IQcolour

Dr. E. M. Granger
RIT School of Print Media

Abstract

IQcolour started by asking how color printing would have evolved if color film had never been invented. The hypothesis is that printing and the automation that followed would have used the processes developed by engravers and colorist that prevailed before the introduction of color film. We then added the late ability to gather color images using silicon imaging devices. Never having seen film or color separation, how would the printing industry incorporate the new image content?

Our hypothesis is that the industry would have carried on the extant practices of the colorist. The new study has been the development of a rendering system that mimics the methods used by painters, colorist and engravers to produce color images. The results to date show that the ancient methods of color rendering produce image that have better color and image quality on modern printers and presses. The early analysis indicates that the IQcolour methods should offer new economies in material use and reduced waste.

Introduction

In 1969 George Spencer-Brown presented a new form of logic in his book “Laws of Form”. The book is very controversial and many believe that it brings nothing new to the mathematics of logic. All this being true, Spencer-Brown does introduce an idea of the calculus of indication. His logic is based on the single fundamental operation of distinction.

The operation of distinction is just the simple idea of a barrier that parses the world, in logic, to lie on one side of the barrier or the other. One example of the logical use of the barrier would be the logical statement of “everything”. In this example, “everything” is on one side of the barrier and the “null set” is on the other side of the barrier. This is then a very simple statement of the null set.

The idea of barriers extends to many human activities. Throughout history, we have numerous examples of the status quo impeding progress and limiting new development. Many new inventions, such as the automobile, have their beginnings limited by the extant models of behavior. In the case of the automobile, the development was limited by the available technology and the forms of land transportation models. So replacing the horse in the front of a buggy with an engine was a natural evolution of land transportation. The new mode of transportation was limited by the wheels, axels and frames (buggy) that were being manufactured at that time.

Printing and image production has had similar barriers in place. The current printing paradigm is based on the use of color photography. The separation of color images into cyan, magenta and yellow monochrome records was accomplished photographically by filtering the color image through red, green and blue filters. The control and measurement of the process were based on density. Density was used because the human visual system has a logarithmic response. Density became a convenient way of controlling the tone scale of both black and white, and color images.

It is only natural that the tool used to manage the photographic system was extended to graphic art reproduction. The control of neutrals in print had direct analogs in color prints. The printing process, like color photographically, controls the tone reproduction of the Cyan, Magenta and Yellow separations to allow neutrals to be reproduced. In this process, color reproduction is limited by the amount of Cyan, Magenta and Yellow that is available. The amount of Magenta and Yellow colorants used to produce a neutral are usually less than the amount of Cyan used in the mix. The limited amount of Magenta and Yellow limit colorfulness of the overprint colors Red, Green and Blue. This problem was solve in photographic reproduction by the introduction of masking which allowed more dye to be coupled to the image in the Red, Green and Blue portions of the image. Print has the same problem and printers solved the problem through the use of mechanical masking.

Electronic image scanning was introduced in the mid 1960s. Image scanning, like the automobile, mimicked all the extant technology. The scanner eliminated the laborious many step process used to produce analog separations. The barrier in this new process was that it incorporated all the old analog process steps and controls. Therefore, the form of the graphic arts reproduction process was not changed with the introduction of electronic scanning. All the problems of the reproduction process remained in the mathematic model of the analog separation procedure.

Let us now use the “Laws of Form” as a construct to change the current reproduction method. Spencer-Brown uses the operation of distinction to separate forms of objects or ideas. The distinction operation is used to construct a logic world where all the graphic arts developments, based on film’s existence, are on one side of the barrier. On the other side is the graphic arts world as it would be if silver halide had not been discovered. Crossing the barrier brings us into anew world where all prior knowledge no longer exists and new operations must be discovered to produce color images for the graphic arts.

The other side of this barrier does exist in time. Before the discovery of film, artists were the source of images in all forms of media. Artists have been able to image their worlds with rocks, chalk, water colors and oil based paints. Wonderful images have been produce over the ages on a wide variety of materials such as cave walls, rice paper and canvas. Our research efforts are concentrated on development of algorithms that imitate the methods used in the time before film, the other side of the barrier.

Colorists were the separation engines and engravers the screen generators before the introduction of film. Working with the colorist, the engraver was able to produce high quality images without the aid of densitometers, gamut mapping or color spaces. These early artists never asked questions about gamut consideration. They used the knowledge gained over thousands of years to make life like images in terms of tone and color.

An artist is always pictured holding a palette of colors from which they mixed the desired hue, saturation and lightness for the image elements they are rendering. The palette of most chromatic colors determined the artist color gamut. The artist uses these colorants to render an image independent of what type of colorants or substrate are being used. The artist has been trained to use appearance to obtain a representation of the scene. The artist's eyes were the only measurement device used in the decision of which pigments to use and how to mix them with black and white pigments to achieve the desired appearance match to the scene.

The new distinction in rendering images uses a method that is the analog of the artist painting a picture. The brightest colors are stored on a two dimensional palette similar to that used by the painter. The colors are arranged in the same rainbow order as the artist uses on his palette. The only difference is that we premix all the desaturated color samples. The edge of the color gamut is determined by the brightest colorants along the edge of the palette. The desaturated colors are found near the center of the palette and increase in saturation until the most saturated colors are reached at the edge of the palette.

