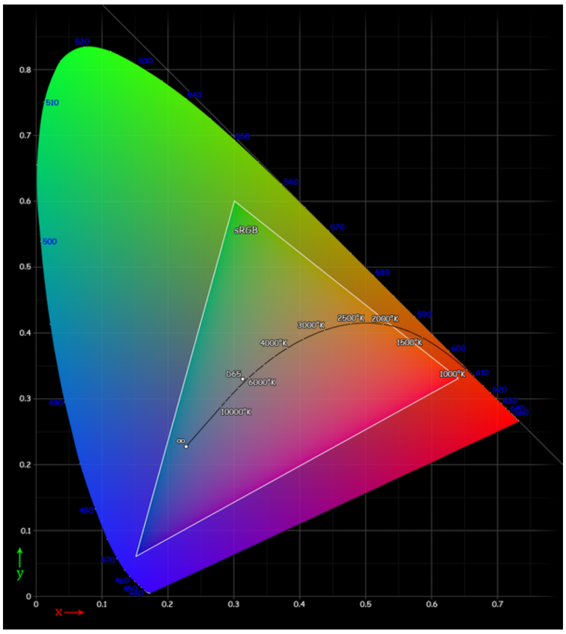
sRGB



CIE 1931 xy chromaticity diagram showing the gamut of the sRGB color space and location of the primaries. The D65 white point is shown in the center. The Planckian locus is shown with color temperatures labeled in kelvins. The outer curved boundary is the spectral (or monochromatic) locus, with wavelengths shown in nanometers (labeled in blue). Note that the colors in this displayed file are being specified using sRGB. Areas outside the triangle cannot be accurately colored because they are out of the gamut of sRGB therefore they have been interpreted. Also note how the D65 label is not an ideal 6500-kelvin blackbody because it is based on atmospheric filtered daylight.

sRGB is the standard RGB color space created cooperatively by HP and Microsoft in 1996 for use on monitors, printers and the Internet, and subsequently standardized by the IEC as IEC 61966-2-1:1999.[1] It is often used as the "default" color space for images that do not contain any color space information, especially if the images are stored as 8-bit integers.

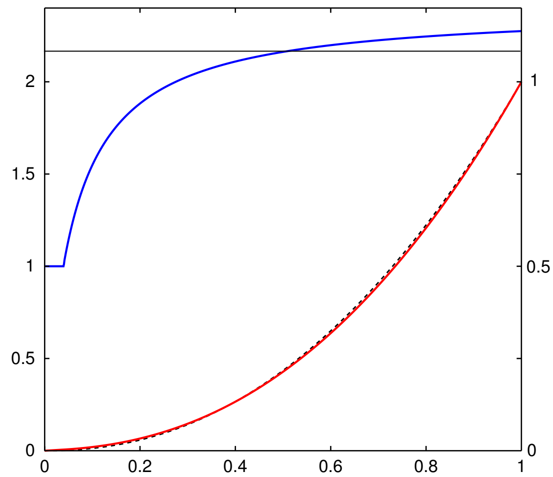
sRGB uses the ITU-R BT.709 primaries, the same as are used in studio monitors and HDTV,[2] a transfer function (gamma curve) typical of CRTs, and a viewing environment designed to match typical home and office viewing conditions. This specification allowed sRGB to be directly displayed on typical CRT monitors of the time, a factor which greatly aided its acceptance.

1 The sRGB gamut

sRGB defines the chromaticities of the red, green, and blue primaries, the colors where one of the three channels is nonzero and the other two are zero. The gamut of chromaticities that can be represented in sRGB is the color triangle defined by these primaries. As with any RGB color space, for non-negative values of R, G, and B it is not possible to represent colors outside this triangle, which is well inside the range of colors visible to a human with normal trichromatic vision.

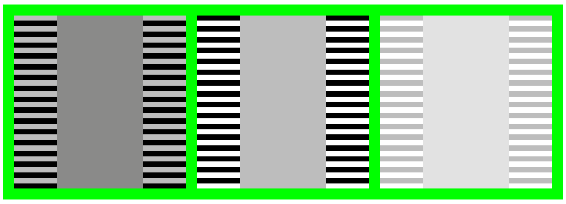
sRGB is sometimes avoided by high-end print publishing professionals because its color gamut is not big enough, especially in the blue-green colors, to include all the colors that can be reproduced in CMYK printing.

