

Color Management Requirements in Contract Proofing

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Abstract

Generally, one can say that ease of use requirements for color management are driven by DTP and home users, whereas since the early days of color management accuracy requirements have been driven by the contract proofing market. Translating colors from one color model to another, matching to targets, dealing with out of gamut colors, etc., were and are issues that drive proofing manufacturers to continuously improve their color management software.

As faster computer hardware and automated measuring devices become available, and as more companies develop color management systems, improvements in color management are realized.

But, the customer requirements change over the years. Items like Pantone colors, paper color, gloss influence, remote proofing, match transferability, etc., change the requirements from the customer.

Finally, most customers still think in CMYK and have problems understanding an L*a*b process, which is commonly used in today's color management systems.

For developers of color management this means a continuous challenge to update their software and utilize the new possibilities that improved hardware delivers. This paper gives an overview of color requirements for contract proofing, how these requirements are met with proofing hardware, and which color management software challenges were and still are to be dealt with to provide accurate digital contract proofs.

Introduction—Contract Proofing Requirements

In the Graphic Arts industry, a proof is used to predict the final printed result. After the design and layout stage, where a page for a magazine or catalog is prepared, a final 'contract proof' is made. As the name says, this contract proof is the contract between the designer and the printer. At sign off, the printer agrees that he can print the final run according to that proof, and the designer agrees that the proof resembles what he intended to have. An analog proof is made on analog systems like DuPont's Cromalin© or Waterproof™ system, and uses films to produce the final proof. Today, a lot of proofs are made on digital systems like DuPont's Cromalin Digital©. These systems produce a proof directly from digital data, so no films are used, saving time and money. Futhermore, the flexibility of digital data processing allows digital proofs to be purposed to more closely match gravure, screen, flexo and letterpress printing than its analog counterparts[1].

The basic requirements for a digital contract proofing system and color management are:

- *Color Consistency*
  Every proof printed from the same data should look exactly the same in color output and image quality
- *Color Fastness*
  The proof should not fade over time, typically up to 3 months
- *Color Gamut*
  The color gamut of the proofer should at least cover the gamut of all conventional printing methods like offset, gravure and flexo printing.
- *Color Manipulation*
  The color output must be controllable so that from the same data different outputs can be generated, based on the profile of the printing method that should be matched.

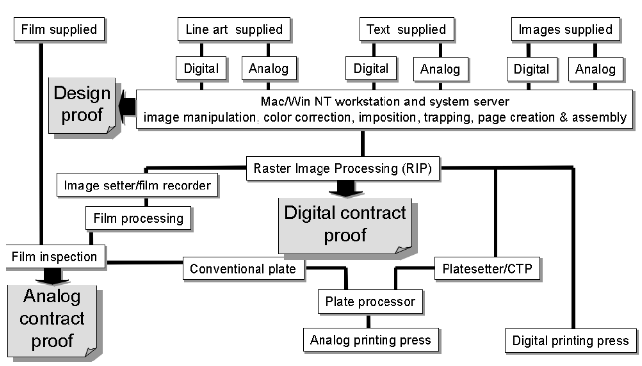

Figure 1. Analog and digital proofing workflow[2]

When changing over from analog to digital proofing, the easiest workflow for the customer is to use standard profiles that make the proofer match analog proofing systems (such as Cromalin©) or analog standards (such as Eurostandard©). This allows a lot of customers to make an easy transition from their traditional way of working to a digital workflow. Traditionally, most printers and designers know how to judge a standard analog proof and how that proof relates to the appearance of their final print job.

However, a more sophisticated workflow is to have the digital proof match the actual printing press of the customer. In this workflow, the customer is asked to print a predefined set of colors (color book) in a standard way on his printing press. The resultant prints are used to characterize the customer's printing press. (This process can become a source of discussion as 'printing in a standard way' is a broad term and the stability of a printing press is usually lower then a proofer. In fact, sometimes press variation exceeds the customer's expected proof to press match tolerance!) The digital proofer uses this characterization as the target color output for its proof. Given that the proofer is very stable, the characterization of the proofer can also be fixed by measuring the output of that same color book.

The main principle of colormanagement in proofing is nothing more then calculating the transformation of the characterization of the proofer into the characterization of the printing press; this we call 'the match profile'. Using this transformation on any given data for a printing job will result in an accurate prediction of the final printing result.

The actual accuracy of this process can be determined by printing the color book with the match profile and then measure the color of each patch. By comparing this with the printing result where the target characterization was made of, one can determine the differences thus match errors.

