RGB should be relatively simple
4) The color gamut should be large enough to encompass most common output devices
5) The color space should be appropriate for common image manipulations such as tone scale modifications, sharpening, etc.
6) It should be easily extensible to different bit-precisions

These criteria are all met by the *Reference Output Medium Metric RGB* (*ROMM RGB*) color space that will be described in the next section.

It should be noted that the *ROMM RGB* color space is designed to be used for *rendered output images*. This is evidenced by the fact that it is tightly coupled to the ICC PCS, which implicitly assumes that the image is reflection-print-like, and is viewed in a reflection print viewing environment. Rendered output images should be distinguished from images which are intended to be an encoding of the colorimetry of an *original scene*. Color spaces, such as *ROMM RGB*, which are intended to be used for encoding rendered output images, would be inappropriate for use in encoding original scene images. Rather, a color space that can be directly related to the color of an original scene should be used. The *Kodak PhotoYCC* Color Interchange Space is one example of a color space of this type.

There are a number of fundamental differences between images that are representations of an original scene, and images that are a representation of a rendered image, but the most significant difference is related to the dynamic range of an original scene relative to the dynamic range of a reflection print. A scene color space, such as the *Kodak PhotoYCC* Color Interchange Space, must be able to encode the larger dynamic range associated with scenes. Before converting an image in a scene color space to *ROMM RGB*, it is first necessary to determine the desired rendered output image colorimetry using some sort of tone/color reproduction aims. Note that this process necessarily involves discarding and/or compressing some of the information in the original scene encoding in order to fit the image within the smaller dynamic range of the rendered image encoding. Therefore, it can be seen that it will sometimes be desirable to apply some manipulations to the image before it is converted to a rendered image encoding such as *ROMM RGB*. For example, if an image needs to be darkened, there would be an advantage to performing this operation before converting the image to an

output-rendered representation. This is because much of the highlight information that could be used to darken the image will be lost during the conversion process.

Since one of the requirements for *ROMM RGB* is that it be tightly coupled to the ICC Profile Connection Space (PCS), it is appropriate to review the important features of this space. Color values in the PCS represent the CIE colorimetry of an image, which will produce the desired color appearance when viewed in a reference viewing environment. Eastman Kodak Company has defined a specific viewing environment that can be used to unambiguously define the PCS for the purposes of producing ICC profiles.[1,2] This reproduction viewing environment is defined to have the following characteristics:

ï   Luminance level is in the range of 160-640†cd/m^2.
ï   Viewing surround is average.
ï   There is 0.5-1.0% viewing flare.
ï   The adaptive white point is specified by the chromaticity values for
    D50: x†=†0.3457 and y†=†0.3585.
ï   The image color values are assumed to be encoded using flareless (or flare corrected) colorimetric measurements based on the CIE 1931 Standard Colorimetric Observer.

II.   Definition of *ROMM RGB*

As mentioned above, there were several criteria that were identified for the selection of the rendered image color manipulation space. These criteria are all satisfied by the *Reference Output Medium Metric RGB* (*ROMM RGB*) color space. It is defined by the color values associated with a hypothetical additive color device having the following characteristics:

ï   Reference primaries defined by the CIE chromaticities given in Table 1.
ï   Equal amounts of the reference primaries produce a neutral with the chromaticity of D50.
ï   The capability of producing a black with L*†=†0.
ï   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 output 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 primaries given in Table†1 were selected to provide a color gamut large enough to encompass most common output devices, and additionally to minimize the introduction of hue rotations during tone scale modifications.

Additionally, a quantization scheme must be specified in order to store the *ROMM RGB* values in an integer form. A simple gamma function non-linearity incorporating a slope limit is defined for this purpose. Both 8-bit/channel and 12-bit/channel quantization schemes will be defined.

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 conveniently used in a system employing ICC profiles by utilizing an appropriately designed monitor profile. The details of the conversion from XYZ to *ROMM RGB* will now be described.

II.A. *ROMM RGB* Conversion Matrix

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

$$\begin{bmatrix} R_{ROMM} \\ G_{ROMM} \\ B_{ROMM} \end{bmatrix} = \begin{bmatrix} 1.3460 & -0.2556 & -0.0511 \\ -0.5446 & 1.5082 & 0.0205 \\ 0.0000 & 0.0000 & 1.2123 \end{bmatrix} \begin{bmatrix} X_{PCS} \\ Y_{PCS} \\ Z_{PCS} \end{bmatrix} , \tag{1}$$

where it is assumed that the PCS tristimulus values have been scaled so that the Y_{PCS} value for an idealized reflection paper media will be 1.0. As required by the definition of the Reference Output Medium, image tristimulus values with the chromaticity of D50 will map to equal *ROMM RGB* values. It can easily be shown that a neutral with a Y_{PCS} value of 1.0 will map to linear *ROMM RGB* values of 1.0. Consistent with the Kodak interpretation of the ICC profile connection space, these unity *ROMM RGB* values will therefore correspond to the white point of an idealized reflection paper media.