The reproduction of bright logo colors is accomplished by using the color at the edge of the palette. Lets us take a logo color like Black & Decker orange. It is obvious that this color can not be equally reproduced by say newsprint and gravure. It is an impossible task to get these two processes to match. This has not stopped newspapers from producing color images. The consumer looking for the product is happy if the color is reproduced at the proper hue and appears to be fully saturated relative to all the other image elements in the advertisement. Will the newsprint ad appear the same as the one properly reproduced using gravure? Will the ad on one grade of paper appear the same as the one properly reproduced on another paper grade for any printing device? The answer is no. But, in all cases the artist would produce the optimum rendering of the advertisement. This logical distinction has produced a definition of color gamut and of gamut mapping that has been in use for centuries by colorist and artists.

Crossing the barrier introduced by color film and moving to the side where the artist is the model for the new distinction produces a new printing paradigm. Why cross the barrier? All the old considerations of gray balance, UCR and GCA, masking, color gamut and image key are removed. The new distinction or paradigm gives graphic arts a new playing field, a new game and new rules. The artist model of printing is exciting in that it promises increased productivity, greater image sharpness, stabile color and lower production cost.

The Current State

Current printing workflows have multiple dependencies. The characteristics and limitations of these multiple elements each must be measured and these measurements communicated clearly to the succeeding parts of the workflow. If they are not, correct reproduction becomes as much a matter of luck as of skill and art. There are many elements to measure and formats to consider, such as color spaces, document formats, device profiles, document scale, etc. In the future, it is important that each element of the system be independent of any other element .

An ideal workflow will eliminate as many dependencies as possible, so that the workflow from creation to final can be streamlined. This will be done by focusing our efforts on three areas:

a) Defining device neutral color spaces for each step of the workflow
b) Improving the user experience of the tools through every stage of the workflow
c) Automating the color measurement and feedback of workflow devices so that they become invisible to the average user

The most important element is the customer and the customer's expectations. There are a wide variety of users that range from the casual user to the heavy duty professional. All want the same results from the reproduction system, namely that the input, display, and output have equal appearance. The elements of the system should be independent from the point of view of the customer. We need to be able to structure applications so that elements can be added to accommodate greater complexity. After all, the average user only wants what George Eastman would have promised in a modern age, namely "You click the mouse, and we will do the rest".

Device independence is not new. A team at Kodak, led by Chuck Reinhart, developed a scanner evaluation target called the Q-60. Chuck presented the new concept at the 1988 TAGA meeting. The Q-60 was the first test target to offer a set of patches that were organized in an orderly fashion. The target patch organization was original in spacing the color samples in orthogonal and equal CIE-Lab steps of hue, chroma, and lightness.

The Q-60 was originally developed as a diagnostic tool for scanner evaluation. The novel construction of the target led to the beginnings of device independence. Before device profiling, the transfer of data was accomplished by converting scanned RGB values to printer CMYK values using proprietary conversions. At that time the reproduction systems locked the scanner and press into a closed system. The Q-60 offered the promise of calibrating a scanner to produce device independent CIE-Lab output that could be passed on to a CIE-Lab calibrated press. For the first time, in theory, color data could be shared in an open system.

Apple Computer introduced ColorSync as a method of connecting system elements. The color space corrections or profiles could be added to a document so that the chainof required transformations were imbedded in the document. For the first time, the system organized color space transformations so that a document could be accurately managed from input to output.

This system works reasonably well in the hands of experts, but is unnecessarily complex for the average user. Although the system produces good results, it requires expert training and expensive tools to deliver its best performance. The designers of much of the hardware and especially of the software seem to have made it a point to make their tools more difficult than necessary to use. In particular, until very recently, user interface design in profiling software, if considered at all, was done with the apparent intent of being as obscure as possible.

Worse yet, in the current workflow, the dependencies are either embedded (Photoshop 7 and Acrobat 5) or are communicated with pointers or links to the profiles. CIE-Lab three-dimensional profiles with a limited number of steps in each dimension have led to the need to connect the input profile directly to the output profile. As a result, we're back to our original problem of complete device dependence. Should users neglect to send a profile or profiles with their job to a printer, the printer is hamstrung, as most documents do not embed profiles for all pieces of a fully composed document, similar to the printer not having all the fonts needed to complete the job. We have gained some flexibility and a good deal of accuracy by using profiles but the current system has its limits.

New thoughts are beginning to emerge about how to reconfigure the system so that the elements are truly autonomous. New color spaces are being proposed to replace CIE-Lab as the profile connection space. An RGB profile connection space is required if we want to build a system that has the proper element independence principles.

The sRGB color space works well with current cathode ray tube displays but may not be as useful for flat panel displays. Not only are the primaries of the flat panels different from those of the cathode ray tubes, but future flat panel displays may incorporate more than three primaries. What is important is to get industry agreement on some RGB definition that can be used as the industry standard. All color data would be stored in this standard format. The sRGB color space , with its current limitations as far as four color process output is concerned, is not be the ideal answer. With gamut extensions and increased precision, it may not be worth the compromises. Alternately, a wider gamut color space which retains more color information may be used for input/working space but only if the elements of the display and output segments of the workflow are considerably more decoupled than they are now.

