Optimizing RGB for the Graphic Arts,

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There are a large number of RGB spaces that already exist. Each has been developed to solve some specific problems in the communication of color throughout a digital imaging system. None of these address the accuracy and gamut requirements for the capture and display of Real world colors, i.e., the colors that exist and can be reproduced by both biologic and man made colorants.

ISO 12640 offers a volumetric gamut of what is considered the “Real World” colors. This standard is used as the basis to develop an optimum RGB color space. The new color space preserves the numerical accuracy required the represent colors specified by ISO 12640. The new RGB primaries have been chosen to transform to the known physiological properties of the human visual system.

A simple 3X3 matrix transform of the RGB primaries produces a visually uniform chromaticity space that supports gamut mapping from the ISO 12640 volumetric gamut to the gamut of all output devices.

This paper discusses the calibration of the three major channels of imaging. They are input, display, and output. Each channel has differing properties that must be taken into account in the transformation of RGB. The calibration and use of each of these channels in imaging is the focus of this paper.

The Real World

The spectrum locus of the CIE1931 color space spans a much greater colorimetric volume than the colors of the “Real World”. The standard defines the chromatic volume for which we should encode colors. In addition, the color space should only span as much of the CIE 1931 color space is needed to encode the color in the “Real World”. Otherwise information will be lost to quantization of regions of color space that will never be seen in the “Real World” of color.

A good example of the need of using color space properly is on input of color from either a scanner or camera. Each of these devices has color mixing functions and can resolve colors all the way to the spectrum locus. It is therefore important in calibrating an input device to limit the signal space to the volume that is defined by the ISO 12640- 3.4 standard. It is also important to Gamut map from the standards-based to the space of either a display or printer.

The next sections of this paper, will discuss in the calibration and mapping of RGB within the standard reproduction volume.

IQrgb

IQrgb was introduced in 2001 by Granger[1]. The new RGB space was set up to span reproduction gamut defined by the ISO 12640-3.4 standard. The choice of the primaries for the system was based on the characteristics of the human visual system, primarily the fact that the human visual system is an opponent system. The other characteristic of the new RGB space is that it is linear using simple integer weights. It also decouples chroma from brightness. This property is useful in that it greatly simplifies the calibration process for input, display and printers.

The simple model is able to predict the known color mixing functions of the human visual system. The model produces a uniform color space for the lighting levels common to graphic arts. The model has not been designed to handle many of the nonlinear effect that occurs outside its range of application.

Input

Detectors in input devices are linear and always respond proportionally to the number of photons absorbed. Therefore, any filter triad will react to light falling on the detector and produce a signal, RGB. If the number of photons is reduced by half, the value of
RGB will be half the starting value. The filtered detectors will produce a unique ratio,
RGB, when stimulated by an illuminant whose tristimulus values are XYZ.
If you reduce the color, XYZ, by an amount, say, c. Then the detectors will produce
RGB reduced by the same factor, c. Since detectors are linear, there is no need to examine more than a single color at a given chromaticity coordinate, (x, y).

We recommend that the calibration target be comprised of colors that have the highest lightness and chroma possible. These colors will yield maximum signal to noise and produce the most accurate calibration. A target[2], like the one shown in Figure 1., is all that is required for input systems.

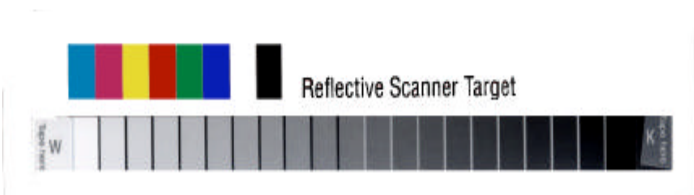

Figure 1

The neutral gray scale is used to check for any metameric problems in the system. This usually occurs in scanning photographic materials. Once the system has been corrected for metamerism of the gray scale, the chromatic transforms can be made. We have elected to use the primaries and overprints of graph art dyes for the characteristic calibration functions. This simple target yields calibration of RGB to XYZ that is as accurate as the more complex calibration targets that are commonly used.

Most input device color matching functions are not close relatives to the color matching functions of human vision. Therefore, no single 3X3 matrix transformation will produce an accurate calibration of most input devices. There are six tetrahedral volumes produced by two adjacent colors and the white and black point. A 3X3 matrix transformation for each of these six volumes does produce accurate color data for the entire volume for most filter sets.

Display

Displays are the easiest to calibrate. There are many good calibration systems for displays. Once the gamma of the display has been measured for each primary, and the chromaticity of each primary has been determined, the transformation of the RGB data is easy since only a single 3X3 transform is required. Unlike input devices and printers, displays are inherently linear devices. There may be some gamut mapping required to accurately display the IQrgb color space on the destination display device. The recommendation, in color adjustment of the source image, is to make the adjustments in the IQrgb color space and to observe the changes gamut mapped to the display. This eliminates the errors that are made with A2B – B2A round tripping. This new method is called “Fate Binding”. With “Fate Binding”, the data in the IQrgb space is never changed until it is passed onto an output device such as a display or a printer.