II.B. Nonlinear Encoding of *ROMM RGB*

The functional form of the *ROMM RGB* nonlinearity is a gamma function with a slope limit imposed at the dark end of the intensity scale:

$$X'_{ROMM} = \begin{cases} 0; & X_{ROMM} < 0.0 \\ 16 \ X_{ROMM} \ I_{max}; & 0.0 \leq X_{ROMM} < E_t \\ \left(X_{ROMM} \right)^{1/1.8} I_{max}; & E_t \leq X_{ROMM} < 1.0 \\ I_{max}; & X_{ROMM} \geq 1.0 \end{cases} , \tag{2}$$

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

$$E_t = 16^{1.8/(1-1.8)} = 0.001953 \quad . \tag{3}$$

For the baseline 8-bit configuration, I_{max} is equal to 255. The slope limit is designed to minimize reversibility problems due to the infinite slope of the gamma function at the zero point.

A 12-bit and a 16-bit version 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. Table 2 shows some sample encodings for a series of neutral

patches of specified relative image intensity, where a relative image intensity of 1.0 corresponds to the white point of the PCS.

Table 2. Sample neutral patch encodings.

Relative Intensity	PCS *L**	*ROMM8 RGB*	*ROMM12 RGB*	*ROMM16 RGB*
0.00	0.00	0	0	0
0.001	0.90	4	66	1049
0.01	8.99	20	317	5074
0.10	37.84	71	1139	18236
0.18	49.50	98	1579	25278
0.35	65.75	142	2285	36574
0.50	76.07	174	2786	44590
0.75	89.39	217	3490	55855
1.00	100.00	255	4095	65535

If *ROMM RGB* images are going to be stored in a file, then the image must be scaled to a bit-depth supported by the file format. In many cases this will limit the image bit-depth to the 8-bit or 16-bit encodings. In particular, for files that are to be read into Adobe Photoshop software it is recommended that the 8-bit or 16-bit encoding options be used since Photoshop software only supports these bit-depths. If it is desired to store a *ROMM12 RGB* image in a file format that does not support 12-bit encoding, it is recommended that the code values first be scaled up by (65535/4095) to convert them to *ROMM16 RGB* values. Alternatively, they could be scaled down by (255/4095) to convert them to *ROM8 RGB* values and stored in an 8-bit file. However, the use of the 8-bit encoding will result in a loss of precision in the image data.

One potential use of the *ROMM RGB* color space is as a working color space for Adobe Photoshop software. However, it should be noted that Adobe Photoshop software currently limits the nonlinearity that can be used to define a valid working space to be a simple gamma function. However, both the Adobe Photoshop software implementation, as well as the Kodak Color Matching Module (CMM) implementation automatically impose a "slope limit" of 16 at the dark end of the tonescale. Although a profile that explicitly incorporates the nonlinearity with the slope limit can not be used by Adobe Photoshop software, a profile using a simple gamma function nonlinearity produces the net effect of Eq. (2) when used by Adobe Photoshop software or the current version of the Kodak CMM. Therefore, to ensure Adobe Photoshop software compatibility, the *ROMM RGB* ICC profile created by Eastman Kodak Company uses a simple gamma function nonlinearity without the slope limit, rather than the form shown in Eq. (2). At some point in the future it may be possible to produce a new ICC profile that explicitly incorporates the slope limit if Adobe were to modify the Photoshop software software to remove this artificial restriction. Although this would not have any effect on the results obtained using Adobe Photoshop software or the Kodak CMM, it would increase the likelihood that equivalent results would be obtained using different CMMs that may or may not include the same slope limiting feature.

III. Inverse of *ROMM RGB* Encoding

It is also necessary to define an inverse transformation to convert *ROMM RGB* values back to rendered image PCS values. This can be accomplished by simply inverting the nonlinear function given in Eq.†(2), and then applying the inverse of the matrix given in Eq. (1).

III.A. Inverse of *ROMM RGB* Nonlinear Encoding

The first step is to undo the nonlinear encoding of the *ROMM RGB* values. This will convert the signals back to linear *ROMM RGB* values.

$$X_{ROMM} = \begin{cases} \dfrac{X'_{ROMM}}{16\ I_{max}}; & 0.0 \leq X'_{ROMM} < 16\ E_t\ I_{max} \\[2em] \left(\dfrac{X'_{ROMM}}{I_{max}}\right)^{1.8}; & 16\ E_t\ I_{max} \leq X'_{ROMM} \leq I_{max} \end{cases}, \tag{4}$$

where X'_{ROM} and X_{ROM} are the nonlinear and linear *ROMM RGB* values, respectively, and as before, X is either R, G, or B.

III.B. Conversion to Profile Connection Space (PCS)

To convert the *ROMM RGB* values to the corresponding D50 PCS tristimulus values, it is simply necessary to multiply by the inverse of the matrix given in Eq.†(1)

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

As expected, when this matrix is applied to linear *ROMM RGB* values that are equal, tristimulus values with the chromaticity of D50 are obtained.

