Color Standards in Graphic Arts and Photography—Past, Present, and Future

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Abstract

Both the photographic and graphic arts industries have undergone significant revolutions over the last two decades. Much of the driving force for these revolutions have been the dramatic increases in the capabilities and cost effectiveness of computing capabilities. This has led both industries to move from systems architectures that were based primarily on analogue technology into fully integrated digital and/or hybrid workflows.

One of the immediate impacts of these revolutions was the need for file format and data exchange standards to allow clear communication of image data both between systems and throughout the workflow. However, once color data could be exchanged, it was quickly realized that exchanging data without a clear definition of the meaning of the data was meaningless.

In this presentation I will describe the evolution of the standards that provide meaning to the color image data being exchanged within the photographic and graphic arts industries. While predicting the future state is always risky, I will also provide my vision for the future form of color data definition in these industries.

Introduction

To best explain the driving force behind the color related standards activities in both the graphic arts and photography, I have chosen to focus initially on the graphic arts. We will then move on to the photography, and to issues of imaging standards in general. The graphic arts is an interesting place to start because it has been producing colored images since the mid 1700s. However, it was not until 1980 that there was sufficient computer power to make it viable to store and manipulate images as digital data.

Prior to the introduction in 1980 of the first color electronic prepress systems (CEPS) all color image manipulation was done using either combinations of film, filters, and photographic masks or, electronic scanning systems that sequentially scanned, processed, and recorded on film small slices of an image using preset transforms. The goal was to produce CMYK separation films that when printed would produce pleasing results.

There were essentially no accredited graphic arts standards, certainly not any color standards. The only real standards used were those prepared by the photographic industry to define status density.

We will come back to those density standards later, but it is worth noting in passing that ISO assigns the identification number to international standards in sequence, and doesn't reuse numbers. The photographic standards for transmission and reflection density carry the number ISO 5. Yes, they were the fifth International Standard, or set of standards, prepared.

While it is true that in 1980 the graphic arts had the computer capability to store a complete image, to manipulate it, and conceptually to begin doing color transforms, things were not as rosy as you might surmise. Using the best custom systems available (the million dollar plus CEPS systems) a full page image could be rotated through any arbitrary angle in 20 to 25 minutes – yes, todays typical desktop PC does that in seconds. More complicated transforms took longer. In that same time frame, the color measurement and computations that we today do in a hand-held device in less than a second, took minutes or hours using the best tools available. We could not produce enough data to warrant color standards.

Today, the color science is still the same, and interestingly the color image manipulation concepts and algorithms have also not changed very much. The thing that has changed is our ability to compute, to store and handle larger files, to do it faster, and to send these files across town or around the world.

What Started Standards in the Graphic Arts

As long as film was the medium used to exchange graphic arts images, the industry felt no need of standards. Prepress and printing were "crafts" and everyone knew how to interpret film, or at least thought they did. Most importantly, you could look at it.

Digital data was a different matter. By 1982 there were 5 significant players in the graphic arts CEPS marketplace. All were storing images—text, line art, and pictures—as raster data. Files were 8-bit per channel CMYK dot values. But there were five schemes used to encode the dot values into the eight bits, and five of the eight possible orientations between the raster data and the image as viewed were used. (You can start scanning in any of the four corners of an image and scan either horizontally or vertically.)

This led some of us to create the first ANSI graphic arts standards committee. Its goal was to simply address ways to allow the sender of a file to tell the recipient sufficient information about the file to allow it to be faithfully decoded. The recipient could recreate the same CMYK data in the same orientation that the sender had intended. That was the ANSI IT8 committee that was known as DDES or Digital Data Exchange Standards and received its final ANSI accreditation in 1987. (Today, the work of the IT8 committee has been absorbed into an ANSI committee known as CGATS or Committee for Graphic Arts Technologies Standards. We will also talk later about ISO/TC130, Graphic technology and ISO/TC42, Photography.)

However, once data could be reliably transmitted, it became important to associate more meaning to the data throughout the graphic arts process. A key element of this data definition was the relationship between the digital data and the input or output color—the color characterization. Unfortunately, defining this relationship is not a simple task.

The Initial Graphic Arts Color Standards

The first steps into color data definition came through the creation of standard targets. First, a target to allow the color of a scanned photographic image to be related to the digital output of the scanner. Unfortunately, the responsivity of the typical scanner does not match human vision - is not colorimetric - and each manufacturer of photographic goods uses different dyes to create the color that we see. This means that one target is not enough.

