Kodak Polychrome Graphics

# Matchprint Virtual Proof: Technical White Paper

## Introduction

This white paper describes the characteristics and system level requirements to achieve accurate remote viewing of subtractive CMYK images on additive RGB displays. When implemented successfully, this process is called *virtual proofing.*

Though we attempt to explain the *virtual proofing* process as straight forwardly as possible, this white paper is intended primarily for individuals having a solid understanding of color management and process control within the print production workflow.

## Remote Hard Copy Proofing, Soft Proofing and Virtual Proofing

CMYK color proofing is traditionally achieved and communicated through a hard copy proof. Publishers, ad agencies, corporate clients and others verify and approve hard copy proofs before going into production. Hard copy proofs must be physically transported from the pre-press service provider to the client - a step costing irrecoverable time. If color-critical proofing could be achieved electronically (essentially eliminating proof transportation time), the proof to print cycle could be significantly simplified and shortened.

Some electronic methods currently exist, but they do not achieve the critical requirement of acceptable color proofing. *Remote hard copy proofing* and *soft proofing* are two examples:

***Remote hard copy proofing*** (sending a print electronically, for hard copy printing at a destination) has been tried over the years. This concept is attractive in theory, but in practice, is difficult and generally undependable due to the uncertainties of the output devices. For example, the person initiating and transmitting the digital file has no idea if the output device on the other end is calibrated or if correct colorants or media are loaded.

***Soft proofing*** (RGB display) is used today for non-color critical applications. The most common form of this is to e-mail a PDF (Portable Document Format) file. When viewed with standard software products, such as Adobe® Acrobat®, the resulting soft proof yields information on position, geometry, layout, fonts, etc., but cannot be trusted with respect to color.

***Virtual proofing*** is the process created by Kodak Polychrome Graphics (KPG) that combines the speed and ease of use offered by PDF files with the added assurance of accurate CMYK color rendition. The result of KPG's research and development to achieve *virtual proofing* is the topic of this technical white paper.

Many integrated, high-performance components, both hardware and software, are required to successfully achieve virtual proofing of CMYK images. Systems already exist that exhibit some measure of the required performance requirements. However, virtual proofing requires substantial enhancements and additions to these existing components and systems.

## Existing Approaches for Color on Monitors

### RealTimeImage® System

This system is specifically designed to practice soft proofing. Users upload native CMYK file formats such as PostScript, PDF, CT/LW, TIFF-IT and others. The remote server processes these files into high resolution CMYK bitmaps which are then converted to a standard RGB color space. Users at remote locations use standard Internet browsers (e.g., Netscape Navigator or Microsoft Internet Explorer) to view thumbnail displays of the processed images, which are organized in folders similar to those used on Macintosh® and Windows®-based systems.

The remote server allows the user to view image areas rapidly by compressing and transmitting only the data needed for viewing. At the local level, conversion can be enabled from standard RGB to the local RGB of the system using the standard Apple ColorSync® protocol on a Macintosh-based system. Annotations and comments from the viewer are password enabled and archived as metadata with the image file at the server.

### Portable Document Format (PDF)

The simplest means to view images and perform annotations is Adobe Acrobat PDF features. The mechanism used for annotations of PDF files is considered adequate (in terms of encryption and authentication) to be considered on par with a hard copy signature.

Neither the RealTimeImage nor PDF image viewing with Adobe Acrobat approaches claim to offer color-critical proofing. In order to achieve that increased performance, new components and processes must be added.

Soft proofing even in a local, controlled environment has only had modest success, often achieved only with significant investment in consultants who are expert in color management tools.

Limitations of current display hardware and calibration technology are central to the overall problem.

## Monitors: CRT vs LCD

Current RGB display technologies fall broadly under two categories: CRT and LCD. The vast majority of either type are not suitable for critical color viewing. Neither CRT nor LCD displays have the full range of properties required to enable virtual proofing in uncontrolled lighting conditions.

***CRT*** (cathode ray tube) is a specialized vacuum tube (e.g., the "picture tube" in television sets) in which images are produced by an electron beam striking a phosphorescent surface. Most desktop computer monitors use CRTs, though the fraction of LCD monitors is continually increasing.