IV.   Conversion Between *ROMM RGB* and *sRGB*

In many cases, it will be necessary to convert *ROMM RGB* values to a video RGB representation for display on a CRT. This can be accomplished by combining the *ROMM RGB* to PCS transformation described above with an appropriate PCS to Video RGB transformation for the CRT. Consider the special case of a CRT that responds according to the *sRGB* specification. Since *sRGB* is defined using a D65 white point, and the PCS is defined using a D50 white point, the first step in the conversion of PCS values to *sRGB* values must be a D50-to-D65 chromatic adaptation:

$$\begin{bmatrix} X_{D65} \\ Y_{D65} \\ Z_{D65} \end{bmatrix} = \begin{bmatrix} 0.9845 & -0.0547 & 0.0678 \\ -0.0060 & 1.0048 & 0.0012 \\ 0.0000 & 0.0000 & 1.3200 \end{bmatrix} \begin{bmatrix} X_{D50} \\ Y_{D50} \\ Z_{D50} \end{bmatrix} = \overline{M}_{A,D50 \rightarrow D65} \begin{bmatrix} X_{D50} \\ Y_{D50} \\ Z_{D50} \end{bmatrix}. \tag{6}$$

The *sRGB* color space is defined using the phosphor primaries associated with Rec.†709. It can be shown that the conversion from D65 tristimulus values to the linear RGB values associated with these primaries is given by the following inverse phosphor matrix:

$$\begin{bmatrix} R_s \\ G_s \\ B_s \end{bmatrix} = \begin{bmatrix} 3.2406 & -1.5372 & -0.4986 \\ -0.9689 & 1.8758 & 0.0415 \\ 0.0557 & -0.2040 & 1.0570 \end{bmatrix} \begin{bmatrix} X_{D65} \\ Y_{D65} \\ Z_{D65} \end{bmatrix} = \overline{M}_P^{-1} \begin{bmatrix} X_{D65} \\ Y_{D65} \\ Z_{D65} \end{bmatrix} \quad . \tag{7}$$

Finally, the desired *sRGB* code values can be computed by applying the appropriate nonlinearity and integerizing:

$$X_s^{'} = \begin{cases} 255\,(12.92\,X_s)\,; & X_s < 0.00304 \\ 255\,(1.055\,X_s^{1/2.4} - 0.055)\,; & X_s \geq 0.00304 \end{cases}, \tag{8}$$

where *X* is either *R*, *G*, or *B*. It should be noted that despite the ì2.4î in the exponent of Eq.†(19), the *effective* ìgammaî value associated with this nonlinearity is actually about 2.2 (where the effective gamma is determined from the slope of the straight-line portion of the log-log curve). This is due to the effect of the offset term in the equation. The *sRGB* nonlinearity is designed to be representative of a typical CRT found on a PC.

Conversion from *ROMM RGB* values to the *sRGB* code values can therefore be accomplished by applying the inverse *ROMM RGB* nonlinearity given in Eq.†(4), followed by the matrices given in Eqs.†(5), (6) and (7), followed by the *sRGB* nonlinearity given in Eq.†(8). The three sequential matrix operations can be combined by cascading the matrices together to form the following single matrix:

$$\begin{bmatrix} R_s \\ G_s \\ B_s \end{bmatrix} = \begin{bmatrix} 2.0564 & -0.7932 & -0.2632 \\ -0.2118 & 1.2490 & -0.0372 \\ -0.0152 & -0.1405 & 1.1556 \end{bmatrix} \begin{bmatrix} R_{ROMM} \\ G_{ROMM} \\ B_{ROMM} \end{bmatrix} \quad . \tag{9}$$

It can be seen that the transformation from *ROMM RGB* to *sRGB* can be implemented with a simple LUT-MAT-LUT chain.

It should be noted that not all colors that can be encoded in *ROMM RGB* will be within the *sRGB* color gamut. As a result, it will be necessary to perform some sort of gamut mapping to clip all of the colors to the appropriate gamut. The simplest form of gamut mapping is just to clip all of the linear *sRGB* values to the range 0.0 to 1.0 before applying the nonlinearity of Eq.†(8). However, this approach can result in noticeable hue shifts in certain cases. As a result, superior results can be obtained using more sophisticated gamut mapping strategies.

The conversion from *sRGB* back to *ROMM RGB* is simply an inverse of the steps that were just discussed. First, the inverse of the *sRGB* nonlinearity given in Eq. (8) is applied to determine the linear RGB_s values,

$$X_s = \begin{cases} \dfrac{(X_s^{'}/255)}{12.92}\,; & X_s^{'} < 10.01 \\[4mm] \left(\dfrac{(X_s^{'}/255) + 0.055}{1.055}\right)^{2.4}; & X_s^{'} \geq 10.01 \end{cases} \quad . \tag{10}$$

Next, the inverse of the matrix in Eq.†(9) is used to compute the linear RGB_{ROM} values,

$$\begin{bmatrix} R_{ROMM} \\ G_{ROMM} \\ B_{ROMM} \end{bmatrix} = \begin{bmatrix} 0.5230 & 0.3468 & 0.1303 \\ 0.0892 & 0.8627 & 0.0481 \\ 0.0177 & 0.1095 & 0.8729 \end{bmatrix} \begin{bmatrix} R_s \\ G_s \\ Bs \end{bmatrix} . \tag{11}$$

Finally, the *ROMM RGB* nonlinearity given in Eq.†(2) is applied to determine the *ROMM RGB* values.

As noted above, there are many colors that can be represented in *ROMM RGB* space that are outside the gamut of *sRGB*. As a result, the process of mapping an image from *ROMM RGB* to *sRGB* and back again is not lossless in general. Therefore, it should be emphasized that, whenever possible, a video RGB color space should not be used as an intermediate color space during the process of manipulating a *ROMM RGB* image. Rather, the image manipulations should be applied to the *ROMM RGB* image directly, and the *ROMM RGB* to *sRGB* transformation should be used to provide an image for video preview purposes only.