In the beginning of the 1990s, a proof was regarded to be a very good match (thus a contract proof) if the average delta-E over all patches was below 2, and the maximum was below delta-E=8. However, everybody familiair with CIE L*a*b color knows that delta-E is not a good parameter to define color errors, as it is not linear over the color space. A delta-E of 2 in a four-color gray patch is generally rejected in a contract proof; however it was accepted in the earlier days as no system, either analog or digital, could produce more accurate results.

However, nowadays the customer requirements grow with the ability of the proofing devices, and many high end users demand the average delta-E < 1 and maximum delta-E < 2. As this is close to the accuracy of measuring devices at a random temperature and humidity, it becomes clear that this leaves little for tolerances for the other components in the proofing chain, either proofer or color management.

Proofer Design Considerations

Given the requirements on color consistency, stability and gamut, not every printer can be used as a contract proofer, although many manufacturers would have the customer believe otherwise.

The combination of parameters like resolution, adressability, number of gray levels, dithering and color gamut determines the image quality of the proofer. If the image looks too grainy or to smooth then the total appearance will not resemble printing stock. Proofing is something different than printing nice pictures.

DuPont's Cromalin Digital© continuous flow inkjet systems, designed and produced by Stork Digital Imaging in the Netherlands, are designed specifically for contract proofing. Every aspect of the printer is targeted for the sole purpose of meeting the contract proofing requirements. Mechanics, electronics and dithering are optimized to remove all banding and represent the image quality, as it is achievable with conventional printing processes as offset or gravure printing.

Furthermore, all components in the proofer have to meet high production tolerances in order to ensure stable performance over the lifetime of the proofer. This also guarantees proofer to proofer consistency, so that a proof from proofer A resembles a proof from proofer B when the same match profile is used.

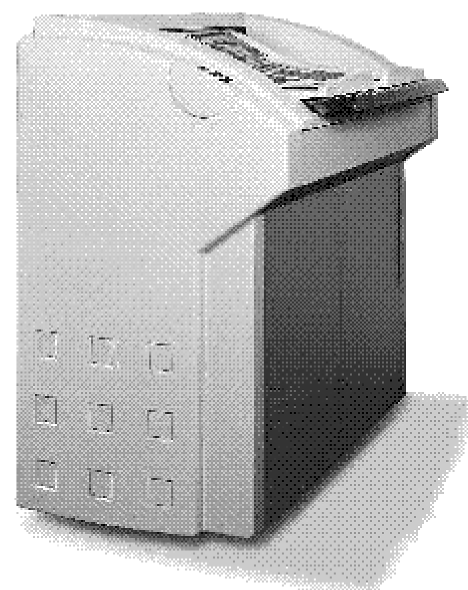

Figure 2.DuPont Cromalin Digital© contract proofer

Like other digital printing equipment, Cromalin Digital© uses remote diagnostics systems to continuously monitor the performance of each proofer in order to pro-actively exchange parts when necessary at a convenient moment for the customer. Furthermore, when an unexpected breakdown occurs, the system is diagnosed remotely and the right spare part is send to the engineer to ensure minimum downtime.

The systems inks are developed to be close to standard printing inks. This ensures that the color management routine needs minimal contamination of colors to achieve target colors when applying the match profile to the input data. The color gamut of the inks is optimized using the characterization data of all customers. The fastness of the inks ensures that all colors fade less than 1.0 delta-E over one month's time.

The proofing paper stock is standardized to ensure proofing results over time and between different proofers. In the beginning, most customers like to proof on their own printing stock, but as soon as they meet the general tolerances on these media, and thus encounter unwanted proof-to-proof variations, they agree that using standardized proofing stock is preferable. Using very white standard proofing paper (L close to 100, a an b close to 0) and simulating the actual printing stock paper color through color management, DuPont's Cromalin Digital© provides a color accurate proof resembling a printed result on actual stock, with the additional guarantee of reproducibility and stability.

History of Color Management

Early color management systems matched the tonal density response curve of the digital proofer with the target output device. Users were able to change the color match by adjusting the tonal density response curves of the devices, first visually and then in later implementations, by using a densitometer. Limitations included the inability to adjust the hue of the primary and no specific color adjustment capability of colors made from 2, 3 and 4 primaries. In fact, for different reasons, these same limitations exist in many of today's thermal imaging systems.