Gary Starkweather of Microsoft has offered an excellent analogy of what needs to be done for all future system elements. Although his talk concentrated on the output side of the reproduction process, his analogy could lead us to the best future state. Gary used an automobile analogy to illustrate his point. He spoke about the complexity of the automobile transmissions before the 1990's. They were a mess of interconnecting hoses, valves, fluids and channels that were used to change the gear ratio from the motor to the rear wheels. As he pointed out, this old transmission is exactly like the current workflow and color management system.

The solution for the automotive transmissions was to add a computer and measure, independently, all the elements required to make the shift point decision. The new transmissions measure air temperature, torque, oxygen level, etc. to make the decision about how to set the transmission. Gary's question was "Why not color devices?"

He gave an example of how a small colorimeter could be attached to a printer. The colorimeteric information could be fed back to the host computer. The host computer could then change the profile to optimize the printer. This information would be used to correct the profile not just for the ink, but also for the ink-paper combination, the humidity and other atmospheric conditions affecting the output, etc. In a system like this, the output device would auto-profile the paper for its characteristics. The original images and spot color information, already coming from auto-calibrated and profiled input and display devices, would automatically relate to the intended destination substrate at the final point of impression. The average user would not need to know, nor care,what color space the scanner had used to acquire the image, nor what profile was being chosen by the computer. This would be automatically selected by the devices for the best possible reproduction. Advanced users could look "under the hood" to fine tune specifications.

The best future state for color space is to have all input devices convert their RGB data directly to an agreed upon RGB metric space. All output devices would be treated as printers. Monitors, printers and all other output devices would have a single profile to convert the PCS to the local color space. To have true orthogonal operation the workflow requires that the profiles belong to the devices and not to the document. The orthogonal system would not imbed profiles in a document. This new system would allow last-minute adjustments to be made in any device at any stage of the reproduction process. There is no need for the document to be involved in the reproduction process. Once we have agreed to a universal RGB space, we can concentrate on the updating of the capture and reproduction processes.

Orthogonality or independence applies to other aspects of a document. An efficient workflow requires that the document be independent of the operating system, of the scale the document, and the state of editing. Adobe has gone a long way toward producing documents that are independent of the operating system. The Adobe Acrobat PDF file structure has done for the document what the ICC has done for color data.

Adobe Postscript gives us the ability to embed scalable type and line art elements into a document. AltaMira Group, Inc. has added this ability for scanned data. It is able to convert the scanned picture into fractal vectors. Fractal vectors are excellent for data compression. These vectors have the advantage that they are scalable just as the type and line art elements are in Postscript. The joining of fractal vectors with PostScript produces a new document that can be scaled to any magnification without exhibiting the artifacts that are common to other data compression techniques. This image storage format is an analog to the universal RGB exchange format used to control color. Moving document structures to be entirely vector based is a requirement that allows last minute change and “FATE” binding of the document.

For users, the bottom line is that they want the system to work, and work well. It should deliver high quality color reproduction from varied original sources onto multiple output devices, without requiring nearly as much work as the systems currently necessitate. With autocalibrating devices in the workflow and universal standards for the exchange of documents, this can be done.

The support for this system must be a universal wide gamut RGB exchange format. The next section of this document presents a new linear color space as a proposed replacement for the CIELab system. The CIELab space has many well known problems in that it was never intended to be an appearance space and is only a approximately a color difference space.

IQRGB and the ATD Color Space

The new RGB rendering space, *IQ*RGB, defined in this paper is based on the actions of the human visual system. The color space offers better arithmetic precision, color space uniformity and support for automatic white point correction. The previous ATD-RGB model is based on an expansion of the sRGB primaries. At that time it was felt this would simplify the display of the stored images. Unfortunately the AEQ (Granger 1994) primary system is not visually uniform and encompasses a very large gamut. It shares the disadvantages of the CIEXYZ space, namely, that much of the vector space is not used to render “real world” images. This requires using more bits of computational precision in XYZ just to guarantee 8-bit precision in rendered images. The solution to this problem is to employ a vision based RGB color space that is wrapped tightly around the gamut of real world colors. *IQ*RGB is designed to fit the “real world” color gamut insuring the system is 8 bit friendly.

Digital photography and scanning are becoming a dominant source of images for reproduction systems, whether it is for home or professional use. Therefore, RGB is becoming the color space of choice. The selection of the RGB primaries in the *IQ*RGB system is not arbitrary. They support a uniform appearance transform. The new transform has tristimulus values denoted ATD. The transform from *IQ*RGB to ATD is a “best” approximation to the known channels of human vision. The new model, while being linear and integer, produces a uniform chromaticity space denoted Qtd. A computationally simple model answers the need for a space that produces uniform color differences.

IQRGB Primaries

Opponent-process color vision theory is well known. The hue of a color can be described in terms of its redness and greenness and its yellowness and blueness. This process is called opponent because the opponents yellow-blue and red-green are not seen simultaneously. The red-green and yellow-blue responses are independent of one another. Therefore, one can never see a spectacular red-green or a beautiful yellow-blue.