On the other hand, if an original image is in a video RGB color space, it should be possible to convert the image to *ROMM RGB* for manipulation purposes, and then convert it back to the video RGB color space again with only minimal losses due to quantization effects. These quantization effects can be reduced to negligible levels by using the 12-bit version of *ROMM RGB*. However, it should be noted that if the manipulation process creates any color values that are outside of the video RGB gamut, that these will be clipped when the processed image is converted back to the original color space.

V.   Conclusions

A new color space known as *Reference Output Medium Metric RGB* (*ROMM RGB*) has been defined. This color space is intended to be used for manipulation and/or interchange of images that exist in a *rendered image* state. Examples of manipulations that might be applied in this color space include manual color/density/contrast/tone scale adjustments, scene balance algorithms, red-eye correction, and dust/scratch removal. Both an 8-bit version as well as a 12-bit version of this color space are defined.

References

1. S. Gregory, R. Poe and D. Walker, ìCommunicating color appearance with the ICC profile format,î in *IS&T and SIDís 2nd Color Imaging Conference: Color Science, Systems and Applications*, 170-174 (1994).

2. "Interpretation of the PCS," appendix to "Kodak ICC Profile for CMYK (SWOP) Input," ANSI CGATS/SC6 N 254, June 3, 1998.

Appendix A: Use of *ROMM RGB* as an *Adobe Photoshop* Software Working Space

Adobe Photoshop V5.0 software offers many new Color Management-related features designed to help professionals produce high quality images more effectively. Two of the more significant new ICC features are ICC Profile Tagging and the decoupling of the monitor definition from RGB editing space (referred to as the "RGB Working Space"). One of the criteria for the definition of *ROMM RGB* was compatibility with usage as an Adobe Photoshop V5.0 software RGB Working Space. This appendix presents guidelines for how *ROMM RGB* can be used for this purpose in practice.

RGB Working Spaces

One of the objectives of the Adobe Photoshop V5.0 software CMS architecture is to allow multiple systems with different monitor spaces to view the same image accurately, without data conversion. To facilitate this, RGB color space editing is now independent from the workstation-specific (device dependent) monitor definition. This capability provides a color managed display image in video RGB while maintaining the ability to store the actual image in the larger color gamut workspace.

The RGB Working Space must be a simple, idealized color space that can be completely defined in terms of a single gamma, white point, and phosphor set. Kodak's provision for compatibility of the *ROMM RGB* with the Photoshop software's RGB Working Space requirements opens up a practical avenue for deployment of *ROMM RGB* as an intermediate processing and transfer space to facilitate ICC production methods. As a result, *ROMM RGB* serves as a convenient storage, edit, archive, and transfer color space for many professional imaging applications.

ICC Profile Tagging

ICC Profile Tagging is the linchpin that will hold together and help automate digital imaging processes in the future. In this scheme, TIFF and EPS images contain a profile that converts from the mode-specific color space to the ICC Profile Connection Space (PCS)—usually LAB. Specifically, *ROMM RGB* images can be tagged with a *ROMM RGB* Working Space profile, and then can be interpreted unambiguously in conforming processes downstream.

The combination of these two features— RGB Working Spaces and ICC Profile Tagging—make device-independent editing methods possible for the first time. Device-independent image editing is highly recommended for sites that plan to store and re-purpose digital image assets. Ultimately, it is anticipated that full-gamut editing will become "coin of the realm" and will continue to gradually displace (or reduce the need for) device-specific RGB and CMYK editing in all but specialty applications.

Creating an RGB Working Space

There are two ways to establish *ROMM RGB* as a working space :

1) Load the Kodak-supplied *ROMM RGB* profile (if available)
2) Enter the corresponding *ROMM RGB* parameters.

When a *ROMM RGB* ICC profile is available, it can be used to define the RGB Working Space in the following manner. First, select the *File>Color Settings>RGB Setup* Menu option:
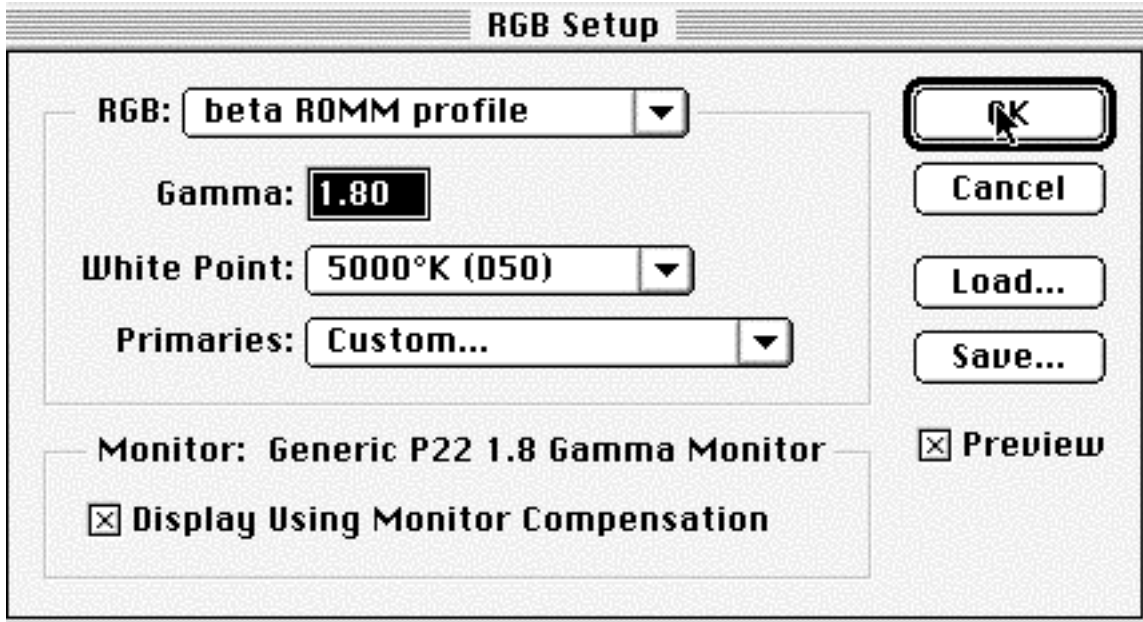

