Print-to-Proof Match: What's Involved?

Understanding what is needed to use measurement data to predict the quality of a match between a proof and a print.

BY DAVID Q. MCDOWELL

One of the most frequent production decisions made in the printing industry is to answer the question, "Do the print and proof match?" Wherever it is made—in prepress, in the press room, by the purchaser of a proofing system, by a trade association certifying proofing systems, etc.—it is a decision that today is based on a visual comparison.

Many, particularly those trying to certify proofing systems, would like to be able to use measurement data to predict the quality of a match between a proof and a print. The ultimate goal is to remove the human element, the visual comparison, with all its uncertainty and individual bias.

On a parallel note, recent discussions of digital proofing at the February ICC (International Color Consortium) meeting in Orlando have identified the need to describe variables involved in both making proofs from digital data and using measurement data to verify the match of proofs and aim characterization data.

These two issues are more intimately related than one would guess at first glance. As part of the validation of any digital proofing system, it is important to determine, and allocate, the variability involved in making individual proofs. Many of these same variables are involved in the analytical comparison of proof and print.

Let's assume that psychophysical testing can give us some measure of the colorimetric variability that can exist between images and still allow us to say they match. We then must identify the sources of variability between the proof and the aim characterization data, or a print made according to that characterization data, and apportion the allowed variability among them. Of course, we must also accept the possibility that there may be too much variability to allow such a prediction to be made.

We will not know until we understand the allowed tolerances based on psychophysical testing and the variability associated with making and measuring the proof.

The Scenario

Before we try to analyze the variables involved, we need to put some boundaries on the problem. Let's assume we are starting with a set of CMYK digital data that have been prepared using CGATS TR 001 as a reference. (For those not familiar with TR 001, it is a characterization data set that provides the relationship between CMYK data and the colors that are measured on a sheet printed or proofed in accordance with the SWOP aims—a digital definition of SWOP.) The goal is to proof the images represented by this data and also print the same data on press and compare the results to each other and to the reference data set. To provide the necessary colorimetric data, we need to print a measurement target at the same time we print the image data that is used for visual comparison.

Making the Proof

In our proofing workflow, we will assume the native behavior of the proofing system does not match the TR 001 characterization and the image data must be modified, using color management, to provide the input data required by the proofer. The intent is that the combination of the modified data and the proofing system's calibrated response will simulate the relationship between the file data and printed color defined by TR 001.

THE CHALLENGE: PRINT-TO-PROOF MATCH

So What Are the Sources of Variability?

First, in order to use color management we need to characterize the proofing device. This involves printing a reference target, measuring the color printed for each patch, and then creating a color profile using this data. The first two sources of variability are:

1. Uncertainty in the colorimetric measurement of the printed reference target used to characterize the proofer.

2. The modeling errors in the proofer profile building process.

Now we are ready to make our proof. The proofer profile we made is used in combination with the profile that characterizes the reference printing condition (which is based on the TR 001 reference data) to modify the image content data so it will provide the proper input to the proofer. We have added three new sources of variability.

3. The modeling errors in the TR 001 profile building process (we assume that the TR 001 data have no variability).

4. The computational errors in the color management system when it applies the profiles to the data.

5. The variability of the proofer (changes in proofing system performance between the time the characterization data was printed and the proof is made).

Now that we have our proof, how close does the target we printed along with the image data match our reference data? To know that, we must measure the target printed with the image data, which adds another source of variability.

6. Uncertainty in the colorimetric measurement of the target printed on the proofing device along with the image data.

Do We Have to Account for Other Variability?

Part of the answer depends on whether we are comparing the proof to the reference data or to a press sheet that has been printed using a press that matches the aim printing conditions (unrealistic, but a simplification for this discussion).

If we are going to evaluate the match to a press sheet, we account for the variability in the measurement of the press sheet.

The Printed Sheet

The printing process itself has variability; and from a systems point of view, we should assign a tolerance to the variability of printing. For now, let's leave that out of the equation and assume that all we want to do is see how well a particular printed sheet matches the proof. Even in that scenario we need to add another source of variability.

continued on page 26

7. Uncertainty in the colorimetric measurement of the reference target on the printed sheet.

The Comparison

When we do a comparison visually, we compare a proof and a print and make a judgment about the quality of that match. To try to evaluate and predict the match for any other comparisons of proof and print, we usually compare several samples and make an educated guess. If all of our comparisons look fairly good, we usually predict that others will also look good and we judge the proofing system being evaluated as acceptable. Not real elegant but the best we have.