The *IQ*RGB primaries are selected to produce an opponent-process based on the perceptually unique blue, green and yellow hues. The deuteranopic confusion point is used as the extraspectral red opponent. The unique blue, green and yellow hues are at wavelengths; 475, 500, and 575 nm. The extraspectral red is located at x =1.4, y = -0.4 (Wyszecki, 1982a) of the CIE xyY color space. The lines connecting the opponent hues are used as the axes of the color model. The line connecting unique red and green is the T axis and yellow and blue, the D axis. The achromatic axis is denoted A. ATD is the tristimulus equivalent of CIEXYZ. ATD can be converted to CIEXYZ by using a 3X3 matrix.

Figure 1 shows the unique yellow and blue hue locations and the D axis. Colors on the D axis are perceived as neutral by Deuteranopes. The blue primary is placed on the alychne. Points on the alychne have no luminosity. They are purely chromatic and non-luminous stimuli. Therefore, changes in the blue primary result in a change of the white point but produce no change in either the A or Y tristimulus values.

The location of the blue primary simplifies illuminant correction in digital photographs. The loci of the D illuminants over the range of color temperatures of 4,000 to 20,000 degree Kelvin are shown on Figure 1. The D illuminants lie on or close to the yellow-blue axis. Therefore, an adjustment of the blue primary's output is all that is required to change the color temperature of a reproduction.

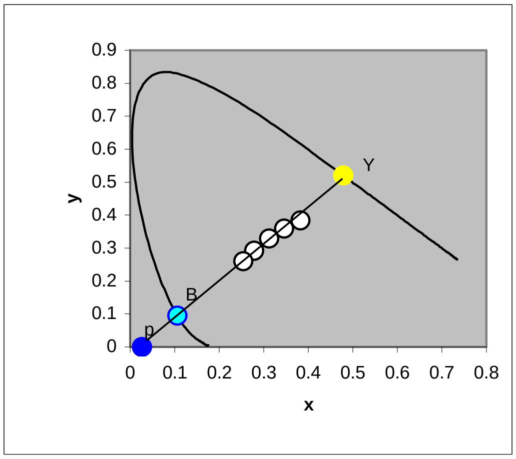


Figure 1 Blue Primary and D axis

The T axis of the ATD system lies on the line that passes thru the unique red and green hues as shown on Figure 2. Tritanopes will interpret all colors that lie on this line as neutral. Figure 3 shows both axes and the D illuminant data. This figure yields the surprising result that the axes intersect at the chromaticity coordinates of the D65 illuminant. This suggests that illuminant D65 is the natural set point for white.

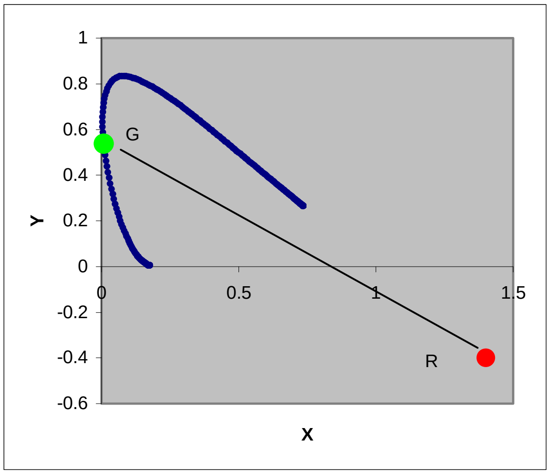


Figure 2 T axis of the ATD Color Space

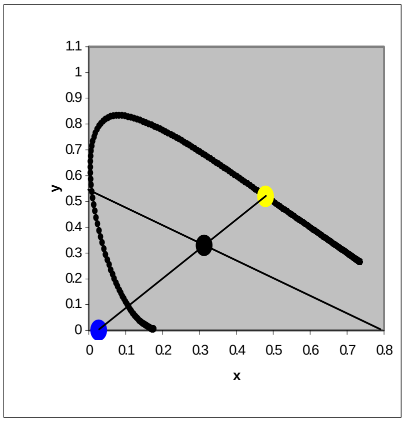


Figure 3 D65 Neutral Point

The red and green primary selection is much more complicated. These primaries must lie on a line that is parallel to the D axis. This is done to approximate the behavior of the tritanopic system. The line is also constrained to pass thru the spectrum locus at 575 nm. This is necessary to produce compact support for colors in the red-green region. The primary separation and location on the red-green line is selected so that the *IQ*RGB color space provides compact support for the most saturated colorants found in nature and industry. The gamut of these colors is called the Real World and is shown on Figure 4.