Fig. E1. Dialog box for *File>Color Settings>RGB Setup* Menu option.

To load the supplied *ROMM RGB* profile, simply select the *"Load..."* option. Navigate to the appropriate profiles directory, and select the *ROMM RGB* profile. The Photoshop software then reads the attributes necessary to activate the profile as a Working Space. The default directory for storing ICC profiles will be a function of the operating system:

• Macintosh OS: System>Preferences>ColorSync* Profiles
• Macintosh OS, with Colorsync 2.5 or higher: System>ColorSync* Profiles
• Windows 95, Windows 98: Windows>System>Color
• Windows NT4.x: Winnt>System32>Color

Display Using Monitor Compensation **must be selected when working in *ROMM RGB*. An accurate Monitor Profile is necessary to establish the proper screen display of the *ROMM RGB* image.** Note: the monitor profile is used <u>only</u> for real-time conversion of the RGB Working Space to corrected monitor RGB values for the display sub-system. (Refer to the Photoshop V5.0 software Technical Paper for information on creating Monitor profiles for Mac and Windows Photoshop software use.[†])

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†   See Kodak.com/go/colorflow as of Feb 1999; or email cheinz@ekbos.com prior to Feb 1999

If a *ROMM RGB* ICC profile is not present, it is necessary to enter the *ROMM RGB* parameters via the RGB Setup dialog, as follows:

- Set Gamma to: 1.80
- Set White Point to: 5000K (D50)
- Set custom *x-y* primaries for Red, Green, and Blue to:

color	*x*	*y*
Red	0.7347	0.2653
Green	0.1596	0.8404
Blue	0.0366	0.00010

After these parameters are entered, select "*Save...*" to create an ICC profile, and store the profile in the default profiles directory. This allows plug-ins and other ICC-compatible applications to create and interpret *ROMM RGB* encoded imagery.

Note: saving the *ROMM RGB* profile is also useful if the RGB Working Space is changed from *ROMM RGB*. In this case, *ROMM RGB* can be re-established as the RGB Working Space by choosing "*Load...*" from RGB Setup dialog box, and selecting the *ROMM RGB* profile.
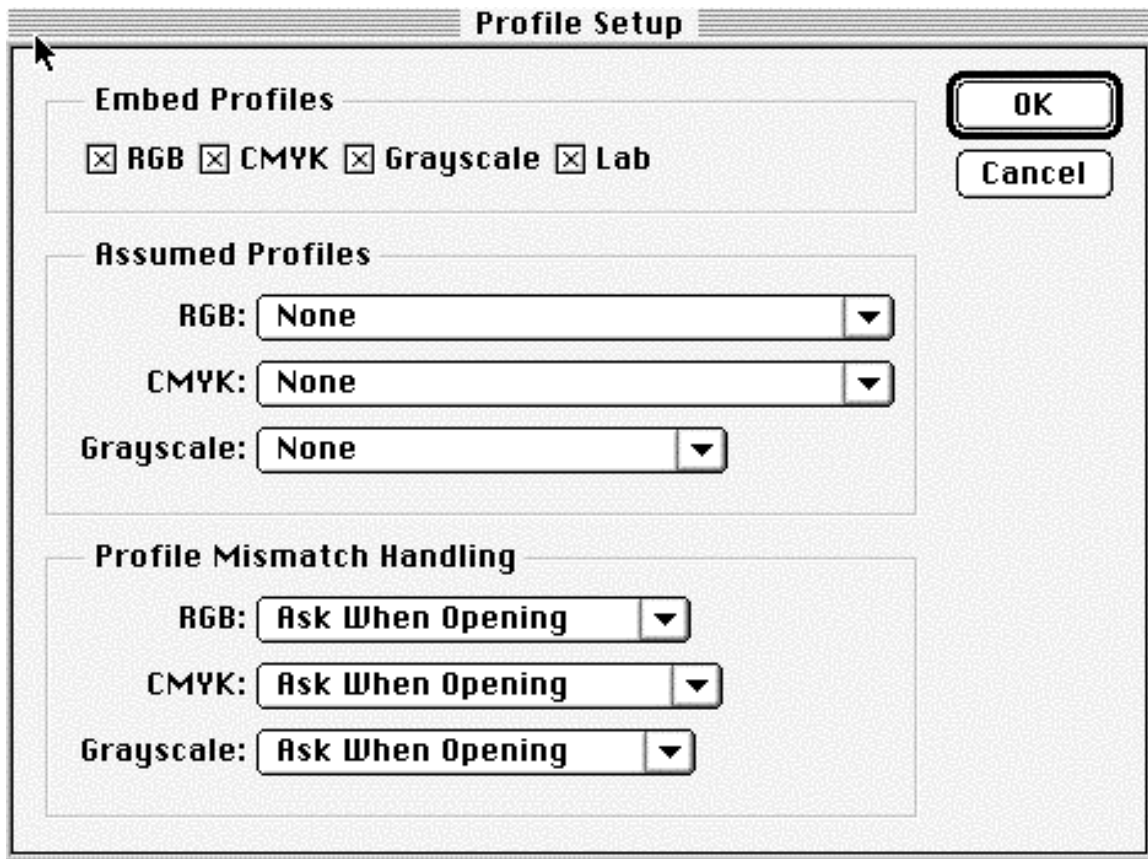