> Pros: CRT displays are a mature technology. They have sufficient color gamut, stable color properties, good uniformity across the monitor (top/down/left/right), smooth, analog voltage-based reproduction behavior, and little change in color appearance when images are viewed from an angle.
>
> Cons: CRT monitors have limited brightness, resolution is limited to ~100 dpi, they're heavy with a significant footprint and there is limited correlation between measured reflective color on paper with the "same" color displayed on the CRT.

***LCD*** (liquid crystal display) is the technology used for displays in notebook / laptop computers and a growing share of desktop installations as well.

> Pros: LCD monitors are capable of much higher intensity (up to 3 times the brightness of CRTs), they have higher contrast ratios than CRTs (1000:1 versus 200:1), better visual correlation of colors on reflective media with those displayed on the LCD, acceptable gamut for simulating CMYK and up to 200 dpi resolution.
>
> Cons: LCD is a less mature technology, typically with poor screen uniformity (top/down/left/right), less smooth, more complex color reproduction behavior, and significant shift in color appearance when images are viewed from angles other than directly in front.

KPG's initial virtual proofing system encompasses CRT technology. CRTs used in conjunction with the inventions described in this white paper are satisfactory for virtual proofing overall. Recent improvements in LCD technology may enable a comparable LCD-based system as a next generation product.

## $LAB_{RGB} = LAB_{CMYK}$ Doesn't Yield a Visual Match

### Current CMYK to RGB conversion technologies

Another barrier to successful virtual proofing is the limitations of CMYK to RGB conversion technologies and systems currently available.

Most CMYK profiling technologies exhibit artifacts and inaccuracies when converting to L*a*b*, RGB, or C'M'Y'K'. Higher order methods for profiling the source CMYK system are necessary for virtual proofing. An example of such a method is described in Dr. William Rozzi's U.S. Patent US6232954, "Arrangement for high-accuracy colorimetric characterization of display devices and method…".

Assuming one has accurate CMYK profiling, another barrier to successful virtual proofing is the visual disparity perceived between the CMYK hard copy and the RGB image displayed. Visual testing at KPG with a number of people viewing color has confirmed the experience of skilled providers of ICC based solutions: when CRT and hard copy measured L*a*b* values agree, the visual match leaves significant room for improvement.

The reasons for these disparities and the technical solutions for them are described here.

## Stability and Calibration Methods are Inadequate

### Current display calibration technologies

KPG's laboratory evaluation of existing high-end, calibrated CRT monitor systems indicated a maximum error of 2 delta E from target with a typical error of 1 delta E. Although this error is considered small by some standards, our laboratory testing indicated that when the total difference between two CRTs is larger than approximately 1 delta E (particularly in the +/- directions of delta a* or delta b*) the visual difference is noticeable to experienced color viewers. State of the art monitor calibration technology does not appear adequate to achieve sufficient CRT to CRT color consistency.

## Barriers to Color Management

### Deficiencies in current color management architectures

Finally, even if a system could be devised and manufactured with accurate calibration and color management, virtual proofing requires a system level infrastructure in order to work reliably.

Color management infrastructure today as embodied in ColorSync (at the operating system level) and ICC support by applications such as PhotoShop (at the application level) are designed to provide a very high degree of flexibility. Files can be converted or rendered to a display device according to the needs of the user. This type of system is very powerful in the hands of a color expert performing research, but can be very risky in a workflow involving many people with varying degrees of skill in color management.

The ultimate system for local and remote virtual proofing is one that permits wide ranging choice and flexibility in the hands of a color expert (referred to as the administrator from here on) and enables complete control by the administrator over the entire workflow.

The administrator should also determine the acceptable degree of risk with regards to calibration. In other words, how does the administrator have confidence or confirm that the system remains in calibration? For example, how could he or she know whether lightning struck nearby a remote site, thereby destabilizing the color properties of the virtual system? The capability to enforce remote calibration or system self-check is necessary to manage the risk from such an event.

## Virtual Proofing: Overview of the Invention

### Hardware system architecture

<u>Color monitors</u>

**Accurate, highly stable, calibrated color monitors:** A true virtual proofing system requires a calibration method for the RGB display system to ensure consistency between any two CRTs over the lifetime of the devices. (The word *consistency* means a nearly identical side by side match for any RGB image displayed.) Monitor to monitor consistency applies equally whether the monitors are side by side or geographically remote from each other. In theory, this technology could be built into a CRT system. Acceptable CRT to CRT consistency has been demonstrated and is the subject of KPG’s pending patent application entitled “Calibration Techniques for Imaging Devices” (Edge).