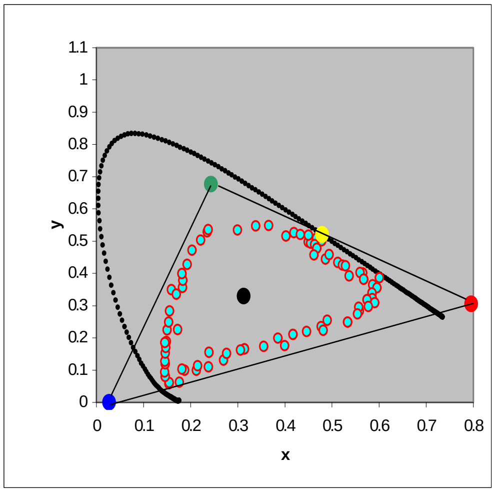


Figure 4 The Real World

The red and green primaries must be adjusted to simultaneously provide a compact support for the Real World and produce a uniform color space. In addition, the matrix relation between *IQ*RGB, CIEXYZ and the relationships and positions of the primaries are not arbitrary. ATD is created so that the luminosity function, A, of the ATD color space is proportional to Y of CIEXYZ. The resulting *IQ*RGB-ATD color space is described below.

The *IQ*RGB-ATD Color Space

The intent of the *IQ*RGB color space is to create a RGB primary set that is based on the actions of the human visual system. The chromaticity locations of the *IQ*RGB primaries are chosen so that a matrix transformation of the primaries yields a perceptually equal color space. The coefficients of the matrix must be integers, and all mathematical operations are performed in integer math. The relation between *IQ*RGB and the ATD color space is;

$$\begin{array}{c} A \\ T \\ D \end{array} = \left| \begin{array}{ccc} 1 & 3 & 0 \\ 1 & -1 & 0 \\ 1/2 & 1/2 & -1 \end{array} \right| * \begin{array}{c} R \\ G \\ B \end{array} \qquad (1)$$

There is a similar but non-integer matrix between the CIEXYZ tristimulus values and those of ATD. The matrix is;

$$\begin{array}{c} A \\ T \\ D \end{array} = \left| \begin{array}{ccc} 0.0000 & 4.0000 & 0.0000 \\ 2.5060 & -2.306 & -0.0688 \\ 0.4427 & 0.5988 & -0.9369 \end{array} \right| * \begin{array}{c} X \\ Y \\ Z \end{array} \qquad (2)$$

The relationships shown in Equations (1) and (2) assume a D65 white point and that (RGB) = (1,1,1) transforms to (XYZ) = (0.9501, 1.000, 1.088). The matrices given in Equations (1) and (2) define the primaries. The red primary is located at CIE (x, y), (0.7844, 0.3128), the green primary at (0.2602, 0.6650) and the blue primary at (0.0267, 0.0000).

The ATD color mixing functions, displayed on Figure 5, are computed using Equation (2). The figure shows that the mixing function for the achromatic vector, A, is scaled four (4) times that used for CIE Y. The factor of 4 is chosen to increase the precision of the integer math calculations to 10 bits and thus, eliminates the need for a compressive transformation of brightness. The diagram also shows that the transformation has kept the neutral points of the T and D vectors. The T color mixing function is zero at 475 and 575 nm where the T vector crosses the D axis. In similar fashion, The D color mixing function has no value at 500 nm where the D vector crosses the T axis.

The ATD tristimulus values are used in image manipulation to change tone scale or color balance. Rendering the image requires transforming the physical values to an appearance space. The next section of this paper discusses the development of a uniform color space. The appearance space maintains the same integer math and simple calculations, as did the definition of the ATD tristimulus values.