2 The sRGB transfer function ("gamma")



Plot of the sRGB intensities versus sRGB numerical values (red), and this function's slope in log-log space (blue) which is the effective gamma at each point. Below a compressed value of 0.04045 or a linear intensity of 0.00313, the curve is linear so the gamma is 1. Behind the red curve is a dashed black curve showing an exact gamma = 2.2 power law.

sRGB also defines a nonlinear transformation between the intensity of these primaries and the actual number stored. The curve is similar to the gamma response of a CRT display. It is more important to replicate this curve than the primaries to get correct display of an sRGB im-



On an sRGB display, each solid bar should look as bright as the surrounding striped dither. (Note: must be viewed at original, 100% size)

age. This nonlinear conversion means that sRGB is a reasonably efficient use of the values in an integer-based image file to display human-discernible light levels.

Unlike most other RGB color spaces, the sRGB gamma cannot be expressed as a single numerical value. The overall gamma is approximately 2.2, consisting of a linear (gamma 1.0) section near black, and a non-linear section elsewhere involving a 2.4 exponent and a gamma (slope of log output versus log input) changing from 1.0 through about 2.3. The purpose of the linear section is so the curve does not have an infinite slope at zero, it is not for matching CRT behavior.

3 Specification of the transformation

3.1 The forward transformation (CIE XYZ to sRGB)

The CIE XYZ values must be scaled so that the Y of D65("white") is 1.0 (X,Y,Z = 0.9505, 1.0000, 1.0890). This is usually true but some color spaces use 100 or other values (such as in the Lab article).

The first step in the calculation of sRGB from CIE XYZ is a linear transformation, which may be carried out by a matrix multiplication. (The numerical values below match those in the official sRGB specification[1] which corrected some small rounding errors in the original publication[3] by sRGB's creators, and assume the 2° standard colorimetric observer for CIE XYZ[3])

$$\begin{bmatrix} R_{\text{linear}} \\ G_{\text{linear}} \\ B_{\text{linear}} \end{bmatrix} = \begin{bmatrix} 3.2406 & -1.5372 & -0.4986 \\ -0.9689 & 1.8758 & 0.0415 \\ 0.0557 & -0.2040 & 1.0570 \end{bmatrix} \begin{bmatrix} X \\ Y \\ Z \end{bmatrix}$$

It is important to note that these linear RGB values are *not* the final result as they have not been adjusted for the gamma correction. sRGB was designed to reflect a typical real-world monitor with a gamma of 2.2, and the following formula transforms the linear RGB values into sRGB. Let C_{linear} be R_{linear} , G_{linear} , or B_{linear} , and C_{srgb} be R_{srgb} , G_{srgb} or B_{srgb} :

$$C_{\text{srgb}} = \begin{cases} 12.92 C_{\text{linear}}, & C_{\text{linear}} \le 0.0031308 \\ (1+a) C_{\text{linear}}^{1/2.4} - a, & C_{\text{linear}} > 0.0031308 \end{cases}$$

- where $a = 0.055$

These gamma-corrected values are in the range 0 to 1. If values in the range 0 to 255 are required, e.g. for video display or 8-bit graphics, the usual technique is to multiply by 255 and round to an integer.

The values are usually clipped to the 0 to 1 range. This clipping can be done before or after this gamma calculation, or done as part of converting to 8 bits.

3.2 The reverse transformation

Again the sRGB component values R_{srgb} , G_{srgb} , B_{srgb} are in the range 0 to 1. (A range of 0 to 255 can simply be divided by 255).

$$C_{\text{linear}} = \begin{cases} \frac{C_{\text{srgb}}}{12.92}, & C_{\text{srgb}} \le 0.04045 \\ \left(\frac{C_{\text{srgb}}+a}{1+a}\right)^{2.4}, & C_{\text{srgb}} > 0.04045 \end{cases}$$

- where $a = 0.055$ and where C is R , G , or B .