The suitable CRT must have a high degree of color uniformity across the entire screen. A desired goal is that any measured area exhibits <1 delta E from the center in a*b* for white and gray, and <2 delta E from center L*.

An accurately calibrated system requires an accurate measurement device. Note that most low cost emissive colorimeters and spectrophotometers commonly vary from each other by +/-2 delta E or more. For some of these devices, the device to device variability is much higher than the random noise of each device. Colorimeters or spectrophotometers for use in a virtual proof calibration system must be calibrated to a defined, highly reproducible standard such that the accuracy of the local measurement device relative to the standard is comparable to the error due to noise and random measurement error of the device. Calibrating the device to a reference standard is achieved and periodically re-confirmed through highly structured manufacturing procedures and equipment. The requirement for the emissive color measurement device for virtual proofing is a repeatability of +/-0.1 delta E and an absolute accuracy (versus the primary standard) of +/-0.5 delta E for all color values.

Viewer for hard copy

Since virtual proofing periodically entails a side by side visual confirmation of colors displayed on the screen with those of contract CMYK hard copy proofs, an accurate illuminated viewing environment is necessary. Note that light booths historically have exhibited variability with regard to color temperature, even among those indicating a standard viewing environment such as D50. However, since light booths are almost never placed side by side, this variability has not been a major issue. To a large degree, human visual perception adapts to the slight differences in color temperature and defines the current viewing condition as “white” when viewing images of snow, white lace, or other “white” backgrounds.

A challenge for successful virtual proofing is a display device which simulates both the effects of the illuminant as well as the paper and color properties of the hard copy proof. When a CRT display is adjacent to a small light box viewer, slight differences between the systems are readily apparent. This problem is handled by selecting viewing equipment which:

- Has uniform intensity, particularly from top to bottom,
- Contains light bulbs or fluorescent tubes that are consistent over time and from lot to lot.

Commercially available D50 (i.e., 5000K color temperature) fluorescent tubes from different manufacturers (or even different lots from the same supplier) can vary significantly from the design center point of 5000K. KPG evaluation has shown that narrow tolerances on these bulbs are necessary to insure color consistency among virtual proofing locations. Additionally, the illumination level in the hard copy viewing equipment must be reduced somewhat to yield an overall perceived brightness comparable to the CRT display device. Note that color temperature or spectral characteristics cannot vary as illumination level is adjusted.

To ensure the color, appearance and contrast of the CRT images are not compromised by stray light, a viewing environment which eliminates or nearly eliminates ambient light (e.g., a kiosk enclosed by an opaque curtain or walls) is necessary. It is possible that LCD's (by virtue of their significantly higher brightness) could be employed in a virtual proofing system with significantly less restriction on ambient light levels.

Standard PC, server, and network connectivity

At a minimum, the virtual proof system requires a local PC (note that "PC" can mean either Macintosh or Windows based computers) to process the image data file and display the images on the display system. The levels of connectivity can be as follows:

- Stand alone workstation - requires a suitable viewing environment (e.g., kiosk), calibrated CRT system, illuminated viewer for hard copy, and (if required) colorimetric measurement device for the viewer, and PC system. All software and color control resides on the PC.

- Interconnected workstations – essentially this includes two or more of the previously mentioned stand-alone workstations supported by some form of network infrastructure for ease of file transfer.

- Server-based solution - multiple display systems interconnected with a server acting as the central, authoritative intermediary. In this scenario, the software components for processing files and converting color data can be distributed. The generalized conversions, including RIP'ing and conversion to standard RGB space can be best performed at the server. T he non-general conversions can be performed at each local system using software in the form of a browser plug-in or native viewing client software and other local applications.

This third example would address issues such as image enhancement or CPU-intensive image processing for a particular display device and conversion from standard RGB to local RGB for that display device.