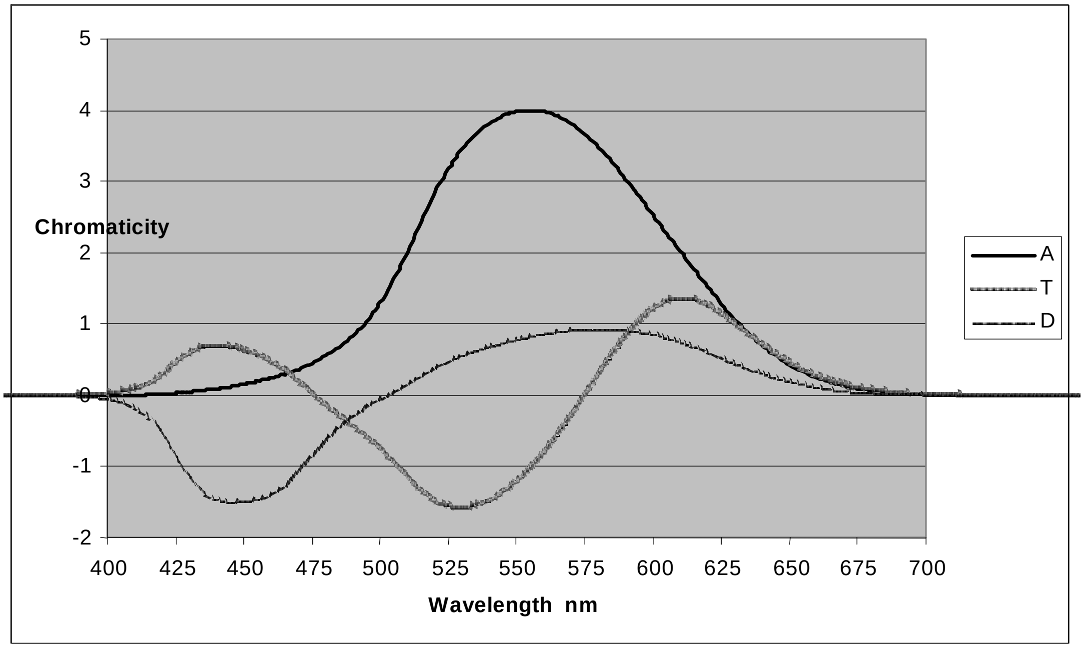


Figure 5 ATD Color Mixing Functions

Preliminary research shows that the chromatic channels' influence on the achromatic channel plays a large role in producing a uniform chromaticity space. Trial chromaticity coordinates are computed by dividing the T and D tristimulus by a normalization factor. This factor is determined by using arbitrary integer multipliers to modify the A, T and D vectors. The magnitude of the normalization factor is found to be a function of hue when the model coefficients are adjusted for best fit to large and small color difference measurements. The spectral shape of the normalization factor is similar to that of the Helmholtz-Kohlrausch, (H-K), effect (Wyszecki, 1982b).

The H-K effect or luminance additivity failure is well known. Highly chromatic colors usually appear brighter than the luminance value predicted by CIE Y. The model used in this paper assumes that the T and D channels of vision are either adding to or subtracting from the brightness of the A channel. Sanchez and Fairchild (2001) have measured the H-K effect for very chromatic colors. They use a monitor in their experiment to produce bright and highly chromatic samples. The brightness-lightness ratios determined by their research are shown on Figure 6.

A new vector Q is defined to model the brightness evoked by the combined actions of the A, T and D channels. The Q vector is a linear function of A, T and D. The coefficients of the model for Q are constrained to be integers and are adjusted to best fit the Sanchez-Fairchild data. The equation for the Q vector is;

$$Q = A + T/2 - D \qquad (3)$$

Although the Q model is very simple, it produces a good fit to the measured H-K effect. The brightness factor, Q, is used as the normalization factor in the definition of chromaticity. Q, shown in Equation 3, produces a very reasonable uniform chromaticity space for both large and small color difference data.

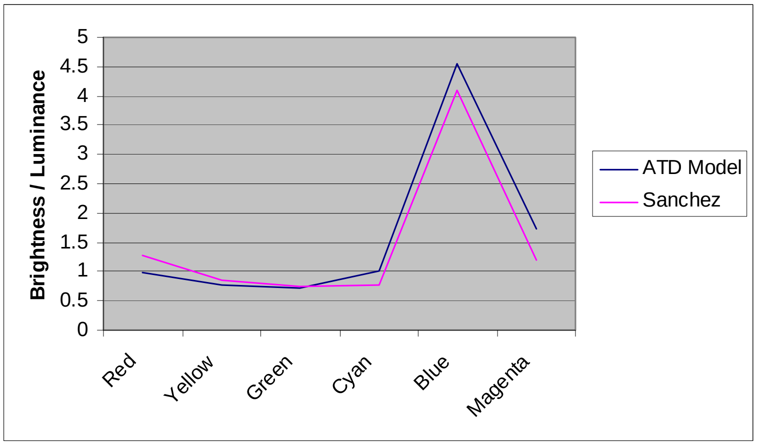


Figure 6 Brightness- Luminance Ratio

The chromaticity coordinates are defined as;

$$t = T / Q$$

and (4)

$$d = D / Q$$

The CIE 1931 spectrum locus is transformed and displayed as a function of the t and d chromaticity coordinates on Figure 7.

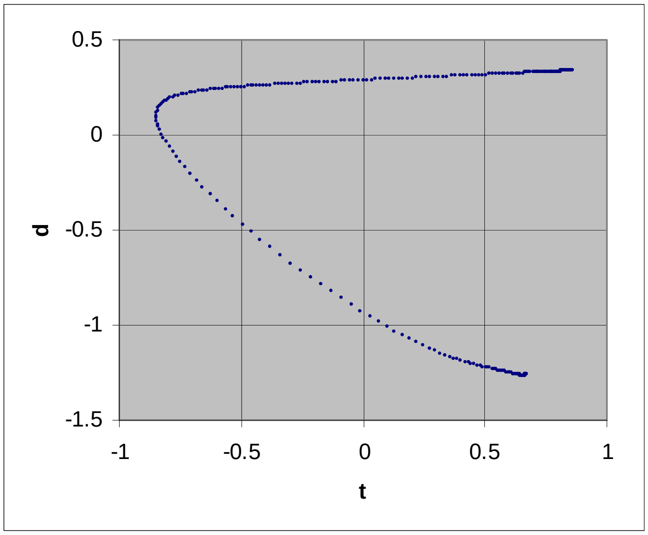


Figure 7 (t, d) Chromaticity Diagram

Testing the *IQ*RGB Model

The new RGB- ATD-Qtd model is compared with CIExyY and CIELAB to illustrate the ability of the model to predict a wide variety of vision data. All test are made at a relative luminance CIELAB L* of 50.0 and a D65 white point. The H-K effect is already modeled in the development of the chromaticity space as shown on Figure 6. The H-K effect is not modeled by either of the comparison spaces.

