Graphic Arts Color Standards

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Abstract: The initial standards thrust in the printing and publishing industry, in the mid 1980s, was to developed standards that would allowed the exchange of electronic data files. However, as soon as the initial data exchange standards were developed, it became critical to define the meaning to the image data being exchanged. The only logical meaning that can be associated with CMYK image data is the color that data is expected to produce on the printed page. However, to define the relationship between printed color and input data requires that the inks, printing processes, measurement tools, characterization targets, and the colorimetric references all are defined and/or standardized.

This requirement led to standards development in both ANSI/CGATS (Committee for Graphic Arts Technologies Standards) and ISO/TC130 (Graphic technology). While at first blush the standards that resulted from this work do not seem to be "color" standards, they are the essence of the definition of "graphic arts color".

The Evolution of Graphic Arts Color Standards

For those not familiar with the standards activities within the graphic arts industry, it is important to briefly summarize the origins of these activities. In the early to mid 1980s, the need to move data between electronic prepress systems was the motivation for the graphic arts industry to become involved in technical standards—virtually for the first time in its history. Once the basic file formats for data exchange were developed, it became obvious that to make effective use of the ability to move data, the meaning of the data being moved

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must be better defined. A key element of this data definition includes the relationship of the data and the intended color output—the color characterization. Unfortunately, this is not a simple task.

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. The relationship between these data values and the color that results on the printed page 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. The industry has an opportunity to change, to both improve the quality of the printed product and to achieve efficiencies that will reduce cost at the same time.

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.

Let's look at the standards already in place and still being developed that support the definition of color within the graphic arts industry. These include standards for measurement, characterization targets, test images, viewing conditions, ink color, process control, and printing characterization.

Key Existing Graphic Arts Color Related Standards

The key existing graphic arts standards closely related to color definition are ISO 13655:1996 *Graphic technology — Spectral measurement and colorimetric computation for graphic arts images*, ISO 12641:1997 *Graphic technology — Prepress digital data exchange — Color targets for input scanner calibration*, ISO 12642:1996 *Graphic technology — Prepress digital data exchange — Input data for characterization of 4-color process printing*, ISO12640:1997 *Graphic technology — Prepress digital data exchange — CMYK standard color image data (CMYK/SCID)*, and ANSI/CGATS TR001:1995 *Graphic technology — Color characterization data for Type 1 printing*. (Equivalent, and prior, ANSI standards are CGATS.5 for ISO 13655, IT8.7/1 and IT8.7/2 for ISO 12641, and IT8.7/3 for ISO 12642.)

ISO 13655 builds on the work of the CIE and defines specific conditions for both metrology and computation of colorimetric data for graphic arts applications. It specifies 0°/45°E or 45°E/0°E geometry for reflection measurements and normal/diffuse (0°/d) or diffuse/normal (d/0°) for transmission measurements. For reflection measurements, a black backing is specified to provide consistency with the densitometry specifications of ISO/TC42 Photography.

For computation of the colorimetric parameters, CIE illuminant D50 and the 1931 standard colorimetric observer (2 degree) are specified. Further, it was felt that specific weighting functions were important to minimize the differences that can arise because of computational techniques and interpretation. Weighting functions for band pass intervals of 10 and 20 nm, drawn from ASTM E308-1985 Standard Method for Computing the Colors of Objects by Using the CIE System, are included. The ASTM recommendations concerning the handling of data for wavelengths beyond the upper and lower values actually measured are also incorporated in this International Standard.

ISO 12641 combines, into one International Standard, the more widely known ANSI IT8.7/1 and IT8.7/2 standards, which describe transmission and reflection targets for input scanner calibration. The technical requirements of ISO 12641 are identical to those of the ANSI standards and most targets being manufactured today carry the ANSI designation. Currently, targets are being manufactured by, and are readily available from, Eastman Kodak Company,

Agfa-Gevaert N.V., and Fuji Photo Film Company. These standards define both the physical layout and colorimetric aim values for these targets. Manufacturers are free to provide either “calibrated” targets or “batch” targets. Under either option, colorimetric data must be made available to users. In the case of batch targets the batch average data must be accompanied by appropriate batch statistics. (Eastman Kodak Company has chosen to make batch average data for their targets available from an Internet site: ftp://ftp.kodak.com/gastds/q60data.) Although the target colorimetric aims were designed around the characteristics of color transparency film and photographic paper, the standards are sufficiently open for the aim values to be used with almost any color reproduction material. These targets are almost better known by the Kodak “Q60" designation than by their official IT8 designation.