**Software system architecture**

The server-based solution, which is the most complex and powerful system for remote virtual proofing is described here. The simpler forms of this system mentioned in the previous bulleted list would be similar in many respects, except that the core processing software would all reside locally on one or more systems rather than separating software and image functions among server and clients.

The following subsection, “Soft Proofing - Database for storing page image files and metadata,” describes the basic infrastructure of a system that implements *soft proofing*. The technology exists today for this type of soft proofing in a product offered by RealTimeImage.

The next subsection, “Specific requirements for virtual remote proofing,” describes the enhancement, additions and modifications required to enable a soft proofing environment to achieve *virtual proofing*.

Soft Proofing - Database for storing page image files and metadata

Most image databases provide standard features such as the ability to search by various fields such as job name, image name, customer name, date, etc., as well as the ability to view thumbnail versions of each page. By design, image databases generally permit metadata (e.g., annotations) or data associated with each page to be archived and retrieved easily. KPG and RealTimeImage have partnered to provide a professional infrastructure for the image database and access via Web browsers.

**Upload/download:** For a distributed system, a simple means of transferring image files to and from the server is required. Most databases permit metadata to be associated and transferred simultaneously with the image file itself at the time of upload. In the case of the RealTimeImage approach, metadata is associated with the destination “folders” that can be designated as workspaces, projects, files, versions, etc. In general, the only requirement is that metadata be easily associated and retrieved.

**Page file interpreter:** The local or remote system must have the means to interpret and process the necessary image file formats. Most commonly, some form of raster image processor (RIP) is incorporated into the system. A well-known example of this is the CPSI PostScript RIP software module by Adobe Systems. The CMYK image data and vector commands are converted to a CMYK bit map ("rasterized" file). Alternatively, the image data and vector commands can be converted to CT/LW format if systems at the remote end are capable of properly interpreting and displaying files in this format.

**Processing parameters:** Each file or job processed by this system must have a set of parameters associated with it. Some soft proofing systems allow the user to set resolution as a parameter while others allow color CMYK simulation to be set. Note that most high-end CMYK proofing systems allow both to be set.

Examples for setting processing parameters in soft proofing systems as well as in high-end digital proofers are:

- Provide a menu of predetermined sets of parameters such as resolution, color target, etc. (e.g., output CMYK controllers such as the Matchprint RIP for driving printers) in the print window.

- Provide a setup window for resolution for each hot folder into which files or jobs are loaded or uploaded (e.g., RealTimeImage software)

Once processing parameters are set, a means of verifying the parameters after the fact must be provided. In the case of hard copy output, it is useful to provide the setup conditions on the border of the proof. In the case of files in a database or server used for soft proofing, metadata must be associated with each file to provide information on the parameters used for processing and displaying the file.

The resulting data are compressed and transmitted from the server to the remote soft proofing location. Of course, loss-less compression is highly desirable, but often difficult to achieve.

**Viewing of images from multiple nodes on the network:** If the mechanism used to perform virtual proofing is a server-based model, then a means of viewing the image must be provided. Since general purpose Internet browsers are not optimized to view high-resolution images, the solution provided by RealTimeImage is convenient and effective. The RealTimeImage approach utilizes data compression technology to send only the necessary high-resolution data (at screen resolution) as users zoom in and out of a high-resolution image file.

The value of the server-based approach is that multiple users can simultaneously access different files at the same time from the same server database. The central server is not used to display imagery – rather all images are displayed remotely via browser and plug-in software or native client viewing software.

**Password protected annotations:** Both the RealTimeImage and Adobe Acrobat systems offer the feature of password protection combined with annotation. Each participant making annotations has both a unique password and color for the annotations performed. Each color-coded annotation has a label with the annotator's name to identify the source of comments.

**Color management:** Both the RealTimeImage and Adobe Acrobat systems offer a degree of color management support. The Acrobat system allows each PDF file to be tagged with a CMYK ICC profile. The Acrobat system renders each CMYK pixel to the RGB display by communicating with the color management system in the operating system (e.g., ColorSync, ICM v2.0, etc.) to determine the default local RGB display profile and to convert the CMYK data to RGB pixels by means of CMYK and local RGB profile.

Prior to partnering with KPG, RealTimeImage (RTI) utilized a standard default CMYK characterization which was then converted to the local RGB display profile. In order to enable virtual proofing, RTI added new color management flexibility as described in the next subsection.