Fig. E2. Dialog box for *File>Color Preferences>Profile Setup* Menu option.

Saving ROMM RGB Images with a Profile Tag

To enable the embedding of RGB profiles in images, choose the "*File>Color Preferences>Profile Setup*" menu option. and select the settings shown in Fig. E2. RGB images must be tagged with the RGB Working Space profile to set up correct use upon re-open. Working in *ROMM RGB*, and tagging with the *ROMM RGB* profile, sets up the most flexible re-use in the future.

Note: profile tagging also allows use of the ICC output conversion process available in applications such as Page Layout, OPI Server, and PS RIP. This is more flexible than converting to an output-specific color space at the capture stage or inside Photoshop software.

Verifying the ROMM RGB Working Space

The following procedure can be used to verify that the *ROMM RGB* Working Space is being used correctly.

• Set the Profile Mismatch handling, in "*File>Color Settings>Profile Setup*" as show in Fig. E2. Setting the Mismatch handling to "*Ask When Opening*" will cause the *Open* command to pause and query the user when the image is tagged differently than the current Working Space.

• For example, open the *Bottles* image that is installed with Adobe V5.0 software, in the *Photoshop application folder>Goodies>Samples*. The *Bottles* image was tagged as *sRGB*. When the *Open* command checks the Working Space and finds *ROMM RGB* (something other than *sRGB*), the user is presented with the following dialog:
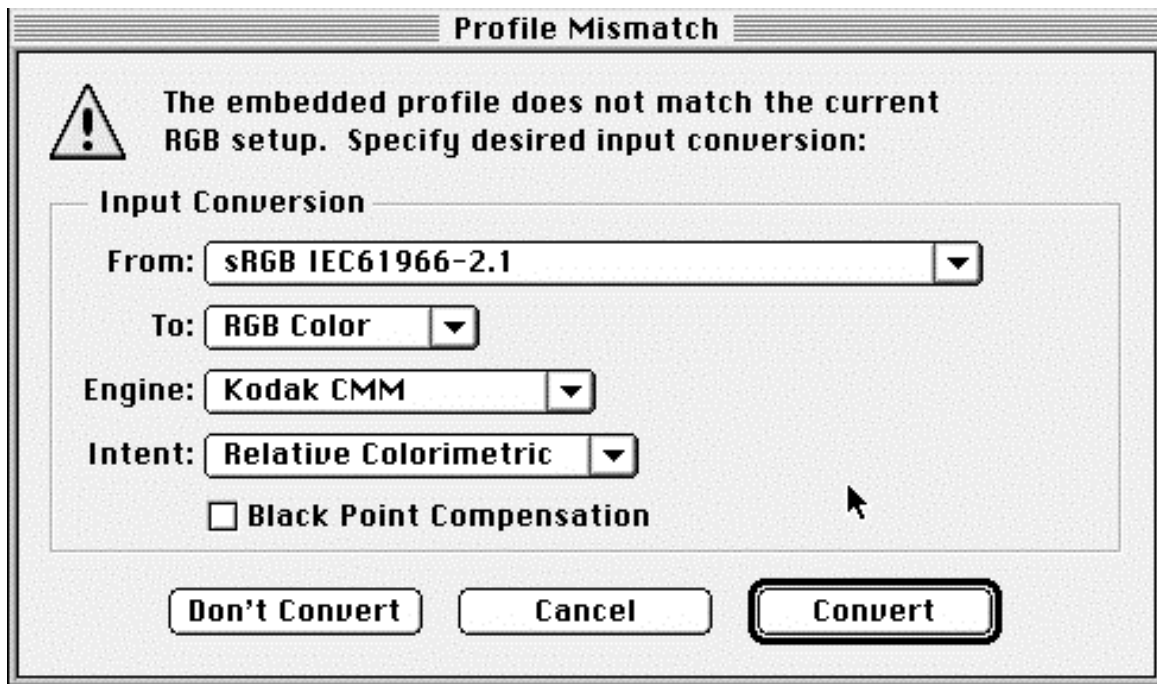

Fig. E3. *Profile Mismatch* Dialog Box.

• *Convert* is the default option and would be the usual selection in order to bring images from various sources into the common RGB Working Space, *ROMM RGB* in this example. (Although Adobe attempted to create a bullet-proof user interface, it is *possible* to work around the Adobe conventions, and either convert improperly or improperly not convert.) Go ahead and select *Convert*.

• *Save* the image as *Bottles.ROMM*. The profile is now tagged to the image.

• *Open* the *Bottles.ROMM* image once more. Now, there should be no *Profile Mismatch* message.

