Low-end Color Devices for Proofing?

Gary Dispoto and Michael Has***
**Hewlett-Packard Company, Palo Alto, California*
***FOGRA Institute, Munich, Germany*

Abstract

In preparing data and samples for subsequent print, accurate color reproduction has traditionally been among the most complex tasks involved. Subsequently, operators focussed control processes (like proofing) for reproduction on color and its accuracy. With the advent of color management, color accuracy and color reproducibility through the process have undergone significant improvement. With that - at least potentially - the focus of proofing can undergo changes again from highlighting color reproducibility to system simulation.

As color management, low-end color devices, and digital networking tools become more available, questions like the following arise:

1. Which devices are able to proof which other devices' behavior?
2. Is color the only characteristic for which simulation is required and why is simulation required?
3. If more than color simulation is required, what hierarchy of importance can be assumed for the other attributes to be simulated for each combination of device and media?

The paper under view deals with these and other involved questions and attempts to address relevant topics with respect to system simulation.

Introduction

In recent years, inexpensive color printers have become commonplace in many environments. The capability of under $500 (US) color printers has grown rather dramatically. Great improvements have been made in color gamut, graininess, resolution, repeatability, lack of undesirable artifacts, printable media, and print stability.[1]

Currently, standardized color management is becoming a widely used tool, with the ICC color management system integrated into the Windows98 operating system as ICM2.0. Good color management has been available to Macintosh users since ColorSync 2.0 became available in 1995. These operating system level color management solutions potentially allow the exchange and reproduction of color image data between open systems to be much more robust, reliable, and accurate than in the past.

The combination of these two elements -- high quality, low-cost desktop color printers and good color management capability -- may form the basis for an adequate color proofing system for many applications. Such a system's ability to function as a proofing engine depends upon whether the printer and media can simulate the aspects of the final print that need to be simulated on the proof and whether the color management system can produce the color accuracy necessary for the proof. It should be noted also that acceptance of this form of proof will also need to overcome the obstacle of non-familiarity to designers, printers, and customers. However, there is already some precedent for proofing on digital printers within closed reproduction systems and it is becoming even more common with the adoption of direct-to-plate technology.

There are a number of practical reasons for which this sort of proofing system would be desirable. The most obvious is low hardware cost, which, in turn, leads to low proof cost. Turnaround time for proofing printers that are already properly profiled would be short. Also, the fact that the proofing engine is inexpensive opens up the possibility of having many of them. The plurality of proofing engines could be run in parallel, different media could be loaded into different printers, or the proofing engines could be conveniently geographically located.

Proofing and System Simulation

The ISO 12647/2 standard describes which of the required properties of print are supposed to be met by a proof. In analyzing those standards, one may draw the conclusion that the focus of the properties of the prints to be met in proof lies in:

1. Dot gain
2. Primaries
3. Color of paper (substrate)
4. Reflectiveness of paper (substrate)
5. Opalescence and Transparency of paper (substrate)
6. Measuring conditions (for viewer, light, angles, gloss, ...)

As one can see there are three features highlighted:

- Color Simulation of one device by another (1.- 3.)
- Materials and their behavior (essentially with respect to color and color appearance) (4. & 5.)
- Measuring conditions

With the advent of color management and the high quality printing devices (which, again, get cheaper and more elaborate over time) and if we are evaluating the situation carefully, there is a new situation arising in several respects:

Color measuring devices turn out to be very reproducible, within some tenth of ΔE_{ab}, but when different measuring devices are compared, one notices that those devices' measurements are not very comparable when not calibrated with the same target. The comparability lies within a range of some 4.5 ΔE_{ab}.[2] When handled appropriately, color management turns out to be more reproducible than comparing those measuring devices.[3] Thus color communication lacks its numerical basis to some degree if based on measuring results, while if based on color management it may well substitute accurate proof if no other clarification is required.[4] In other words, the accuracy of color management systems is greater (the average color error is smaller) than the instrument to instrument repeatability of different measuring devices plus the noise on the signal of a press. This again calls for new paradigms for color measurement in proofing situations, especially if remote proofing is aimed at.

A proof may also serve as a legally binding representation of the intended output. With digital networks becoming pervasive, more and more business communication will be based on remote cooperation. It may be estimated that proofing will have to undergo some changes with respect to its meaning in times of color management and remote cooperation.

If a user is proofing in the traditional sense, he has to use a device that is able to reproduce the print characteristics of the press a way described by the standard mentioned above. If the proofing device is digital, that requires the pressmen to supply the customer with his press profile. For proofing, the customer has then to access the file as it was generated using the press profile, undergo a colorimetric match to the profile connection space (PCS), and then - again with a colorimetric match - use the proofing printer's profile and then print on the proofing printer. The software calculations, the measurement steps and its associated problems, plus the noise on the printing signal result in larger inaccuracies than if just forwarding the file in its CIELAB representation form and then printing and measuring it. However, the legal situation still takes a signed analog contract proof as a reference. This is understandable since properties of the paper (paper weight, thickness, and opalescence) and the problem of visual judgements of self illuminating versus illuminated samples make the analog still preferable.