Wavelength Discrimination

Wavelength discrimination is a test of the uniformity of the spaces for the most saturated color, those on the spectrum locus. Figure 8 shows the wavelength discrimination data measured by Wright and Pitt (Wyszecki, 1982c).

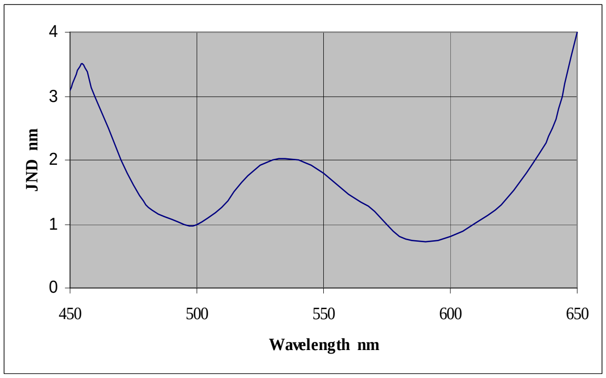


Figure 8 Wavelength Discrimination -Wright & Pitt

Wavelength discrimination for *IQ*RGB and CIELAB is modeled by transforming the CIE 1931 chromaticity diagram to (t, d) and (a*, b*) and taking the inverse of the distance between adjacent 1 nm points on the spectrum locus as shown on Figure 7. The just noticeable difference (JND) between points is scaled to match the known visual data.

The Qtd wavelength JND versus wavelength is shown on Figure 9 and the *IQ*RGB JNDs are displayed on Figure 10. The comparison of the curves on these three plots shows that *IQ*RGB transformation best models the known wavelength data.

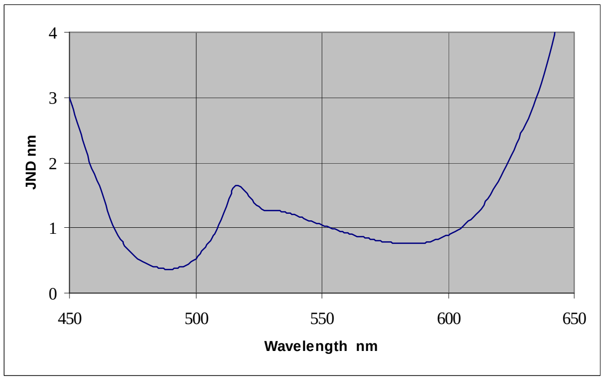


Figure 9 Wavelength Discrimination -*IQ*RGB

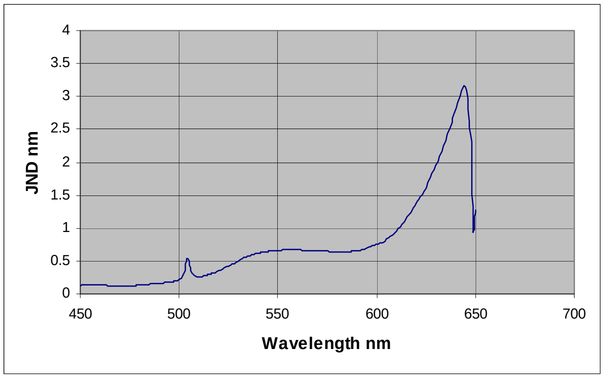


Figure 10 Wavelength Discrimination -CIELab

Large Color Differences

The Munsell Renotation System (Wyszecki, 1982e) is a well-researched uniform color scale. Figure 11 plots the CIE xyY data at the level where CIE-L* = 50.0. This data is corrected to a D65 white point. This is necessary since the *IQ*RGB color system assumes a D65 white. The figure displays the *IQ*RGB transformed Munsell data. In like manner, Figure 11 shows the D65 normalized Munsell data transformed to CIELAB. The CIELAB transformation produces exaggerated saturation spacing for the yellow region. The hue angle spacing appears to be less even with a large gap in the green region. The CIELAB lines of constant hue have much more curvature than those of *IQ*RGB. In comparison, the *IQ*RGB model generates uniform data point spacing. The chromatic data is arranged on this plot much like the color palette of an artist. The Qtd color space is mathematically uniform and allows a simple table lookup of the chromatic portion of the *IQ*colour rendering model.