<u>Specific requirements for remote virtual proofing</u>

The previous subsection, "Soft Proofing - Database for storing page image files and metadata," describes the state of existing soft proofing technologies today. In many cases, soft proofing is adequate in itself without need for the additional critical color performance enabled by virtual proofing. Of course, virtual proofing encompasses all the requirements of soft proofing, with the following additional requirements:

**Color Administrator:** Each virtual proofing site should have a designated color administrator and a system administrator (who can be the same person). The color administrator must have the flexibility to adjust the unique process parameters described in the following sections (in particular, color simulation targets). Participants without administrator privileges are not able to view or change the options available to the administrator. This ensures all participants will see a page in the same way with a similar degree of color precision.

 

**Selection of color target simulation:** Each page, project, or group of jobs needs a designated CMYK proof simulation. The administrator for the project needs to choose which ICC profile is associated with the each viewed page.

For remote virtual proofing using the server-based approach, RTI has added CMYK simulation (i.e., the CMYK ICC profile) as a process parameter for the job (determined by the administrator, using password access.) Non-administrators can view and confirm which color simulation was chosen for the job, but are not allowed to modify the choice. This arrangement ensures flexibility and complete control.

**Optimized color management for print CMYK to display RGB:** The profile and the CMYK to the local display RGB conversion must include the corrections to XYZ and are the subject of KPG's pending patent application entitled "Correction Techniques for Soft Proofing" (Edge).

This patent application describes correction of XYZ data measured on CRTs to correlate with XYZ data measured on CMYK hard copy.

When accurate CMYK profiling is combined with the RGB transformations described in these invention records and with accurate display calibration, critical color viewing by way of virtual proofing is achieved.

**Image enhancement for screen viewing:** In order to give the visual appearance contrast and detail, the RGB data rendered on the display device should be dynamically enhanced. Because CRT screen resolution is limited to approximately 100 dpi, image enhancement is needed to achieve appearance comparable to the corresponding hard copy proof. As a higher zoom ratio is used, less enhancement (or none) is required since the rendering of the image detail is now visually equivalent between hard copy and virtual proof.

**Control of time between calibrations:** The display system (display hardware plus calibration software/hardware) must employ accurate calibration technology described in KPG's pending patent application entitled "Calibration Techniques for Imaging Devices" (Edge).

One of the difficulties in remote hard copy proofing is the challenge of getting remote proofing devices to match each other or a common standard. There is a further challenge to enforce periodic calibration to ensure a continuing satisfactory match between multiple proofing systems.

The solution to these issues entails enabling the color administrator to define both a default maximum time between calibrations as well as to optionally establish a calibration time interval specific to one image or job. This allows the flexibility to require calibration once per day for most jobs as well as to enforce calibration immediately prior to viewing particularly critical images.

By adding this "MaxCalTime" parameter to the parameter window or equivalent, the administrator can set a default MaxCalTime for groups of jobs similar to setting the color simulation target, resolution, etc. The administrator can also set MaxCalTime = 0, meaning that calibration is mandatory immediately prior to viewing a particular file or image.

The process for images requiring immediate calibration is as follows:

1. The reviewer selects an image for view.

2. The local browser plug-in or viewing software receives image parameters from the server.

3. One of the image parameters communicated to the plug-in is the MaxCalTime.

4. If MaxCalTime is greater than the time since last calibration, or if MaxCalTime=0, the plug-in communicates to the user that calibration must be performed as a prerequisite to viewing the image. If the user elects to proceed, calibration software is automatically launched.

5. After the calibration procedure is complete, the calibration software returns control to the browser plug-in or local viewer application.

6. The image or file is viewed normally.

In this manner, the color administrator implements and enforces color confidence requirement for images viewed at remote locations.

If the MaxCalTime is considered unnecessary or objectionable by the remote viewer, they can elect not to view the image or to view in non-color critical mode. Thus, the trade-off between having nearly 100% color confidence and the few minutes needed for calibration can be mutually agreed by the parties involved. However, as with parameters such as resolution and color target simulation, only the administrator has the authority to make the decision, thereby minimizing the risk of confusion due to accidental change of parameters.