Color management may also serve for simulating certain properties of the substrate to be printed on. For example, the dot gain of the press and substrate under a particular set of conditions will be embodied in the press ICC profile. Hence, while the proof may not be capable of producing the halftone of the final print, it will simulate the dot gain.

Status of Low-end Color Output Devices

It is remarkable that low-end output devices are generating better and better print quality with respect to:

- resolution
- variable color spaces with the use of different colorants and the accessibility of intelligent software generates the
- ability to simulate certain color appearance related behavior of different output devices
- ability to print on different types of media (glossy, matte, textured, fabrics, etc.).

The issue of resolution refers to more than simply the number of dots per inch that the printer is capable of laying down. Today's printers are using a number of techniques to improve their effective resolution. These include, but are not limited to, reducing the dot spacing, reducing the dot size, allowing multiple numbers of ink marks to be placed over the same spot center, reducing the dye load of the inks to produce lighter tones, and so forth. On some current low-end devices, combinations of these techniques produce output that rivals silver halide prints in terms of clarity and sharpness. It should be noted few, perhaps none, of today's low-end color printers have the resolution necessary to reproduce traditional press halftones. Hence, in most cases, it will not be possible to proof for moiré problems.

On some media, current low-end devices may have color gamuts that completely, or nearly completely, enclose the gamut of a final press print on similar media. In addition, third parties are now developing ink sets for desktop printers designed to encompass press gamuts.[5]

Color appearance models may by used to transform colors for one viewing condition to others. Standard color appearance models, such as CIECAM97s, can transform color data to be viewed in the print shop's viewing booth or the standard proof viewing condition to color data to be viewed in the customer's environment. In the proofing case, the current ICC specification's handling of white point is adequate, since the press standard, proofing standard, and ICC PCS white points are all D50.

For ink jet printers, in particular, the media available for printing is beginning to expand. Most desktop printers are capable of printing on papers of various weights and glossiness, and extended media types, such as fabrics, highly, textured papers, and plastic films, are available through third party vendors.

New Possibilities for Proofing

Subsequently, from a user's point of view, the workflow and the duties required to generate a print proof may change from the traditional proofing workflow and duties to the following:

1. choose the proof printer depending on a comparison of capabilities of the printer,
2. choose material,
3. apply color management to data,
4. print data.

One can imagine intelligent software that either performs these steps or informs the user that a proof cannot be generated with the system on hand. Such intelligence could be embodied in a software tool that operates similarly to a printer driver, but requires more information from the user than does a standard printer driver. This tool would offer the user the option of creating a proof, rather than a standard print. Once proofing has been selected, the software would require the specification of the device and media being proofed. The software would then examine the potential capabilities of the devices available on the local network to determine their suitability for creating the proof. For those printers with the potential to generate the proof, the tool would call for the devices or RIPs to indicate whether the paper loaded matches that specified in the required ICC profile for the device. It may also be necessary to check that the press and proofing device profiles are produced by compatible profiling software, since the current ICC specification allows for some interpretation and pairs of profiles from different profilers may cause color interoperability problems.[6] Likewise, it may be necessary to check compatibility with the CMM.

Based on the profiles and media availability, the software would then determine and indicate which desktop printers on the network could proof the final output, what aspects of the final output could not be proofed on each, and what simple changes could be made to improve the proofing situation. If the only limitation of a device was that the wrong paper was loaded, the user would be informed. For each device that could create a proof, the user would be given information about the possible limitations of the proof with respect to paper stock, gamut, dot gain, halftoning, etc. Finally, the user will be required to select one of the proofing device candidates.

Note that the proposed software tool requires some infrastructure for the state of the printer to be communicated back to the tool, so that, for example, the paper type loaded may be determined. This is an implicit problem with implementing the tool -- standardized analysis mechanisms that inform their environment about the state of the printer currently do not exist.

A true proof would only be deemed possible if a colorimetric match of the image as printed on the press could be produced on the proofing device and the media met certain qualifications as a simulator of the final media. This means that the image's gamut must be encompassed by the proofing device's gamut. Recall that the processing path processes the image data through the ICC profiles of both devices using the colorimetric intent. It follows that the gamut-encompassing requirement requires that the proofing media color closely matches the final output media color, or that the color of the final output paper can be produced by the proofing system by laying ink on the paper. In practice, the latter may prove undesirable, since white areas may not be clear of ink marks. If the media of the proofing device is not a close colorimetric match to the final print media, a white point transformation will be necessary and only an appearance match will be possible.

The ICC system may meet the relevant needs of such an intelligent system with a specification of a media tag and a white point tag. However, the current way in which the media white point tag is specified, "referenced to the profile connection space so that the media white point as represented in the PCS is equivalent to this tag value"[7] may make checking that the two media are a close colorimetric match problematic. The definition of this tag seems to indicate that the value placed in that tag is simply the PCS white point, not the CIE relative colorimetry of the media.