Color management tools soon supported targeted color space adjustments and settings to simulate the first and last printable dot of the output device. However, consistently adequate color matching was still elusive. Fundamentally missing was a good color transformation to serve as a basis for minor adjustments, a stable color response of the output devices, and intuitive color adjustment tools. Much time was spent adjusting color, with little quantitative improvement in the overall transformation.

In 1931, the International Commission on Illumination (CIE) developed a color system based on human perception. In the early 1990's, color measurement instrumentation and desktop computing improved enough to make the calculation and use of the CIE L*a*b color system feasible in color proofing.

Many of today's color management systems are based on the CIE color system.

Challenges in the Nineties

One must have an in-depth knowledge of the changing printing and pre-press industries to understand their color proofing needs. Satisfying those needs requires the innovative application of diverse technologies such as: mechanical machine design; chemical ink formulation; fluid dynamics; paper coating technology; color measure-ment; color science; image processing; computer science; and computer networking. Balancing needs and technology in the following areas were the challenges in the 1990's.

Optimized Color Profiling:

Color profiling is the mapping of a device dependent color space (such as CMYK) to a device independent color space (such as L*a*b). The optimal color profile is obtained by printing and measuring every possible CMYK combination multiple times. This means there are approximately 256 x 256 x 256 x 256 color patches that need to be printed and measured for each profile. Add to this the fact that a separate color profile is required for each target device and each proofing device. This quickly becomes unmanageable.

Optimized color profiling means high accuracy, few measurements, low cost/accurate instrumentation, and minimal operator interaction. Solutions are based on the technologies of image processing (sampling and signal detection), color measurement (employing fast spectrophotometers) and computer science (speed optimized algorithms).

Color behavior of a certain class of devices is determined by measuring many instances of that device type under controlled measurement conditions. DuPont Cromalin Digital© optimizes color profiling by coupling the prior knowledge of a given device type's color behav-ior with a small sample set of the specific output device to be profiled.

Optimized Color Matching:

Color matching or linking is the connection of two or more color profiles through device independent color space. The optimal CMYK to CMYK match is theoreti-cally obtained by minimizing color differences in device independent space.

Theoretically, K may be considered redundant. That is, each level of black (K) is interchangeable with some combination of levels of cyan, magenta and yellow. This also means that the relationship of L*a*b to CMYK is one to many.

This theoretical relationship between K and CMY has both advantages and disadvantages. It has enabled some simplifying assumptions to reduce computational complexity and sampling frequency. Namely, color managers perform a CMY to CMY match and then match the K levels of the devices separately. The results achieved by color managers employing this type of matching are highly dependent on their black substitution algorithms.

The disadvantage to the one to many relationship between L*a*b and CMYK is that an optimal match cannot be obtained by simply minimizing the color differences in device independent space. Other cost functions must be developed. The challenge is to develop cost functions that yield continuous functions in CMYK space while minimizing errors in device independent space.

Spot Colors:

To establish optimal results many customers choose to use special colors in addition to, or in place of, standard process colors. Many times, the same special colors are used over and over. For instance, DuPont's corporate color is red. Our advertising designers may choose to substitute DuPont red for magenta in all DuPont advertisements. The advantage of this is that the corporate logo is correctly colored and the remainder of the image is color managed to compensate for the substitution. Proofing this type of substitution can be accomplished by profiling the output device. This is a real test of the color management software assumptions, as the characteristics of the new "magenta" are very contaminated versus the original process color.

A more difficult scenario is the one time use of a Pantone color. Here, the customer can not spend any appreciable time profiling the color behavior, yet a reasonably accurate proof is required. DuPont Cromalin Digital© deduces the behavior of the special color from the behavior of the process colors measured during the normal profiling of the target device to achieve the desired result.

Perhaps the most challenging scenario is modeling the behavior of a special color defined by only one 100% data point when it is printed on top of a normal process color combination. Process color behavior is again used to deduce special color behavior. The effect of a special color ink over a process color ink must also be modeled to achieve the necessary results.

Editing Tools:

Editing tools are useful only when the initial color match is quite good and the proofing device is quite stable. It is technically attractive to edit in L*a*b color space, however most people within the industry think about color in terms of CMYK color space.