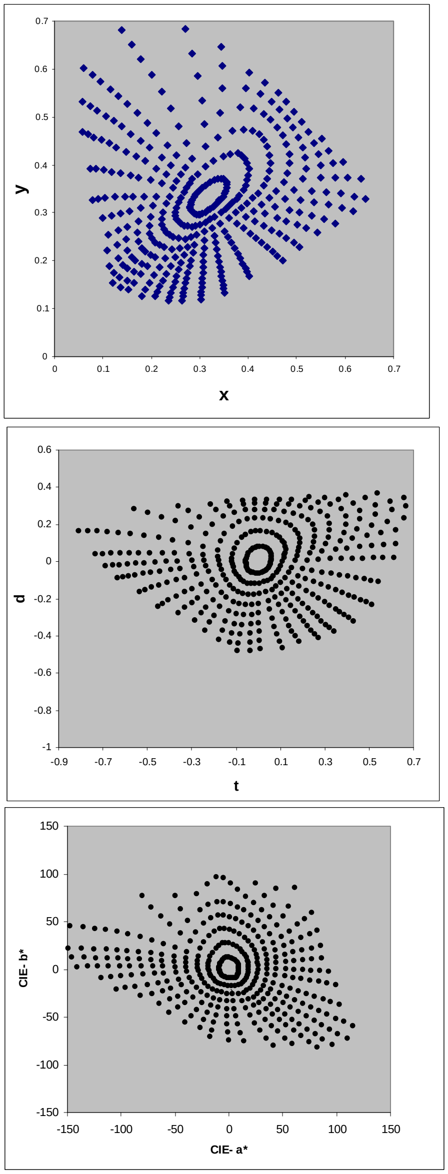
Shadow

The *IQ*colour rendering model includes a simple encoding of the shadows in a real image. The use of shadow follows the use of darkening components used by colorist and painters. The shadow is unique in that it does not use the colorant components that have been use in traditional image separation algorithms. The separation of color and shadow gives new degrees of freedom in the appearance rendering of an image.

*IQ*RGB and the Real World

*IQ*RGB, the companion ATD luminance- chrominance color space and the Qtd appearance space have been tested against a wide variety of visual data and are found to produce a reasonable uniform color space for application in the graphic arts.

We introduced the concept of the Real World of colors that encompasses all of the surface colors in nature and industry. The *IQ*RGB color space is an efficient vector set that is a compact support for the Real World. The *IQ*RGB vectors are chosen so that a simple binary integer transformation of the vectors produces a reasonably uniform color space. The ATD-Qtd color space is optimum for efficient communication of color data. As such, the model is not meant to be comprehensive and is limited to the graphic arts and for the communication of data in digital imaging.



CIExyY

*IQ*RGB

CIELAB

Figure 11 Munsell Renotation System

Color Management Problems

The choice of the CIELAB space for the profile exchange is one of the larger sources of problems. CIELAB is useful for color specification and control of small color differences. The space is nonlinear and does not preserve hue. The problems with CIELAB led to the development of the alternate ATD color space. The ATD space still does not address the problems found discussed below in using the ICC color system.

Color management methods currently employed are based on the premise that a three dimensional target space can be used to produce a transformation that will compensate for the nonlinearities of the devices being profiled. The problem is that this is a one size fits all solution.

The biggest problem with this solution is on input. Input devices such as Camera and scanners have Color Matching Functions not primaries. Therefore there is no gamut or gamut limits for input devises. The use of a calibration target limits the gamut range of the input device unnecessarily. An even greater problem is that the scanner filters are usually narrow band RGB band pass. The narrow band filters look nothing like the Color Matching Functions of human vision, the well known CIEXYZ functions. This filter mismatch results in a color error known as metamerism. Metamers are colors that have identical XYZ tristimulus values but have different RGB values when imaged by a camera or scanner. The problem with metameric error is that arbitrary colors cannot be used to calibrate the system.

Displays have a new set of problems. Over the last few years, CRT based displays are being displaced by a wide variety of flat panel displays. None of these new displays have the physical characteristics of the older CRTs. The use of color spaces like sRGB becomes irrelevant when the primaries and signal transfer characteristics of each type of display are different from the CRT and each other.

A larger problem that must be addressed is that the extant gamma adjustment methodsare nonlinear. This nonlinear transformation does not maintain the hue of colors that are close to cyan, magenta and yellow. This is a problem that must be solved if displays are to be used for soft proofing.

Printers have their own set of problems. Gamut mapping is always the big question with printing systems. The problem comes with intents. The current workable intents are relative colorimetric, appearance and saturation used for business graphics. The problem is still that we are trying to fit a problem into a one bag solution.

An investigation of a large number of printer types has shown that the problem is probably better addressed as a function of hue angle. Our investigation is done using the new ATD color space where lines of constant hue are nearly straight unlike the CIELAB color space. What we have found is that printers have nearly total gamut coverage particularly in the yellow and red region and are usually poor in the blue and cyan regions. This has lead our research into a new adaptive gamut mapping that is a function of the printer’s capability on a hue by hue basis.

Summary

The Universal IQRGB color space which includes the ATD color space has been shown to provide a uniform color space for the graphic arts. The new space will allow new definitions of Gamut mapping. Since all input source data can be expressed in a common wide gamut RGB, there is no longer a need to keep any information about the source of the image. Documents can be free of profiles because the image RGB is converted to the color space of the output device. The output can be a monitor or any kind of printer. This can be accomplished because the new Shadow approach to controlling darkness eliminates the need of repurposing the image content of a document.

References Cited

Granger, E.M.
1994 " ATD, Appearance Equivalence, and Desktop Publishing", SPIE, Vol. 2170
Sanchez, M and Fairchild, M
2001 " Perceptual Amplification of Color: Observer Data and Models," CIC9, Ninth Color Conference, Scottsdale, AZ
Wyszecki, G. and Stiles, W.S.
1982a "Color Science: Concepts and Methods, Quantitative Data and Formulae" (Wiley, New York), 2nd ed, 615 pp.
1982b, 410 pp.
1982c, 570 pp.
1982d, 871 pp.
1982e, 840 pp.
1982f, 309 pp.
1982g, 801 pp.