The ANSI/IT8 committee chose to define the colors that should appear in the target, and then leave it to each manufacturer of photographic goods to produce targets using their dye sets. The committee also specified the data to be reported and an associated data format. This enables a user to build a color characterization for their scanner for that particular film type. These requirements are defined in the ANSI IT8.7/1 and ANSI IT8.7/2 standards. Their official titles are Graphic technology — Color transmission target for input scanner calibration and Graphic technology — Color reflection target for input scanner calibration. These two standards have been combined as ISO 12641:1997 Graphic technology — Prepress digital data exchange — Color targets for input scanner calibration. Targets meeting these standards are being produced by Kodak, Agfa, and Fuji and in many ways are the cornerstone of todays color management systems.

Output color characterization is both simpler and at the same time more complicated. The IT8 committee created a CMYK output target to enable the relationship between CMYK data and printed color to be measured in a consistent fashion. That target, IT8.7/3, contains 928 patches—combinations of CKYK dot values—that map both the single color scales as well as the overprint colors with varying levels of black. This same target has also been standardized in ISO as ISO 12642. While this target is used to characterize any particular printing condition, the more complicated part involves defining the printing condition as well as defining the related metrology issues associated with both measurement and process control.

Metrology Issues

The two metrology issues that required standards action were color and density. Color for obvious reasons and density because of its key role in process control. While the measurement of color and the computation of colorimetric parameters is clearly spelled out by the International Commission on Illumination, or the CIE as it is better know. Unfortunately, in some ways the CIE does too good a job. They describe how to measure color in under a wide variety of geometries and illuminants, and make no recommendations as to the specific conditions preferable for a specific application. And, in fact, the choice is often arbitrary. However, if one group chooses one arbitrary set of conditions and another group chooses a different set, they cannot meaningfully exchange data.

To facilitate the exchange of color data within the graphic arts, ANSI/CGATS (Committee for Graphic Arts Technologies Standards) chose a set of conditions and described these in CGATS.5, Graphic technology — Spectral measurement and colorimetric computation for graphic arts images. This became ISO 13655 with the same title. The conditions are not earth shaking, simply practical, and when followed allow data to be reliably exchanged. These standards specify D50 illuminant, 2 degree observer, diffuse/normal geometry for transmission and 0/45 degree geometry with black backing for reflection.

While the graphic arts industry has used the ISO 5 series of photographic density standards as the reference for graphic arts applications they do not exactly fit. There is no reference to the measurement of halftone images, polarization, computation of density from spectral data, etc. Recent work in ISO TC130, Graphic technology, to create an international standard for graphic arts densitometry has led to the creation of a joint working group (JWG) between TC130 and TC42 to revise the full set of densitometry standards. The intent of this revision is to better include the needs of the graphic arts industry and at the same time to clearly separate the definitions of the various "types" of density and the requirements and tolerances on the measurement of density.

Before you remind me that density is not a measure of color, let me point out that filter densitometry is a far more practical tool for process control that colorimetry. Both the cost of the equipment and the ability to select a filter set (a status) that is most sensitive to the colorants being used are attractive. It is also true that when the spectral characteristics of the specific pigment or dye being used is fixed, as they are in a given ink or photographic dye, then the same density results in the same color. Given this, the

ISO 5 density standards are an important part of the color standards for graphic arts and photography.

While viewing conditions are not a metrology issue, they are closely allied. As expected the viewing conditions for graphic technology and photography closely parallel the color metrology standard. A joint working group of TC42 and TC130 has just completed a revision of ISO 3664 who's new title is "Viewing conditions — Graphic technology and photography". This replaces the earlier 1975 version of this standard and the ANSI viewing standard, PH 2.30 has been withdrawn in favor of the new ISO standard.

ISO 3664 specifies CIE illuminant D50 and defines three measures of the fidelity with which the spectral power distribution of the actual viewing illumination must match the spectral power distribution of D50. These measures, which must all be met, are chromaticity coordinates, color rendering index, and metameric index in both the visible and UV portions of the spectrum. In addition a level of 2000 lux is specified for comparison of images, such as a print to a proof, and 500 lux for the evaluation of the appearance of an individual image. This new viewing standard also includes recommendations for the viewing environment for the use of CRT monitors and for the display and judging of photographic art work.

