Technical Information

Color Gamut

Color gamut refers to the range of colors that can be reproduced under a given set of conditions. These conditions could be the inks and paper used for printing or the illuminated phosphors in a monitor display. In addition, color gamut can also refer to the range of colors that a scanner sees, or even the range of colors that can be recorded in a photograph or seen by the eye. Color scientists have conventions for displaying this kind of information, and in this article, we will look at those conventions and see how they relate to scanning, viewing, and reproducing images.

Chromaticity diagrams

Color scientists have been trying to define the perfect color space since early in this century. A goal of this research was to develop a mathematical definition of what is at best a very subjective topic: human color vision. One result of that research was the Commission International de l'Eclairage[1] (CIE) 1931 chromaticity diagram shown in Figure 1.

[1]More information on CIE color spaces appears in these Linotype-Hell Technical Information articles: *Color Spaces & PostScript Level 2, Color Management,* and *Color Space Conversion.*

Chromaticity is a measure of both the hue and chroma of a given color. The tinted area in Figure 1 represents the colors in the visible spectrum that can be seen by a so-called standard observer. Chromaticity diagrams show only the hue and chroma of a color, so one factor is still missing: luminance (also known as lightness or value). To display the luminance portion of the color would require a vertical axis (see Figure 2), and this makes sense, because to accurately display a color space the diagram must be three dimensional.

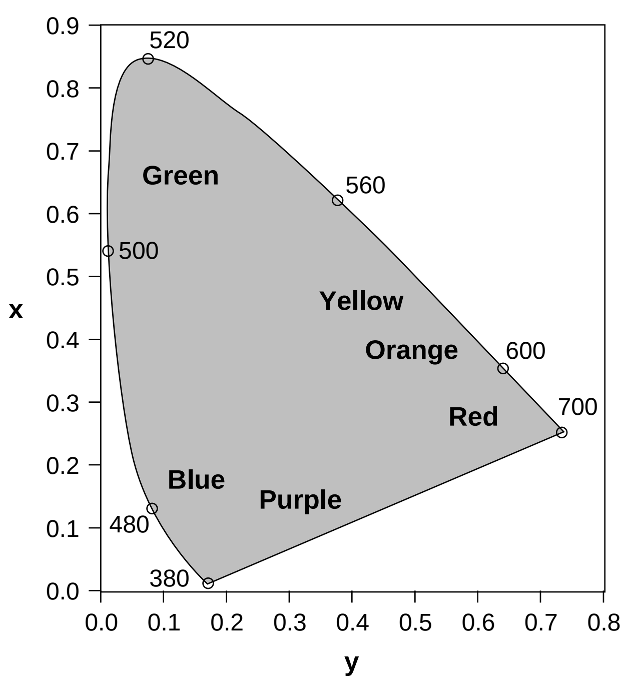

Figure 1 – 1931 CIE chromaticity diagram marked with the colors in the visible spectrum. The numbers along the edge of the tinted area represent the wavelengths (in nanometers) at selected points.

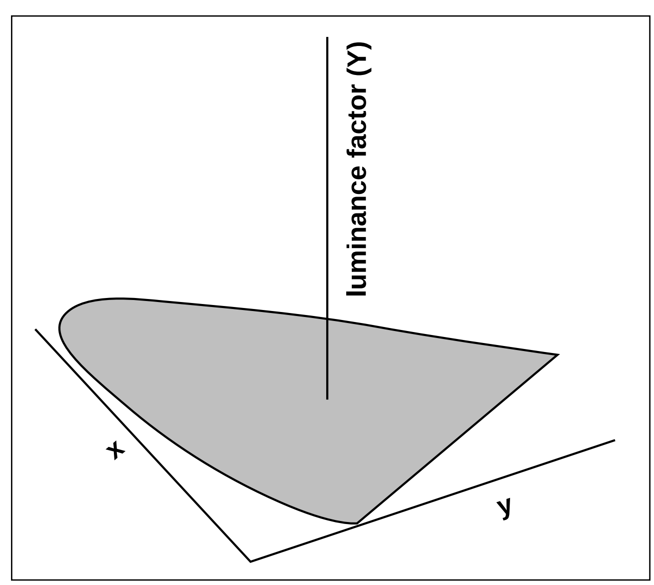

Figure 2 – 1931 CIE chromaticity diagram including a vertical axis representing a luminance factor.

Source for Figures 1 & 2: Billmeyer and Saltzman, Principles of Color Technology, 2nd Edition.