• *Open* the original *Bottles* image again. This time, answer "*Don't Convert*" for testing purposes. The image will contain sRGB data but will display as if it is *ROMM RGB*, so the image will appear over-saturated. Open the *RGB Setup* dialog, and turn off "*Display using Monitor Compensation*" temporarily. The image will appear less saturated (closer to proper display, since sRGB is a monitor definition). Close the dialog.

• Select the *Bottles.ROMM* image. The image will look desaturated relative to the *sRGB* image when "*Display using Monitor Compensation*" is turned OFF.

• Turn on "*Display using Monitor Compensation*" to display the image properly. Notice that the original *Bottles* image is now over-saturated relative to the correctly displayed *Bottles.ROMM* image.

• Close the *Bottles* image without saving it. (If it were saved, the *ROMM RGB* profile would be improperly tagged to the image in place of the *sRGB* tag.)

Troubleshooting Tips:

• If an image looks over-saturated on screen, then it's possible that a monitor-like RGB image was not converted to *ROMM RGB* upon open.

• If an image looks desaturated on screen then "*Display using Monitor Compensation*" might be turned OFF (it should be ON when using *ROMM RGB* as the Working Space).

• If an image looks desaturated on output then the *ROMM RGB* image might not have been converted to the output-specific color space (either within the Photoshop software or via an ICC-aware page layout or output system).

Opening Images and Converting to ROMM RGB *Working Space*

• PHOTO CD Open File Format Plugin

The Kodak ICC PHOTO CD Open file format plug-in is ICC-compatible. The Source is a PhotoCD input profile, while the destination can be LAB, CMYK, monitor RGB, or output RGB.

Direct ICC conversion to a destination device color space is still available and useful within Adobe V5.0 software. However, using the RGB Working Space as a Destination profile is preferred. The procedure is as follows:

1) If you don't already have a *ROMM RGB* ICC profile, create an ICC profile by selecting *Save..* from the *RGB Setup* dialog box.
2) In the Open dialog, select the PHOTO CD input profile as Source profile (as usual). Select the ROMM RGB working space ICC profile as destination.
3) Edit the image if needed
4) Save the image to disk (ROMM RGB Working Space profile is embedded).

• Use of Non-ICC Acquire Modules

Input devices such as Kodak digital cameras and film scanners ship with Acquire plug-ins for the Adobe Photoshop software. These plug-ins are compatible with Adobe V5.0 software, even though they are not ICC-aware. There are a few user techniques that will aid the transition to Photoshop V5.0 software.

The most effective procedure is to convert from the input RGB to the RGB Working Space upon *Open*, by selecting *Image>Mode> Profile to Profile*. Select the custom input profile as the *Source*, and select the RGB Working Space profile as the *Destination*. (It is possible to build an *Action* that can be triggered at the touch of a function key to call the appropriate Action for the given source device.)

An alternative method is to set the custom input profile as the *Assumed Profile* for RGB images. This is convenient because the *Profile Setup* dialog can be set to apply the assumed profile upon open, in cases where the image is not already tagged. With this method, the conversion also utilizes the custom input profile as *Source*, and the RGB Working Space as *Destination*. However, if an image from another source (such as a different scanner, or digital camera) is opened, this image will be (incorrectly) converted. In summary, this approach is fine for single source workstations, but is not recommended for general use.

• Opening Legacy Files

If an RGB image is "origin unknown", the normal procedure is to determine whether it came from a PC or Macintosh platform if possible. If it came from a PC, it is usually reasonable to convert from *sRGB* to the *ROMM RGB* Working Space. If it came from a Macintosh, it is reasonable to convert from *Colormatch* to the *ROMM RGB* Working Space.

If an image was originally stored in a monitor RGB space such as *Colormatch*, there will generally be some saturated colors that were clipped or compressed into the original monitor gamut. Therefore, this method should be considered to be "best efforts" only and is not necessarily optimal. The good news is that nothing will be lost by interchanging in and out of *ROMM RGB* during subsequent conversions.

Legacy CMYK files can also be re-expressed in alternate color spaces if an output profile is available that is representative of the site's output process. (Unfortunately, the result would include some gamut compression from having been stored in CMYK, but this approach can still be useful in many cases.) An *Action* can be established to *Open* a folder of CMYK images, convert from CMYK to *ROMM RGB*, and *Save* each image as a tagged *ROMM RGB* Tiff file.

Opening ROMM RGB Images

In order to exchange image files properly among workstations, all should be set up with the same profile preferences so that *ROMM RGB* images are not converted inadvertently. Specifically, *ROMM RGB* should be set as the Working Space, and profile embedding should be turned on for the saving of an RGB image.

This procedure avoids excessive conversions. If the tag equals the Working Space, no conversion is performed. Aside from converting legacy images to *ROMM RGB* upon *Open*, or converting images acquired from non-ICC devices, there is no reason to convert upon open. In particular, avoid exchanging images with a workstation that is not set to *ROMM RGB* because it will be needlessly converted there to a smaller gamut image – which defeats the purpose of adopting full gamut *ROMM RGB* editing.

ROMM RGB images can be created using an off-line process (e.g., Colorflow Imaging Server), or using another workstation with Photoshop software. The tagging protocol in Imaging Server V1.1 will conform to Adobe Photoshop V5.0 software, so that the Server can be used as a 100% compatible feeder to the Photoshop software.