Process Control as a Part of Color Standards

In graphic arts, the final image data used to create the proof or printed sheet is usually expressed as relative amounts of cyan, magenta, yellow, and black (CMYK) ink areas, usually thought of as the intended dot values. While any instance of the relationship between these data values and the color that results on the printed page can be measured using the IT8.7/3 target described above that relationship is dependent on many variables, most of them only partially controlled or sometimes even unknown. A partial list would include the color and transparency of the ink in the can, the paper, the interaction of ink and paper (and water in offset printing), the computer data to film to plate changes in dot size, the screen ruling and dot shape used for printing, the printing characteristics of plate and press (or other process) used, etc.

In most of the world, the traditional process has been to use a proofing system that generally simulates the average values of the printing process to be used. When the image appearance on the proof is satisfactory, the relative amounts of CMYK are deemed to be correct. The color proof, the halftone films produced from the electronic data (or the electronic data itself) are then given to the printer who is responsible for doing whatever is necessary to produce a printed sheet on the equipment that matches the proof.

However, the advances in available computer power, the increased use of electronic data exchange, and the advent of digital proofing systems is changing this process. For the first time in history, the computer power necessary to manipulate images in real-time is becoming available at reasonable cost. We can reasonably consider transforming images based on colorimetric analysis and computation using color management principals. Equally important, more and more images are available in electronic form and digital input color proofers are a proven and accepted technology.

Within the graphic arts, the two meaningful definitions of the "color" of electronic image data are either the color that is expected from a specific printing process, or a colorimetric definition of the color desired regardless of the printing process used. For either of these definitions, all of the steps between the data in the computer and the final reproduction must be defined and/or characterized before any real tie exists between the data and reproduced color. This has required a major change in thinking and practice within the printing industry that has only recently been accepted and is slowly being implemented.

There are many new process control standards already in place or still being developed that support this approach. These include standards for ink, paper, printing conditions, targets, test images, and printing characterization.

In the study of any color reproduction system both subjective evaluations (by viewing the final output image) and objective evaluations (by measurement of control elements) play a role. Because the results of subjective evaluations are strongly affected by the image content, it is often difficult to compare results when common images are not used. In response to this need ISO/TC130 created ISO 12640, a set of test images consisting of 8 natural images (pretty pictures) and 10 synthetic images. These are all encoded as CMYK raster data. These data are recorded on a CD-ROM. The natural images include flesh tones, images with detail in the extreme high-lights or shadows, neutral colors, colors in the brown and wood tone area, memory colors, complicated geometric shapes, fine detail, and highlight and shadow vignettes. The synthetic images include resolution charts, uniform vignettes in both the primary and secondary colors, and a physical representation of the CMYK data set defined in ISO 12642 for the characterization of 4-color process printing. It is worth noting that this is one of the first ISO standards that includes image data as a normative part of the standard.

While the test images contained in ISO 12640 have proven very useful, they are in CMYK and, therefore, have already undergone the tone scale mapping and gamut compression required for pleasing reproduction on the printed sheet. As we move more and more into the evaluation of color management systems and the use of data encoded in other color space definitions, there is a need for additional sets of test images. In response to this need, TC130 has undertaken the creation of additional sets of images, to complement ISO 12640. Two sets are currently being considered. One will be restricted to the sRGB gamut which represents typical monitor data. The other will probably be a "large gamut" set encoded as CIELAB data. For the large gamut set, natural images will be selected and scanned to maintain as large a color gamut as possible, consistent with pleasing images. Synthetic images will encompass the full data encoding range selected. This image work is typically referred to as XYZ SCID, even though the eventual encoding of both sets will probably be CIELAB.

The testing of ink, and the measurement and definition of ink color, is a key link in the chain leading to control and standardization of the printing process. ISO 2846-1:1997, Graphic technology — Color and transparency of ink sets for four-color printing — Part 1: Sheet-fed and heat-set web offset lithography printing, is the first of a series of standards that address the color of the ink in the can. Additional parts of ISO 2846 include: Part 2: Coldset web offset lithographic printing on newsprint, Part 3: Gravure printing, Part 4: Screen printing. and Part 5: Flexography.