R = Red
G = Green
B = Blue

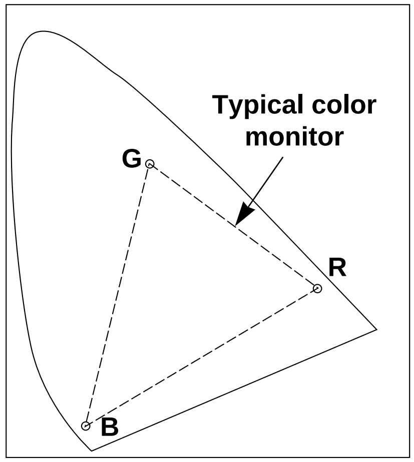

Figure 3 – The color gamut of a typical color monitor.

Source: Richard Herbert, Pantone, Inc.

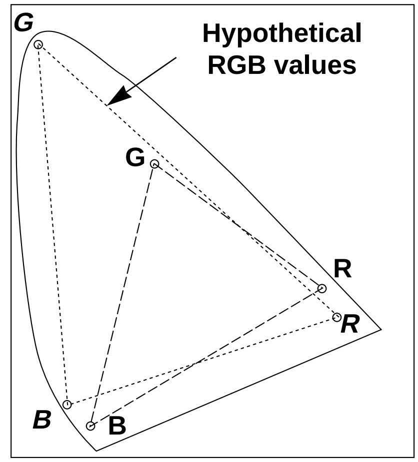

Figure 4 – The color gamut of a typical color monitor compared with the color gamut of three primaries that would provide a larger gamut, but which are purely hypothetical and could not be produced in a real monitor.

The x axis and the y axis of the chromaticity diagram represent the chromaticity coordinates x and y. The outermost edge of the color space in Figure 1 is marked with numbers which represent various wavelengths (in nanometers) of visible light. Comparisons of the color gamuts of different reproduction processes are most often shown on a chromaticity diagram like this. By overlaying color gamuts of different processes it is possible to see what colors fall inside the color gamut and are therefore reproducible, and which ones fall outside of the gamut and are unreproducible.

Color gamut example

Figure 3 and 4 demonstrate how a chromaticity diagram can be used to compare color gamuts. Figure 3 shows the color gamut of a typical color monitor. Figure 4 shows the same color gamut with an additional (hypothetical) color gamut superimposed over it. This second color gamut is made up of three arbitrarily chosen values for red (R), green (G), and blue (B). You can see from the diagram that these RGB values would be able to produce a larger color gamut, particularly in the green portion of the color spectrum. However, there would be certain small areas (near blue and red) that could be produced by the typical color monitor, and not by the hypothetical RGB values chosen for this demonstration. You can also see that no three RGB values could be chosen that would reproduce the entire spectrum. This is one drawback of so-called trichromatic systems.

Impurities in process inks

One of the key issues in color reproduction, whether it is an RGB color monitor display or a process color printed piece, has to do with how close the colors come to some scientific ideal. A lot of study has gone into the area of imperfections in the process inks used for printing. Even the most expensive process color inks aren’t perfect. Scientists have found it difficult to make inks that perfectly match the ideal cyan (C), magenta (M), and yellow (Y).

If the process colors were perfect, then cyan, magenta, and yellow overprinted would produce black, but they don’t. Overprinting solid cyan, magenta, and yellow results in something closer to dark brown. As a result a black ink (K) is needed to provide a good neutral dark black, and also to provide detail. The impurities in process inks[2] are generally as follows:

[2]Hue error is the term used to describe these impurities. Hue error is the amount that a process color ink strays from an ideal cyan, magenta, or yellow.

R = Red
G = Green
B = Blue

C = Cyan
M = Magenta
Y= Yellow

Overprints
CM = Cyan/Magenta
CY = Cyan/Yellow
MY = Magenta/Yellow

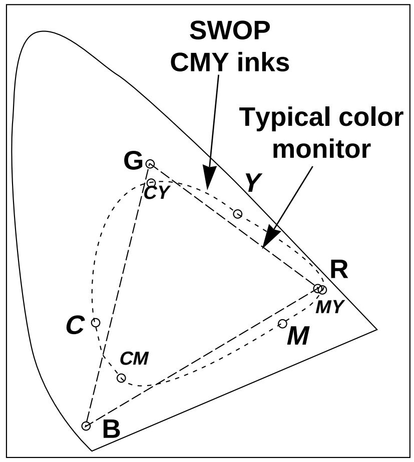

Figure 5 – The color gamut of a typical color monitor, compared with the color gamut of SWOP CMY inks.

Source: Richard Herbert, Pantone, Inc.