The qualifications to be met by the media, other than the color, are related to paper weight, opacity, and gloss/texture. Tolerances for all these variables are required, and are likely to vary by particular proofing application. These variables represent a reduction of a number of other properties on the press, including:

- Mechanical properties
  - Roughness of paper
- Optical properties
  - absorption of light
  - scattering of light
    - in effect, the sum of both might be described as opacity.
- Ink related properties
  - ink transfer
  - ink paper interaction
    - soaking of solvent and pigment in ink
  - absorption of light
  - scattering of light
    - dependent on the screening
  - Tack of liquid ink
  - Roughness
- Paper class families determining the ink/paper interaction
  - glossy
  - matte
  - coated / uncoated
    - coating is the deciding factor for the scattering coefficient of the paper
- Screening
  - size of dots
  - shape of dots

Current color management approaches do make use of this reduction of properties when creating a profile for an offset press under view by simply defining a process profile averaging over all the properties mentioned above.

However, it should be pointed out that the list of factors given above should alert the press operator to highly care about the reproducibility of the conditions the devices (rip, imagesetter, plate, etc.) are operated in.

Furthermore the listed properties of the paper does have an obvious impact on the color appearance leading to the requirement of a highly paper type related ICC profile.

Concluding this section it needs to be pointed out that the ICC profile of a press is a function

- of the dot gain which again is basically dependent from process parameters,
- opacity of the paper, and
- the white point and glossiness of the paper.

What is a Proof?

As can be seen from the previous discussion, the legal situation with regards to proofing may potentially undergo significant change. Currently, the proof simply should match the press. The recent developments in color management, low-end printers, and remote cooperation may change the very definition of a proof to: if a printer plus the required software for separation, screening, ripping meets a certain qualification with respect to

1. being able to use different materials having properties that can not be simulated with the use of software,
2. being addressable with color managed data,
3. and be reproducible within the limits of the device to be used as a proof printer,

then a legally-binding proof may be composed of a data file, the ICC profile and an analog print on a low end device with given properties of device and substrate.

The term "certain qualification," of course, calls for a precise definition that, including some parameters, may serve as definition, as it is required to clarify which devices are able to proof which other devices behavior with respect to color.

Is color the only characteristic for which simulation is required? It appears as if the market for high-end proofers may become more limited both because of both the traditional definition of proofing and the increased capabilities of printers and software. With that, one could take the viewpoint that print becomes somewhat obsolete in some of the markets as they traditionally required proofing. However, these highly developed abilities may also on the one hand generate new usage scenarios as proofing more than just colors is now within access.

If more than color simulation is required, what hierarchy of importance can be assumed for the other attributes to be simulated for each combination of device and media? In a previous paper[8] the idea of "related genre" has been introduced. The concept is essentially based on the observation that multipurposing does not work and that, since it might be useful to approach the reuse of data for different output devices in novel terms.

In that context, the production process and the databases involved in the production were analyzed and it was concluded that, if both the databases and the production process are defined and divided appropriately it turns out that for the resulting products one may define relationships. These relationships may then be defined in terms of the "alikeness" of the intermediate operations and intermediate products used in the generation of the genre.

It is likely that uniform, non-color proofing requirements for applications within a genre can be developed, since the fundamental workflows and dataflows within a genre remain constant.

Conclusion

The advent of high-quality low-end color printers and good, readily available color management software create new possibilities for graphic arts proofing. Intelligent software may be developed which determines the suitability of a particular low-end desktop printer on some media for producing a proof intended to simulate some particular final press output. This color simulation suitability decision is based upon the availability and compatibility of ICC profiles as well as characteristics of the two printers and their media, which may be learned from information in their ICC profiles. This new capability may well redefine what a proof is.

References

1. Ross Allen, "Achieving Photographic Image Quality With HP Thermal Inkjet", Specialty Papers and Films '97 Conference, Diamond Research Corporation, (1997)
2. Michael Has, et. al., *TAGA-98 Proceedings*, "Error Propagation Analysis in Printing", in press, (1998).
3. Has, *ibid.*, (1998)
4. Michael Has, et. al., *Fifth Color Imaging Conference Proceedings*, "Color Management-how accurate need it be?", p. 270, (1997).
5. Nationwide Plastics Co, Inc., *Visions Epson Compatible Products* brochure, (1998)
6. Todd Newman, *Fifth Color Imaging Conference Proceedings*, "Making Color 'Plug and Play'," p. 284, (1997).
7. International Color Consortium, *ICC Profile Format Specification Version 3.4*, p. 42, (1997).
8. Michael Has, et. al., Proceedings of the SPIE Conference, Zurich, "Some Aspects of the use of Contextual Information in Production", in press, (1998).

Biography

Gary Dispoto is the project manager for the Computational Color Reproduction project at Hewlett-Packard Laboratories. Gary holds a BS and an MS in Electrical Engineering from Stanford University. He joined the Printing Technology Department at HPL in June 1985, where he has been involved in research and development in thermal ink jet color printing algorithms, halftoning techniques, color printer characterization and calibration, and color appearance. Gary currently serves as HP's alternate representative to the ICC.