While targets and measurement standards are important for the characterization of an output process, such characterization is of little value if the process being characterized is not defined or repeatable. CGATS.6:1995 Graphic technology — Specifications for graphic arts printing — Type 1, based on SWOP, was the first printing process control standard. In TC130, ISO 12647 Graphic technology — Process control for half-tone color separations, proofs and productions prints is being prepared as a multi-part document. ISO 12647-1:1996 Part 1: Parameters and measurement methods, identifies those parameters that are used to define a printing process. The subsequent parts of the document provide the detailed parameters for different classes of printing. Work is completed on ISO 12647-2:1997 Part 2: Offset processes and ISO 12647-3:1997 Part 3: Coldset offset and letterpress on newsprint. Work is ongoing for Part 4: Gravure printing, and Part 5: Screen printing, and Part 6: Flexographic printing.

Reference Printing Conditions

The increasing use of electronic data exchange, coupled with todays computer power and color management technology, means that print-ready images no longer need to be the exact CMYK values needed by the printing plate. As long as the color gamut of the intended output is specified, along with the relationship between the CMYK code values used and the printed color expected, the data is fully defined. In fact, using output profiles defined by the ICC (International Color Consortium) architecture, the specific CMYK data needed can even be created from a wide variety of three component color data types.

This has led to the proposal that a limited number of reference printing conditions may be adequate for most data exchange and color proofing applications within the graphic arts industry. In this context, a reference printing condition consists of a defined color gamut and an arbitrary set of characterization data to related the CMYK data values to printed color. Because of the nature of ink lay-down on paper, each gamut step is associated more with the type of paper used than with any other characteristic of the printing. It is true that some processes will be able to achieve a larger gamut on a given paper than others. For example, for any grade of paper, gravure can probably achieve more gamut than can offset. As long as the steps in gamut are reasonably spaced this should not present any problem, but rather will make it easier to make trade-offs between paper, process, run length, etc.

It is believed that as few as four or five such reference printing conditions will cover the full printing gamut available, in reasonable steps. Some of the proposed conditions are: premium printing, commercial printing on 60# plus paper with brightness greater than 75; publication, as represented by the current SWOP TR001 aims; newsprint, essentially the SNAP (Specifications for Non-heatset Advertising Publications) aims currently in final development; with one or two utility conditions between SWOP and SNAP, probably super calendered paper and machine finished uncoated paper.

These reference printing conditions would become the interface between prepress and the printer. Image data would be adjusted such that it was optimized for printing with the gamut of the selected reference printing condition. CMYK data aims (either real data or color management profiles) would also use the reference data encoding. Digital color proofing inputs would be based on these gamut and data encoding information.

While final agreement as to the number of reference printing conditions needed and their definition is still ongoing, a number of candidate data sets are being developed. The first set of publicly available color characterization data for a major printing process is contained in ANSI CGATS TR 001:1995, Graphic technology — Color characterization data for Type 1 printing. (Type 1 Printing is directly related to SWOP proofing which is the industry aim for publication advertising in the United States.) This characterization data is being used as the aim for both offset and gravure printing. ANSI/CGATS is also developing similar data for printing on newsprint where the printing process include offset, letterpress, flexography, and gravure.

Within TC130, printing samples based on the conditions defined in ISO 12647-2 have been prepared by the German printing research institute, FOGRA, and measured data is being evaluated for use in preparing a set of ISO Technical Reports. In addition, the Japanese National Standards Body has prepared a Japanese standard providing color characterization data for a publication printing condition identified as “Japan Color”.

Color Standards in Photography

We have already discussed many of the standards being developed by TC42/WG3 in the area of densitometry, viewing conditions etc. Many of these, reflecting their broad applicability, are joint activities with ISO/TC 130. In addition TC42/WG18 is actively involved in developing a series of standards that support electronic still picture imaging. Like the work in TC130 these include issues of file formats, color characterization, and color encoding.

While these may at first blush look like color standards they all bear on the quality of the color image delivered.

Two of these projects are again joint activities with TC130. ISO 17321, Color characterization of digital still cameras (DSC's) using colour targets and spectral illumination, will include provisions for both spectral measurement techniques as well as the use of colored targets. The second joint activity is a new proposal for a multi-part standard for "Extended colour encoding for digital still image storage, manipulation and interchange". The goal will be to define one or more large gamut color space encodings to allow the full range of scene and or captured images to be efficiently recorded.