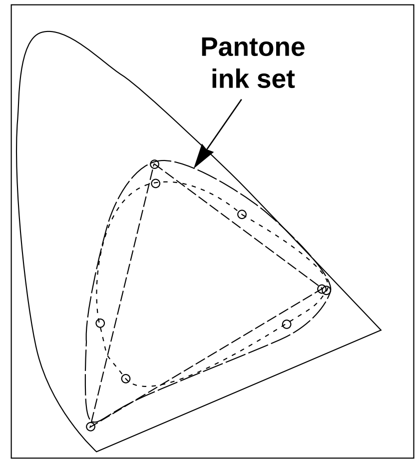

Figure 6 – The color gamut of a typical color monitor, CMY inks, and the Pantone ink set.

Source: Richard Herbert, Pantone, Inc.

- Cyan is contaminated with some magenta and yellow ink.
- Magenta is contaminated with some yellow ink.
- Yellow is the purest color but is contaminated with a little magenta.

The nature of ink impurity has been known for a long time, and, in fact, it is possible to make adjustments for this in the scanning process. Adjustments for the impurities in ink are known as color correction. Most recently, the term color correction has been used for a grab bag of tweaking that goes on to make the image look more like the original, but really, that should be called selective color correction since it refers to selectively changing the color in only certain areas of an image.

RGB versus CMY

Figure 5 compares the color gamuts of two processes: a typical color monitor and SWOP (Specifications for Web Offset Publications) color inks. Overlaying these color gamuts tells us something about the colors that one process can reproduce but the other can't. For example, from Figure 5 it is clear that there are some blues that will display on a typical monitor, but will not be reproducible in print with a SWOP ink set. In addition, there is a range of colors throughout the spectrum that can be printed, but exceed the gamut of what can be viewed on the monitor.

Pay specific attention to the two-letter markings on the CMY color gamut in Figure 5. These represent two-color overprints: cyan/magenta (CY), cyan/yellow (CY), and magenta/yellow (MY). The CMY color gamut isn't a perfect triangle like the RGB monitor gamut. This is due to the nature of subtractive color mixtures. The two-color overprints actually produce a more saturated color than might be expected.

High fidelity color

There has been quite a lot of discussion recently about the topic of high fidelity color. One aspect of high fidelity color is an extended ink set that may include as many as seven inks. The primary function of these additional inks is to expand the color gamut beyond what is available using conventional CMYK inks. Experiments done by Pantone with their wide range of inks have shown that the color gamut could be increased to go beyond the color gamut of a typical color monitor (see Figure 6).

Color gamut and scanners

Color gamut also plays a role in what scanners 'see'. Films of different types use different emulsions and dyes to reproduce color. Scanners may see these different emulsions differently. Colors that appear one way on the original may be seen somewhat differently on a scanner. This is most obvious in cases where a photograph or transparency has been retouched by hand. The materials used for retouching may differ significantly from the dyes used in the emulsion of the film, and as a result unexpected colors may appear when retouched photographs are scanned. Because of the role that film emulsion plays, for the utmost accuracy there should be scanner settings for the emulsion type of the original photograph, slide, or transparency.

Influence of paper

The paper stock plays a large role in the color gamut that a given set of inks will be able to reproduce. To see why, try laying the paper that this article is printed on over a copy of your daily newspaper. The newspaper will seem amazingly gray. In the same way, the same color ink would appear grayish and less saturated when printed on newsprint as opposed to a whiter stock.

Reproducible or not?

As we can see from the Figure 5, there are some reds which can be reproduced by SWOP inks which are too saturated to display on monitor. Similarly, there are some blues which cannot be reproduced by SWOP inks. Obviously these facts need to be taken into account by any color management system.[3] For a true WYSIWYG system, the monitor display must reflect the print gamut. Yet even when this is done there will be colors which can be printed with CMYK but which can't be displayed on an RGB monitor.

[3] See the Linotype-Hell Technical Information article entitled *Color Management* for more information on calibrating for the print process.

Calibration

The colors that a monitor can reproduce may vary over time due to changes in the monitor's phosphors. In addition, an uncalibrated monitor will display a different color gamut than a calibrated one. Inks vary too. One important function in any printing plant is quality control of incoming materials. Printers who use large quantities of ink, must pay special attention that the ink colors do not vary from batch to batch.

Conclusion

While color is a very subjective topic, color scientists have found some very specific ways to measure the perception of color. Chromaticity diagrams provide a way for us to see how color is used in practice. And this makes it possible for us to adjust for limitations in the reproduction process.

References

The diagrams in this article have been based on material from three sources:

- *Unraveling the Mystery of Color Space,* Richard Herbert, High Color magazine, January/February 1993.
- *The Reproduction of Colour in Photography, Printing, and Color,* Dr. R.W.G. Hunt, 1987, Fountain Press, Tolworth, England.
- *Principles of Color Technology, 2nd Edition,* Fred W. Billmeyer Jr.and Max Saltzman, John Wiley and Sons, New York.

Acknowledgements

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