When we move to an evaluation based on measurement data, it becomes much more complicated.

What we would like to do is predict, based on colorimetric measurements, the probability that a given proofing system will consistently produce proofs that predict (match) a given set of printing characterization data and/or printing based on that characterization data. This means that we must account for all of the variability between the input data and the proof and compare that to allowed tolerances that are based on visual comparison tests.

Let's start by looking at our seven sources of variability and see what we know about them.

Print-to-Proof Match Sources of Variability

1. Uncertainty in the colorimetric measurement of printed reference target used to characterize proofer.

2. Modeling errors in proofer profile building process.

3. Modeling errors in the TR 001 profile building process.

4. Computational errors in the color management system when it applies profiles to data.

5. Variability of the proofer.

6. Uncertainty in the colorimetric measurement of the target printed on the proofing device along with image data.

7. Uncertainty in colorimetric measurement of the reference target on the printed sheet.

Variability Estimates

Measurement Variability: Three of our seven sources of variability (variables 1, 6, and 7 above) involve the uncertainty in the colorimetric measurement process. Frankly we do not have a good estimate of the variability between instruments, either of the same design or between instruments from different manufacturers. At the ICC meeting, Dr. Danny Rich reported that he is participating in a program with Rochester Institute of Technology to try to get some estimates of instrument variability. This should begin to provide sorely needed data to allow the variability of these steps to be properly estimated.

Some very coarse initial data suggests that the 50 percentile point (in a cumulative distribution plot) for replicate measurements with the same instrument on the same sheet at different times (the reproducibility) may be on the order of 0.3 to 0.5 delta E. This number will certainly be larger when multiple instruments are involved and still greater when instruments from different manufacturers are included.

Proofer Variability: Most discussions of proofer variability identify within-sheet and between-sheet variability as key ingredients in any estimate. If standard tests were established, this could be a parameter that proofing system manufacturers were asked to provide as part of the specification of their units (variable 5 above). At this point in time, we neither have a standard test nor even a coarse estimate of this parameter. This is probably a task that CGATS or TC130 should be asked to take on relatively quickly.

Some proofing materials experience considerable change after they are initially made (similar to ink drying effects) and they should be held for a specified time before they are used or measured. In addition, some materials have a finite lifetime during which their characteristics are stable. These short- and long-term changes in reflection characteristics of proofing materials, and recommendations concerning recommended hold and/or keeping times, are probably best included as part of this source of variability. ISO/TC42 has a number of standards that can be used as the basis for a stability/fading test for graphic arts materials—none are directly applicable. Again, CGATS and/or TC130 probably should develop such a standard specifically for graphic arts proofing.

Color Management System Variability: As noted, the color management process itself contributes additional sources of variability (variables 2, 3, and 4 above). Profile transforms (even the colorimetric transforms that are used in our scenario) do not perfectly describe the data-to-color relationships of the measured characterization data. In addition, applying these transforms to real data in a CMM (color management module—the name given to the computational engine that applies transforms to data) involves additional interpolation and rounding errors.

There are no published estimates of the magnitude of the variability from these contributors. In our scenario we build two profiles—one from TR 001 data and one from data measured from the proofing system. We then apply these profiles to data in a CMM or build a device link profile and apply that to the data. (A device link profile is a special case where the transforms from two profiles are combined to create a single set of transforms that may also have added capabilities such as preserving the characteristics of the black printing channel, etc.)

The ICC needs to be asked to provide estimates of both these sources of variability.

How Good Does the Match Have to Be?

We have identified the major sources of variability, which at this point are poorly quantified, and even suggested some activities that may give us better estimates. However, the bottom line is—how good does it have to be?

Unfortunately, we do not know!

Some groups have suggested that if we use an IT8.7/3 target or an ECI 2000 target and have an average delta E (metric distance in CIELAB space between two points) between the proof and print of 2 and a max of 5 or 6 that is good enough. Others have pointed out that these targets do not sample color space equally. Because of the large numbers of patches in the IT8.7/3 or ECI 2000 target that call for black ink, the data set is biased toward the darker, less chromatic colors.