ISO 12642, the output data set, defines a data set of 928 combinations of CMYK dot values that are used to create characterization data for CMYK imaging processes. This International Standard is identical to ANSI IT8.7/3, of the same title, and is more widely known by the ANSI designation. A particular arrangement of these data has been included as a raster image in ISO 12640 (see below), and this arrangement has been used extensively in graphic arts printing characterization work. Many of the scanner calibration and color management vendor packages use all or part of this target data set, often with a different arrangement of patch locations than found in the typical ANSI/ISO layout. The most widely known printing characterization data, based on this standard, is for the US SWOP (Specifications for Web Offset Publications) publication proofing specification. It is documented in ANSI Technical Report ANSI/CGATS TR001.

ISO 12640, known as the SCID images, is one of the first ISO standards that includes image data as a normative part of the standard. 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 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 formatted in accordance with ISO 9660. The file format is TIFF/IT as defined in ISO 12639. 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.

Other Graphic Arts Standards That Support Color

Complete output process characterization requires that all of the steps between the data in the computer and the final reproduction, that may potentially affect the color of the printed image, must be defined, controlled, and characterized. Different issues must be addressed at various stages of the process. The ink maker and the printer need to be able to define the color of the ink in the can. The pressman cares about the color of the ink on the particular printing stock being used along with the other process control parameters that define the printing process. The color separator needs data that relates the color printed in both the solid and overprint areas to the input CMYK data for a particular ink set and printing process. Each is part of the overall color characterization of the printed output, but to some extent can be specified independently.

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 heatset web offset lithography printing* is the first of a new series of standards that address the color of the ink in the can. Additional parts of ISO 2846, already in process in TC130, 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 multipart 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 just starting on *Part 6: Flexographic printing*.

New Activities

Change is the order of the day within both the standards community and the graphic arts industry. This applies equally to the standards being developed and to the underlying concepts that they are intended to support. We are clearly seeing a need to move to new understandings of color definition and new tools to evaluate color reproduction.

Test Images

While the test images contained in ISO 12640 have proven very useful, they are in CMYK and 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 (being standardized by IEC/TC100) gamut that 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.

Colorimetric Characterization of Printing

ANSI CGATS TR 001:1995, *Graphic technology — Color characterization data for Type 1 printing*, is the first set of publicly available color characterization data for a major printing process. (Type 1 Printing is directly related to SWOP proofing). Following this lead, work is also underway to provide color characterization data for other printing conditions.

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". Within the United States, The Gravure Association of America (GAA) is studying color characterization data for gravure printing on several paper grades. Similar work is being done in Europe, Japan, and Brazil. In addition, CGATS is working with the SNAP

(Specifications for Non-Heat Advertising printing) Committee to characterize printing on newsprint.

This work has also led to a new concept called "reference printing conditions" that is being studied. The increasing use of electronic data exchange, coupled with today's 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.

The current proposal is 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 laydown 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.

At the printer, individual printing conditions (press, ink, plate making, etc.) would be calibrated to match the gamut of one or another of the reference printing conditions. When so calibrated, characterization data could be prepared. Based on these data, transforms could be created to modify the reference data to the data needed by the specific printing setup (press etc.) to be used. In this way, printed results could easily match the provided proof and the colorimetric results defined by the reference printing conditions. This would allow prepress and printing to be far more decoupled than it is today, but consistent matching of results between prepress, proofing, and printing could still be achieved across a wide diversity of printing organizations.

Other Standards Activities that Affect Graphic Arts Color

The graphic arts industry also draws heavily on standards developed in other technical areas and in industry consortia. Some of these activities that specifically impact on color are noted below.

Densitometry

ISO/TC42, Photography, is one of the older ISO standards committees that is actively involved in imagery. While we do not think of densitometry as a color related standard, densitometry is the key to much of the process control used in the graphic arts. As noted above, without process control, quality printed color simply cannot be achieved. The ISO 5 series of standards therefore is a key reference for graphic arts as well as photography. ISO 5, *Photography — Density measurements*, has a number of parts that are: *Part 1: Terms, symbols, and notations, Part 2: Geometric conditions for transmission density, Part 3: Spectral conditions,* and *Part 4: Geometric conditions for reflection density.*

Viewing Conditions

An often overlooked issue is the reality that the three dyes used in photography and the four pigments used in printing, depend on metameric matching under specific viewing conditions to allow us to visually match one to the other. The proliferation of new technologies used for proofing of graphic arts images adds to the complexity of the issue of metameric matching. The colorants and overprint characteristics of dye sublimation, inkjet, photography, etc. vary widely and can only match under carefully defined viewing conditions.