Editing ROMM RGB Images

RGB mode in Adobe Photoshop V5.0 software offers 16-bit editing. This makes it possible to make a major tone move while in 16 bit mode with minimal artifacts. If the image is originally in an 8-bit image encoding, the 8-bit image can be mode changed to 16-bit in order to apply the Image adjust moves, then dropped back to 8-bit for final adjustments and output. The effect on the image data can be observed by comparing histograms of an image adjusted in 8-bit mode to that of an image adjusted in 16-bit mode.

Edits are possible while viewing the image in full gamut or with respect to output. While viewing and editing in full gamut, edits can be made without regard for the specific output process; this is equivalent to establishing the desired color appearance of the image (in ICC terms).

Alternatively, while viewing in Output Simulation, preferred reproduction characteristics can be imparted to an image that take into account the color gamut available for the chosen output process. Note: When storage and edit of the image in a device space is necessary, it is advisable to archive the device independent image prior to conversion.

ICC Soft Proof Filter

With Photoshop V5.0 software, accurate monitor viewing is finally in place for most image reproduction applications. RGB output simulations are the notable exception. The lack of support for viewing RGB simulations in the Photoshop V5.0 software suggests the use of Kodak ColorFlow ICC *soft proof* filters for certain applications.

Specifically, images that are in *ROMM RGB* but are intended for an RGB Output process (such as Durst Lambda), or images that have already been converted to an Output RGB color space, can be viewed properly with the help of the Soft Proof filter. (Note: ICC Soft Proof is available for Macintosh only; a recent patch provides compatibility with OS 8.5.)

The editing of *ROMM RGB* images is possible in 8-bit or 16-bit depth. Although most filters are not available for use on 16 bit images, ICC Soft Proof is an exception. The Soft Proof filter is a toggle filter that operates on the contents of the graphics display buffer, so it remains active for 16-bit images that are displayed (although it must first be activated while an 8 bit image is displayed).

Printing ROMM RGB Images from Photoshop software

It would be ideal to maintain a single RGB file and convert the data while printing to different output devices. However, in Adobe Photoshop V5.0 software, you lose the flexibility of controlling rendering intent and color matching engine when the ICC conversion is invoked at print time.

Also, the printer color management checkbox doesn't control whether your printer uses color management or not, but only whether PS5 embeds color information describing your RGB work space in the stream of data sent to the print driver. It is unclear whether ICC profiles are being directly stored or whether they are being converted to CRDs, for use with PS Level 2 RIPS or higher. In either case, a non-compliant printer might show no conversion, or supersede it with an arbitrary "printer's default" conversion.

In summary,: conversion at print time is still a risky business, but may be useful for closed-loop systems. Contact your printer vendor to establish the degree of PS5 and ICC/CRD compliance of a particular model.

A tried and true method is to convert the pixels to output device color space via a *Profile to Profile* command. Again, the use of a canned *Action* is suggested. In this case, it is especially important to avoid over-writing the *ROMM RGB* image with transient device data. For example:

1) Select *Profile to Profile* to convert from *ROMM RGB* Working Space to XLS 8650 RGB, and print.
2) Close the image without saving, to maintain the *ROMM RGB* image. Re-open the *ROMM RGB* image if additional output-specific images are needed.

Use of Tagged ROMM RGB images in other applications

If Adobe Photoshop V5.0 software is viewed in isolation, the tagging features are sufficient to allow proper saving and opening of *ROMM RGB* images. A standardized tagging mechanism allows a digital image to be transported to different applications and platforms without ambiguity about its origin. Additional application upgrades will emerge, that recognize and act upon the profile tag properly. Specifically, an ICC tagging compliant application will be able to use the tagged profile as *Source*, while supplying the *Destination* profile (monitor or output for example) to complete the reproduction chain.

In the next 6-12 months there will be very few applications other than the Photoshop software that are fully ICC-compliant, especially with the flavor of tagging introduced in Adobe Photoshop V5.0 software. Therefore, an alternative working space may be useful in conditions where a workstation downstream may not have Adobe Photoshop V5.0 software. If the ultimate user of the image data will NOT be using a color-managed application to convert the data to output-specific data, then the output will generally not be printed properly, and will typically be quite desaturated because of the encoding in the

ROMM RGB Working Space. A Working Space such as Adobe RGB 98 may be more effective under this circumstance (note: V5.02 of the Photoshop software introduced Adobe RGB 98 as an additional Working Space). At minimum, take steps to ensure that the application is compatible with images created with a tagged RGB Working Space.

Bit Depth for ROMM RGB Working Space

An important consideration relative to the "editability" of an image in the ROMM RGB Working Space is the bit depth. RGB Working Spaces in the Photoshop software offer both 8-bit and 16-bit modes. (As discussed above, it is generally recommended that *ROMM12 RGB* images be converted to a 16-bit encoding when stored in a file that is to be read into Adobe Photoshop software.) Where possible, the 16-bit Working Space should be maintained in the Photoshop software for the manipulation of *ROMM16 RGB* images. In some cases it will be desirable to use the 16-bit Working Space option even for the manipulation of *ROMM8 RGB* images. This makes it possible to apply more aggressive image adjustments to an image with the minimal introduction of artifacts. The recommended approach for the most discerning color imaging professional is to make all major color appearance adjustments while in 16-bit *ROMM RGB* Working Space, then only drop back to 8-bit for any final fine tuning and specific "output preparation" adjustments.

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