**Critical color mode indicator:** Systems implementing virtual proofing could also be used in an adjunct, non-color critical mode. An example could be an advertising agency professional who wishes to view images for content from a laptop computer while traveling. In this case, the capabilities of soft proofing are available from the aggregate virtual proofing system, though critical color viewing is missing. In these cases, the browser plug-in or viewing application must be recognize that critical color viewing capabilities are not currently enabled. Although images can be accessed, displayed, and annotated, a plainly obvious means must be implemented to advise the user that the local viewing system is not currently in critical color mode. An example might be a banner or mark on or adjacent to the image being viewed. In a similar fashion, all annotations performed while the system is in non-critical color mode should clearly indicate they were made in this mode.

**Indicator of measurement CIELAB values:** In order to relate color of virtual proof images to quality assurance and process control systems already in place, an “eye-dropper” tool that supports CIELAB values is advisable.

The virtual proofing system described in this document would best provide an eye-dropper tool with the characteristics indicated below. Working with KPG, RealTimeImage has enhanced the standard eye-dropper tool to meet these requirements for virtual proofing:

- Displays the original CMYK pixel value when the tool is pointing toward a particular pixel location in the displayed image.

- Displays an accurate prediction of the measured value of L*a*b* along with the value of CMYK. This value should be consistent with a particular color measurement device such as a Gretag SPM50 at D50 illumination, 2-degree observer. This value should be calculated and displayed to an accuracy of one decimal place (e.g., it should read L*a*b* = (97.5, 0.3, -0.2) rather than L*a*b* = (98, 0, 0)).

The reason for displaying the predicted color measurement value is to permit a press operator or other user to measure a specific color to confirm whether it matches the L*a*b* color value intended in the original image file.

**Requirement for system warm-up:** A final quality assurance mechanism required in a virtual proofing system is adequate warm-up time. Laboratory studies have shown that CRTs often emit more light when first switched on, but equilibrate and remain very stable for long periods of time once temperature stability is achieved.

Consider a CRT set to a particular target white point value (for example, an illumination white point of D50 and intensity Y = 82.0 candlellas/$m^2$). If the CRT is switched off, allowed to cool and then switched back on, brightness can typically be higher by 5 units in L*. Furthermore, the properties of the gamma curve behavior as outlined in "**Accurate, calibrated additive color display,**" are stable only after approximately one hour warm-up time.

To address this issue, the virtual proofing system must include a local startup application that detects whether the system has been shut down and rebooted. Off time can be used to determine the needed warm-up time.

There are several ways to prevent premature use of the system using this startup application:

- The startup application could create a time stamp file that is read by the browser or image viewer application. The viewer application will preclude image viewing in "color critical" mode until the appropriate warm-up time has transpired.
- The calibration application could inhibit calibration until warm-up has occurred.
- The startup application could launch the calibration application, which can then alert the user that warm-up must occur. Meanwhile, the user can position the measurement device on the CRT and leave the area. After the specified warm-up time, the calibrator would automatically proceed to measure, validate and/or calibrate the CRT. Upon returning, the user would then be prompted to follow the calibration procedure for the second CRT if more than one is installed with the system. The system is then "good to go".

One option for connecting the CRTs to the computer is to disable the on/off switch on the CRT so that is it always in the "on" state. Then connect both the PC and CRT to a single power source. Thus the computer being on/off is indicative of the CRT being on/off.

As an extra precaution, the startup application can run continuously in the background and periodically communicate with the CRTs via protocols such as VESA specified DDC/CI to ensure the CRT is in fact on and functioning.

## Our Expectations of Virtual Proofing

The virtual proofing system described in this white paper has a number of highly beneficial characteristics:

- It renders subtractive CMYK images to an additive RGB CRT screen so accurately that users will feel they are viewing and interacting with a traditional hard copy proof,
- The system effects of ambient light are eliminated,
- The system ensures consistency between images viewed at multiple locations at multiple times,
- The system allows the administrator to determine proofing color targets for jobs viewed at multiple locations,
- The system enables the administrator to require and enforce calibration before certain color-critical images are viewed,
- The system manages risk by eliminating common causes of color variability,

With the virtual proofing characteristics described here coupled with the collaborative capabilities of soft proofing, critical color virtual proofing becomes a reality.

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