From the photographic industry, we know color differences in the paper, or Dmin area, of as little as 0.5 delta E can be objectionable.

The CIE has done a lot of work in the area of color difference calculation. Unfortunately, virtually all the work has been concentrated on the detectability of differences in large patches under D65 illumination using the 10-degree observer. The textile and fabric industry has been the motivating force for this work. What we are concerned about is acceptability of differences in complex images viewed under D50 and assuming a 2-degree observer. A whole different ball game.

Technical Committee 8-02 of CIE Division 8 was set up to study the issue of color differences in complex images. It is not an easy task. To date they have developed some metrics to relate color and spatial effects and some suggested studies that will lead to more understanding—but no answers.

CGATS/SC3/TF1 has been looking at some of the SWOP and GRACoL proofing system evaluations, but have not yet been able to derive correlations between acceptability and delta E.

The Bottom Line

The bottom line is that we have a good handle on the sources of variability, but do not have any idea about their magnitude. From statistics we can probably predict that the way to sum their contribution (when we know what they are) is to say that "the square root of the sum of the squares" should not exceed our allowable tolerance. But we also have to determine a metric that allows us to predict a match—which is our allowed tolerance.

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What's Next?

Is it hopeless? Not at all.

We think we know what has to be determined. We know some of the groups that are in the best position to find the answers. We just have to find a way to all pull in the same direction and share the necessary knowledge.

Some Proposed Assignments

Let's pretend that all of the groups that we have mentioned were part of some larger organization and we could assign tasks to them individually or in groups. I would suggest that the following set of assignments might get us moving in the right direction and would provide some working tolerances.

ICC-I would assign the ICC the task of providing an estimate of the average error (and associated statistics about the error distribution) between characterization data and data predicted by colorimetric transforms in a typical CMYK profile. I would also ask them to provide an estimate of the error (and associated statistics about the error distribution) associated with typical CMM processing of transform data (variables 2, 3, and 4).

ISO/TC130-I would ask TC130 to develop standard tests to measure the within-sheet and between-sheet variability of a proofing system such that an estimate could be provided of the expected variability between a sheet used for characterization and a sheet printed sometime in the future.

It would be beneficial if TC130 also were to develop standardized tests for short- and longer-term image stability. This could build on the image-keeping work of TC 42/WG5 but should focus on issues related to the time required after printing to reach a stability plateau and the length of this plateau (with very tight tolerances on allowable change) as a function of storage and viewing conditions. Here, long term is weeks to months vs. the years typically studied by TC42.

The individual device manufacturers would need to conduct tests based on these standards and report appropriate data for their systems. These are all part of variable 5.

CIE, TC130, or ASTM-A valid estimate of the uncertainty of colorimetric measurements is critical for both the direct comparison of measurements of proofs and prints and for development of charac-

Industry Acronyms Cited in This Article

ANSI-American National Standards Institute, the industry organization that coordinates standards development in the United States and U.S. involvement in ISO and IEC.

ASTM International-American Society for Testing and Materials.

BSI-British Standards Institution, the UK's national standards body, which also represents the UK in international standards making.

CGATS-Committee for Graphic Arts Technologies Standards, the ANSI committee responsible for U.S. standards for the printing and publishing industry.

CIE-Commission Internationale de l'Eclairage, also known as International Commission on Illumination, an organization devoted to international cooperation and exchange of information on matters relating to the science and art of lighting.

CMM-Color Management Module, the name given to the computational engine that applies transforms to data.

ECI-European Color Initiative, a group dedicated to advancing media-neutral color data processing in digital publishing systems.

FOGRA-Graphic Technology Research Association, the German national printing research organization.

GRACoL-General Requirements for Applications in Commercial Offset Lithography, a committee of the IDEAlliance.

ICC-International Color Consortium, develops color management specifications.

IFRA-IFRA deals with all issues related to production of publications in general, but is primarily focused on newspaper printing.

IPA-The Association of Graphic Solutions Providers.

IT8.7/3-IT8 standard-*Graphic technology-Input data for characterization of 4-color process printing*.