Other TC42/WG18 projects include: ISO 12231, Photography - Electronic still picture cameras - Terminology; ISO 12232:1998, Photography - Electronic still picture cameras - Determination of ISO speed; ISO 12233, Photography - Electronic still picture cameras - Resolution measurements; ISO 12234-1, Photography - Electronic still picture cameras – Removable memory - Part 1: Basic removable memory reference model; ISO 12234-2, Photography - Electronic still picture cameras – Removable memory - Part 2: Image data format - TIFF/EP; ISO 12234-3, Photography - Electronic still imaging – Part 3: Design rule for camera file system (DCF); ISO 14524:1999, Photography - still picture cameras- Methods for measuring opto-electronic conversion functions (OECFs); ISO 15739, Photography - Electronic still picture imaging - Noise measurements; and SO 15740, Photography – Electronic still picture imaging - Picture Transfer Protocol (PTP) for Digital Still Photography Devices.

Other Activities That Impact Graphic Arts and Photography

Two other standards activities that have a strong impact on both photography and graphic arts are the work of CIE Division 8 and the International Color Consortium (ICC).

CIE Division 8, Image technology, was formed in 1998 in response to strong inputs from the imaging industry. Its terms of reference are "To study procedures and prepare guides and standards for the optical, visual and metrological aspects of the communication, processing, and reproduction of images, using all types of analogue and digital imaging devices, storage media and imaging media." A full description of the work of Division 8 is not appropriate here, but the interested reader is directed to www.colour.org.

The ICC is currently an industry consortium that has indicated interest in moving their work into the accredited standards arena when it has been tested and validated. Much of the industry work in color management and color data exchange builds on the color management architecture model of the ICC and on their profile format specification. Central to this architecture is the concept of a profile connection space that provides a reference environment to which images can be referenced. Profiles relate input and output device code values to the image appearance in the profile connection space. Within the ICC architecture profiles may have different intents: colorimetric, perceptual, or saturation preserving. Again, a discussion of the ICC is not appropriate here and the reader is directed to www.color.org (Note that this is not a typo but simply two variations in spelling of the word that describes the key focus of these groups.)

Where Are We Going ?

As the joint activities between TC42 and TC130 indicate, particular technology issues are no longer restricted to one application area. The model for future standards development will be cooperative activities between application groups to ensure that the standards developed will have broad applicability. Even more importantly, many of the key activities are outside of the traditional ISO or IEC standards arenas. The real challenge for all of us involved in standards development is to find ways to co-ordinate the work of these diverse groups to minimize the overlap or conflicts and maximize the interoperability between the standards and specifications developed. We do not have the luxury of either time or budget to tolerate duplication of effort or competition between groups.

Another challenge to the accredited standards process (the ISO and IEC) is to find ways to build upon the work of industry vendors (defacto standards like Adobe's Postscript and PDF), trade groups, and consortia (like the ICC). We must find ways to bring the work of these groups into a common environment with the traditional standards where the various classes of standards can complement each other rather than be seen as competing. Fortunately, both ISO and IEC are working to develop procedures for fast tracking industry or "publically available specifications" (PAS) to enable them to be recognized within the traditional standards environment.

As the pace of technology quickens, and as the available manpower and budgets tighten, we must continue to develop ways to move the standards process forward more quickly. Whether it is in a single company, a trade group, a consortia, or an accredited standards committee, the pacing item is always reaching agreement between competing interests to find a workable common solution. Once technical agreement is reached, creating a specification or standard moves quickly. The only time advantage that companies, trade groups, and consortia have is that the smaller the group the more arbitrary the decisions and the fewer the inputs that must be considered. Unfortunately, this is often counter to broad applicability. This then is the conundrum, how to reach broad consensus on technical solutions quickly!

More Information

More information about these standards activities can be found at various web sites. A short list of those directly involved include:

Graphic arts: www.npes.org, www.din.de;
Photography: www.pima.net;
General: www.iso.ch, www.iec.ch.

Biography

David Q. McDowell, a 1957 graduate of the University of Rhode Island with a B.Sc. degree in Engineering Physics, recently retired from his position as a Senior Technical Associate in the Professional Imaging Division of Eastman Kodak Company where he worked for 42 years. In retirement, he is continuing his involvement with the national and international standards activities.

McDowell is the Chairman of ISO/IEC Joint Technical Advisory Group (JTAG) for Image Technology, Chairman of the US Technical Advisory Group (USTAG) to ISO/TC 130 (Graphic technology), Chairman of CGATS/SC8 (Color Data Definition), Secretary of TC42/JWG21 (Revision of ISO 5), and Secretary of CIE Division 8 (Image Technology). He is also the IS&T Standards Chair and Standards Editor of the IS&T Newsletter.

He is a longtime member of both IS&T and TAGA and is a past president of TAGA.