Viewing conditions for graphic arts are currently defined in an ISO/TC 42 standard called ISO 3664:1975, *Photography — Illumination conditions for viewing color transparencies and their reproductions*, and in ANSI PH2.30-1989, *Graphic Arts and Photography — Color Prints, Transparencies, and*

Photomechanical Reproductions — Viewing Conditions. A joint TC42/TC130 special task force on viewing conditions has created a revised version of the viewing conditions standard. The revised document is ISO 3664, *Viewing conditions — For graphic technology and photography*, which has received approval as a DIS. Preparation of the FDIS and final publication is expected early in 1999. It is expected that this same document will receive ANSI endorsement and will replace ANSI PH2.30.

Two of the key changes, from prior versions of the standard, are the introduction of spectral power distribution specifications in the wavelength region of 340 to 400 nm in consideration of fluorescence issues, and the introduction of CIE Publication 51, in addition to the color rendering index (CRI), to evaluate compliance of the spectral power distribution of a source to that of D50.

Also included in the new standard are two levels of illumination. One, for critical comparison between two or more images, specifies an illuminance of 2000 ± 500 lux. The other, for practical appraisal of tone reproduction, inspection, etc. of a single image in isolation, specifies an illuminance of 500 ± 125 lux. The specification of viewing conditions for color monitors is also included. Conditions for the display of prints in galleries etc., addressed in earlier standards, will be included in an informative annex rather than in the main body of the standard.

Electronic Photography

WG 18 of TC42 is actively involved in developing a series of standards that support electronic still picture imaging. These include such issues as methods to determine ISO speed, resolution, noise, as well as file formats, command structure, removable memory, etc. (A full listing of these document is available at www.pima.net/standards/tc42.htm.)

Of particular interest from the color perspective is ISO17321, Graphic Technology and Photography - Colour target and procedures for the colour characterisation of digital still cameras (DSCs). This activity is also a joint project with ISO/TC130 and is presently at a 2nd working draft stage of development. The scope of this standard is : This International Standard shall specify a colour target, metrology, and procedures for the colour characterization of digital still cameras to be used for photography and graphic technology. Such characterization shall be limited to DSC data that either has not been processed for colour, or has been processed to estimate scene or original colorimetry (as opposed to the colorimetry of a reproduction)."

CIE Division 8

A recent new development has been the formation of a new division of CIE, which has as its responsibility the broad area of image technology. The terms of reference of this new division 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."

Five technical committees have been formed and started work. All will provide tools useful to the graphic arts. Their titles are: TC8-01: Colour Appearance Modeling for Colour Management Applications; TC8-02: Colour Difference Evaluation; TC8-03: Gamut Mapping; TC8-04: Adaptation Under Mixed Illumination Conditions; and TC8-05 Communication of Colour Information.

International Color Consortium

The International Color Consortium (ICC) is playing an increasingly important role in the area of color definition. Although the ICC is not a formal standards organization, it is in the business of building specifications that will assist the exchange of color information. It is hoped by many that the ICC consortium will eventually agree to move its work into one of the accredited standards activities.

Summary

Much of the work relating to color standards, being done within the graphic arts community, is specific to graphic arts. However, the metrology, methodology, and overall results will have broad reaching impact on many other color reproduction areas. In particular, the characterization test targets, color characterization data, and viewing standards have applicability in almost any color imaging area. Successful integration of color across all application areas requires increasing cooperation between groups. Color images can no longer be classified as unique to a specific application. They must be transportable. This requires consistent color data definition and file format architectures.

References and Acknowledgments

A summary of all of the applicable documents and references is simply to voluminous to consider. For more information the reader is directed to the web site of NPES The Association for Suppliers of Printing , Publishing and Converting Technologies (http://www.npes.org/standards/index.htm). NPES is the trade association providing secretariat support for the graphic arts standards activities in the United States.