Followed by a matrix multiplication of the linear values to get XYZ:

$$\begin{bmatrix} X \\ Y \\ Z \end{bmatrix} = \begin{bmatrix} 0.4124 & 0.3576 & 0.1805 \\ 0.2126 & 0.7152 & 0.0722 \\ 0.0193 & 0.1192 & 0.9505 \end{bmatrix} \begin{bmatrix} R_{\text{linear}} \\ G_{\text{linear}} \\ B_{\text{linear}} \end{bmatrix}$$

4 Theory of the transformation

It is often casually stated that the decoding gamma for sRGB data is 2.2, yet the above transform shows an exponent of 2.4. This is because the net effect of the piecewise decomposition is necessarily a changing instantaneous gamma at each point in the range: it goes from gamma = 1 at zero to a gamma of 2.4 at maximum intensity with a median value being close to 2.2. The transformation was designed to approximate a gamma of about 2.2, but with a linear portion near zero to avoid having an infinite slope at $K = 0$, which can cause numerical problems. The continuity condition for the curve C_{linear} which is defined above as a piecewise function of C_{srgb} , is

$$\left(\frac{K_0 + a}{1+a}\right)^{\gamma} = \frac{K_0}{\phi}.$$

Solving with $\gamma = 2.4$ and the standard value $\phi = 12.92$ yields two solutions, $K_0 \approx 0.0381548$ or $K_0 \approx$

0.0404482 . The IEC 61966-2-1 standard uses the rounded value $K_0 = 0.04045$. However, if we impose the condition that the slopes match as well then we must have

$$\gamma\left(\frac{K_0+a}{1+a}\right)^{\gamma-1}\left(\frac{1}{1+a}\right)=\frac{1}{\phi}.$$

We now have two equations. If we take the two unknowns to be K_0 and ϕ then we can solve to give

$$K_0=\frac{a}{\gamma-1},\quad \phi=\frac{(1+a)^\gamma(\gamma-1)^{\gamma-1}}{(a^{\gamma-1})(\gamma^\gamma)}.$$

Substituting $a = 0.055$ and $\gamma = 2.4$ gives $K_0 \approx 0.0392857$ and $\phi \approx 12.9232102$, with the corresponding linear-domain threshold at $K_0/\phi \approx 0.00303993$. These values, rounded to $K_0 = 0.03928$, $\phi = 12.92321$, and $K_0/\phi = 0.00304$, are sometimes used to describe sRGB conversion.[4] Publications by sRGB's creators[3] rounded to $K_0 = 0.03928$ and $\phi = 12.92$, resulting in a small discontinuity in the curve. Some authors adopted these values in spite of the discontinuity.[5] For the standard, the rounded value $\phi = 12.92$ was kept and the K_0 value was recomputed to make the resulting curve continuous, as described above, resulting in a slope discontinuity from 12.92 below the intersection to 12.70 above.

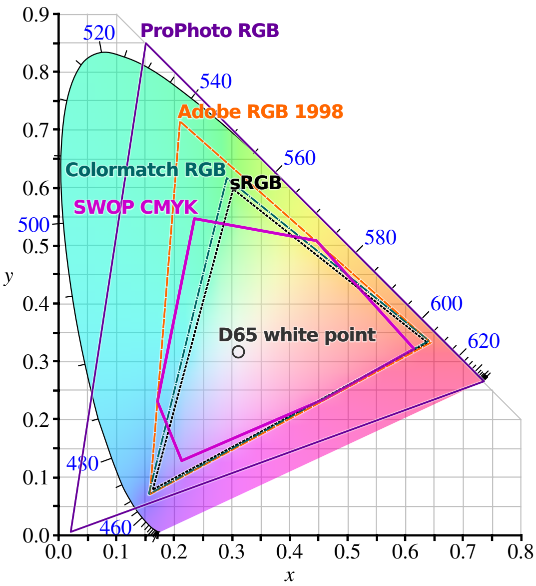
5 Viewing environment

The sRGB specification assumes a dimly lit encoding (creation) environment with an ambient correlated color temperature (CCT) of 5000 K. It is interesting to note that this differs from the CCT of the illuminant (D65). Using D50 for both would have made the white point of most photographic paper appear excessively blue.[6] The other parameters, such as the luminance level, are representative of a typical CRT monitor.

For optimal results, the ICC recommends using the encoding viewing environment (i.e., dim, diffuse lighting) rather than the less-stringent typical viewing environment.[3]

6 Usage

Due to the standardization of sRGB on the Internet, on computers, and on printers, many low- to medium-end consumer digital cameras and scanners use sRGB as the default (or only available) working color space. As the sRGB gamut meets or exceeds the gamut of a low-end inkjet printer, an sRGB image is often regarded as satisfactory for home use. However, consumer-level CCDs are typically uncalibrated, meaning that even though the



Comparison of some RGB and CMYK colour gamuts on a CIE 1931 xy chromaticity diagram

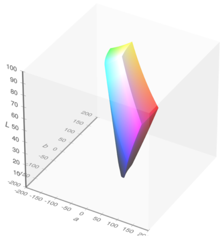
image is being labeled as sRGB, one can't conclude that the image is color-accurate sRGB.