Editing tools must balance the capability to make local and global changes within the color transformation while minimizing discontinuities in color response. DuPont Cromalin Digital© achieved a good balance by defining each color in terms of its 4-color, 3-color, 2-color and primary components. (where the 3-color component is defined as the 3-color gray minus the 4-color gray; the secondary color component is defined as the secondary color level minus the 3 color gray level; and the primary component is defined as the primary level minus the secondary color level.) Still, some customers need to make more localized edits, at the expense of risking greater discontinuities in the color space. For these customers, color consultants familiar with high-powered adjustment tools may be the best solution.

Edited color transformations must be transportable. This can be achieved by calculating the target profile necessary to produce the edited color transformation given the proofer profile used in the match. With this approach, all of the tools that allow you to move targets from proofer to proofer can also be used to move edited color matches.

Challenges for the New Millennium

Rapid improvements in all supporting technologies enable the developers of contract proofing solutions to meet many new challenges.

Spectral Color Matching:

The spectral color model may provide the most accurate device independent color space. Spectrophotometers measure spectral response within about 20 different ranges. With a spectral based match, the CMYK to CMYK transformation will be calculated through a 20 dimensional color space rather than the much smaller 3 dimensional CIE based color space. Computation speed is now approaching a level where such a calculation is becoming attractive.

Spectral measurements may also improve interpolations between measured points within a profile, resulting in fewer discontinuities. A color space represented in a spectral model may appear more regular than the same color space represented in the CIE perceptual model.

Remote Proofing:

With today's networks and the reduced cost of proofing devices, it is now feasible to frequently transfer images from one site to another for remote proofing. The challenge of remote proofing is to provide a simple, cost-effective mechanism to assure that the remote proof is as color accurate as the local proof. Remote proofing is only possible as the challenges of local proofing are solved to the satisfaction of the majority of customers.

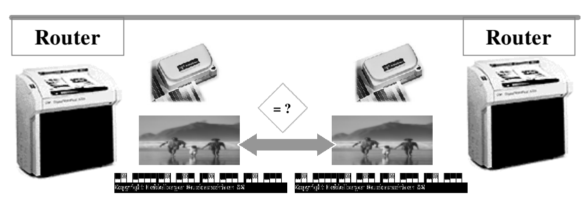

Figure 3.Typical Remote Proofing Configuration

Paper Gloss:

As color matches improve, inaccuracies due to a mismatch of gloss between the proofer and target colors become significant. A glossy finish reflects more light back to the spectrophotometer, making the color measurement lighter. This causes the color management to adjust the color with a glossy finish to be darker. To the human eye, the glossy patch will now appear too dark. To complicate matters, the finish of the sample may become more or less glossy depending on the amount of ink printed. In order to improve the appearance of a color match, this relationship must be well understood and compensated for in the color manager.

Auto Calibration:

Calibration with a spectrophotometer is feasible as long as the cost is reasonable and the accuracy is quite good. However, the user must still intervene to perform a calibration. In the near future, small, inexpensive spectrophotometers may be mounted within the proofer to provide auto-calibration. Today, the accuracy of many candidate internal spectrophotometers is not much greater then the accuracy of the proofer, thus diminishing their usefulness on high end proofing engines.

Conclusion

Making digital proofs match actual printing results puts the highest demands to printer manufacturers and color management developers. Probably more than any other application for digital printing equipment, proofing requirements take accuracy demands for printers and color management software to the limit. As the ultimate proof is a perfect match to print result, these requirements become an iterative process with the achievable accuracy in all the system components. Due to this, it is valid to state that color management software for proofing applications is ahead of all other color management packages, and thus provides the foundation for color science and software development.

The successful development of a digital color proofer requires a keen understanding of customer needs, recognition and application of pertinent technologies and, perhaps most importantly, a collaborative effort between developers of ink, paper, ink delivery systems, color management algorithms and software. The co-operation between DuPont and Stork is a unique example of such a collaborative effort.

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Biography

Jos Notermans holds a degree in Mechanical Engineering from the Technical University of Eindhoven, The Netherlands. He started his career in Stork Digital Imaging BV in development of continuous flow inkjet systems. After several jobs in project management, program management and product management he presently holds the title of business manager for the graphic arts activities at Stork Digital Imaging BV. He is responsible for all Stork activities in the joint venture with DuPont Color Proofing.

William Hulsman holds a Bachelors degree in Electrical and Biomedical Engineering from Duke University and a Masters Degree in Engineering Management from the University of Massachusetts. He has specialized in developing, commercializing and supporting software products that have significant color and imaging technology components. Bill presently holds the title of software development manager within DuPont Color Proofing and is responsible for all DuPont development activities for continuous flow inkjet systems.