Output

Printers are the most difficult to characterize. The color produced is a function of the paper, ink and dot structure just to name a few of the important variables. The color of the over prints will vary with paper conditions, temperature and humidity. It was determined that measuring the characteristics of the primary inks was not good enough for best color control. The first target used is a 100 step target that is created for all primaries and their overprints. The target also includes a gray scale. The density of the steps is measured using an adaptive 10 nm narrow band measurement of each color ramp. Dot gain is computed using the Murray-Davies equation. At the same time, the hue, saturation and darkness of each step is measured. Saturation and darkness are used to determine the point at which a primary or an over print is no longer increasing saturation and is contributing more to darkness. This method produces the maximum bright gamut of colors that the printing system can reproduce. The darker colors are produced by a new method of adding darkness to each color. In the new system there is no need to produce dark patches. The IQ Colour system has separated hue and chroma from darkness so they are independent in the color reproduction process.

Samples are taken from equal saturation steps of the primaries and over prints. The samples are randomly arranged and repeated 5 times in the color calibration document. A color space representation of the test target is shown in Figure2. These patches are measured, and a Taylor series expansion of the Neugebauer equations is used to produce a chroma table that has 256 hue angles and 192 saturation samples along each hue line. A representation of the chroma table produced by this process is shown in Figure 3.

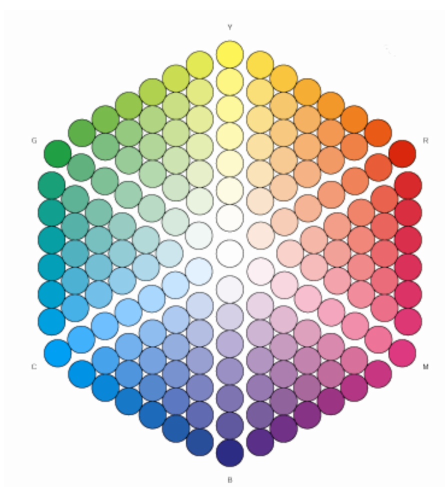

Figure 2

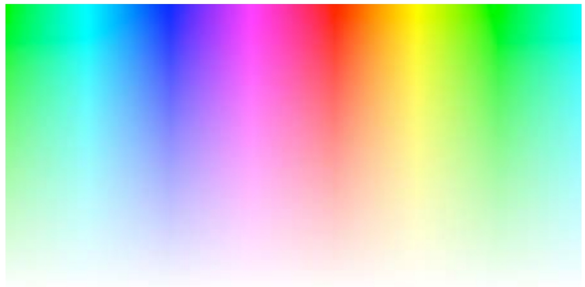

Figure 3

The new black addition system uses approximately 1000 levels of darkness to darken each of the 49000 colors in the table shown in Figure 3. This new system is a complete break from the traditional method of treating black addition using UCR and GCA.

Although the new printer calibration system is more complex to calibrate, the resulting color is more stable. The use of a linear uniform chromaticity color space model allows the separation of chroma and darkness. This produces a tolerant reproduction system. The inclusion of the over prints and the elimination of dirty colors aids the stability of the reproductions.

The system also eliminates the need for A2B – B2A round tripping. This results in very accurate hue stability. That is, what you see on the monitor will be seen in the final print.

Conclusion

A new RGB space called IQrgb has been defined that produces a linear-uniform reproduction- chromaticity space that just spans the reproduction volume specified by the ISO 12640- 3.4 standard. The space and its transformations imitate the actions of the human visual system for the luminance levels used in the graphic arts. It is not meant to be full feature vision model.

This space spans the required volume while maintaining the greatest digital accuracy. The IQrgb system uses a new concept of "FATE" binding. "FATE" binding eliminates the losses in hue reproduction by not having to use A2B – B2A round tripping in the imaging process.

"FATE" binding maintains the bits of data in the native color space. Soft proofing is done by transforming the data going to the monitor. The adjustments in the native IQrgb space are viewed on the monitor but not modified by the IQrgb to monitor RGB mapping.

The same is true for printing. The transformation of the IQrgb data is done at the RIP. Therefore, a document stored in IQrgb can be sent to any output device and be accurately rendered. The use of the linear chromaticity space has allowed us to separate color and darkness. This has resulted in a new method adding darkness or black to bright chromatic colors to reproduce all the colors that lie in the volume beneath the bright colors. Resulting in cleaner, brighter and more stabile color reproduction on press.

References

1] E.M.Granger, “A Vision Based RGB Color Space” TAGA, 2001
2] E.M.Granger,” The ABC of Input” TAGA, 1999