ISO/TC42-Technical Committee 42, Photography, ISO Committee for photographic industry standards.

NPES-The Association for Suppliers of Printing, Publishing and Converting Technologies, acts as secretariat for several standards organizations.

PIA/GATF-Printing Industries of America/Graphic Arts Technical Foundation.

PPA-Professional Photographers Association in the United Kingdom.

SC-Subcommittee, a subgroup within a TC (Technical Committee).

SICOGIF-Syndicat National des Industries de la Communication Graphique et de l'Imprimerie Françaises, the French National Association of Graphic Communication and Printing Industries.

SNAP-Specifications for Newspaper Advertising Production Committee, goal is to improve reproduction quality in newsprint production and provide guidelines for exchange of information.

SWOP-Specifications for Web Offset Publications, focuses on specification of parameters necessary to ensure consistent quality of advertising in publications.

TR 001-CGATS standard, *Graphic technology-Color characterization data for Type 1 printing*.

TC130-Technical Committee 130, Graphic technology, the ISO standards committee responsible for standards for the printing and publishing industry.

WG-Working Group, a subgroup within an SC or a TC.

terization data. Such estimates need to have provisions for measurements made with a single instrument, made with multiple instruments of the same model, and made with multiple instruments of different models (but same geometry).

It is not clear who is in the best position to provide the testing methodology and coordinate testing of this type. Some combination of CIE, TC130, and Committee E-12 of ASTM come to mind. The assistance and cooperation of the spectrophotometer manufacturers is also critical to provide valid estimates of the variability attributable to colorimetric measurement (variables 1, 6 and 7).

CIE Division 8 (with help from TC130 and industry groups)-The most critical need is to develop a colorimetric criteria that can be used to determine an acceptable match between reproductions (proof-to-print, proof-to-proof, etc.) of complex images. While there may be a necessity to initially include the color distribution and spatial characteristics of the image content, ideally the acceptability criteria need to be content independent.

CIE TC8-02 has spent the last several years studying the issues and has completed a comprehensive literature survey that included factors that affect the evaluation of color differences of digital images. This information should be sufficient to aid the definition of further experiments to investigate the use of current color-difference formulae, and suggest further developments of color difference formulae or targets specifically for application to complex images. However, there are no answers yet.

There are also a number of industry groups in the United States and worldwide that are trying to develop ways to certify proofing systems, i.e., the ability of a proofing system to replicate a specified printing condition. The dominant industry groups involved in such activities are SWOP, GRACoL, SNAP, IFRA, PPA (United Kingdom), SICOGIF (France), ECI/FOGRA.

In addition, groups like IPA, GATF, IFRA, etc., routinely have proofing "shootouts" and industry competitions/comparisons. These groups depend largely on visual comparisons. In addition, ANSI CGATS is studying metrology techniques that might assist in such certification processes.

Unfortunately, to date, there has not been extensive interaction between the groups evaluating proofing systems and those looking at the comparison problem from a more theoretical perspective. Although each could learn from the others' work, it would add additional complexity to both tasks.

Our most critical issue is to determine the metric that predicts the probability of a visual match between images. We must find a way to feed information (and collect the additional information required) from the groups doing ongoing comparisons into the theoretical work being done by the color community.

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So Who Is in Charge? Or Where Do We Go from Here?

The short answer is that there is no umbrella group that can take charge. One possible way to proceed is to call a meeting that involves all of the potential players, share knowledge, and propose some cooperative efforts.

Such a meeting is being arranged. It tentatively will be held as part of the TC130 WG3 meeting on Friday, May 13, 2005, at BSI in London. This meeting is being arranged by Dr. Fred Dolezalek (dolezalek.f@freenet.de), who is chairman of TC130, and Craig Revie (craig.revie@ffei.co.uk), who serves as chairman of the ICC.

This is also an open invitation to participate in the discussions around this issue and/or commit your group to be involved. If you want to be involved, contact me at mcdowell@Kodak.com or mcdowell@npes.org (or Fred or Craig) and I will see that your interest is forwarded to the appropriate people.

If you would like to discuss the perspectives proposed, or suggest changes to this scenario, please do not hesitate to contact me so that together we can help find the best way forward.