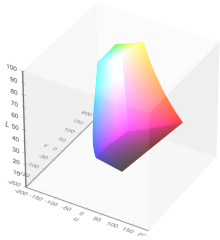
If the color space of an image is unknown and it is an 8- to 16-bit image format, assuming it is in the sRGB color space is a safe choice. This allows a program to identify a color space for all images, which may be much easier and more reliable than trying to track the "unknown" color space. An ICC profile may be used; the ICC distributes three such profiles:[7] a profile conforming to version 4 of the ICC specification, which they recommend, and two profiles conforming to version 2, which is still commonly used.

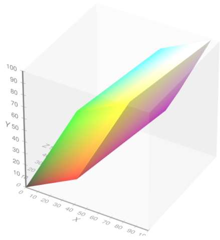
Images intended for professional printing via a fully color-managed workflow, e.g. prepress output, sometimes use another color space such as Adobe RGB (1998), which allows for a wider gamut. If such images are to be used on the Internet they may be converted to sRGB using color management tools that are usually included with software that works in these other color spaces.

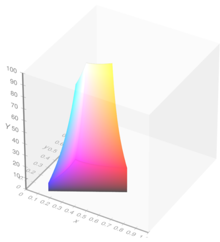
The two dominant programming interfaces for 3D graphics, OpenGL and Direct3D, have both incorporated support for the sRGB gamma curve. OpenGL supports textures with sRGB gamma encoded color components (first introduced with EXT_texture_sRGB extension, added to the core in OpenGL 2.1) and rendering into sRGB gamma encoded framebuffers (first introduced with EXT_framebuffer_sRGB extension, added to the core in OpenGL 3.0). Direct3D supports sRGB gamma textures and rendering into sRGB gamma surfaces starting with DirectX 9. Correct mipmapping and interpolation of sRGB gamma textures has direct hardware support in texturing units of most modern GPUs (for example nVidia GeForce 8 performs conversion from 8-bit texture to linear values before interpolating those values), and does not have any performance penalty.[8]

- The sRGB gamut projected into other color spaces

-  CIELAB

-  CIELUV

-  CIEXYZ

-  CIExyY

7 See also

- RGB color space
- scRGB

8 References

[1] "IEC 61966-2-1:1999". *IEC Webstore*. International Electrotechnical Commission. Retrieved 3 March 2017.

[2] Charles A. Poynton (2003). *Digital Video and HDTV: Algorithms and Interfaces*. Morgan Kaufmann. ISBN 1-55860-792-7.

[3] Michael Stokes; Matthew Anderson; Srinivasan Chandrasekar; Ricardo Motta (November 5, 1996). "A Standard Default Color Space for the Internet – sRGB, Version 1.10".

[4] Phil Green & Lindsay W. MacDonald (2002). *Colour Engineering: Achieving Device Independent Colour*. John Wiley and Sons. ISBN 0-471-48688-4.

[5] Jon Y. Hardeberg (2001). *Acquisition and Reproduction of Color Images: Colorimetric and Multispectral Approaches*. Universal-Publishers.com. ISBN 1-58112-135-0.

[6] Rodney, Andrew (2005). *Color Management for Photographers*. Focal Press. p. 121. ISBN 978-0-240-80649-5. Why Calibrate Monitor to D65 When Light Booth is D50

[7] sRGB profiles, ICC

[8] "GPU Gems 3: Chapter 24. The Importance of Being Linear, section 24.4.1". NVIDIA Corporation. Retrieved 3 March 2017.

8.1 Standards

- IEC 61966-2-1:1999 is the official specification of sRGB. It provides viewing environment, encoding, and colorimetric details.
- Amendment A1:2003 to IEC 61966-2-1:1999 describes an analogous sYCC encoding for YCbCr color spaces, an extended-gamut RGB encoding, and a CIELAB transformation.
- sRGB on www.color.org
- The fourth working draft of IEC 61966-2-1 is available online, but is not the complete standard. It can be downloaded from www2.units.it.

9 External links

- International Color Consortium
- Archive copy of http://www.srgb.com, now unavailable, containing much information on the design, principles and use of sRGB
- A Standard Default Color Space for the Internet – sRGB at w3.org
- OpenGL extension for sRGB gamma textures at sgi.com
- Conversion matrices for RGB vs. XYZ conversion
- Will the Real sRGB Profile Please Stand Up?

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