CMS for digital photography, a case study
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ABSTRACT
The objectives of the study was to compare image quality from digital photography to RGB-printer under two digital imaging workflows: legacy-based and CMS-based. Due to the difference in judging criteria, the study shows that legacy-based digital imaging workflow can produce pleasing images as good as CMS-based workflow. But ICC-based CMS out performs legacy-based workflow in matching the color appearance of the source images. This is a welcome feature in direct mail catalogs whereby printed images need to match the appearance of the merchandise closely.

Keywords: Color management, digital photography, workflow, image quality

1. INTRODUCTION
A number of technology advancements prompted this study: (1) the abundance and affordability of multi-mega pixel digital cameras; (2) RGB-based digital printers require less user skills to yield good print quality; and (3) improved ICC-based color management technology since its inception in 1993\(^1\). This study attempts to find out if ICC-based color management offers distinct advantages in terms of image quality and productivity over a legacy-based digital imaging workflow.

2. LEGACY-BASE WORKFLOW VS. CMS-BASED WORKFLOW
To carry out this study, the difference between a legacy-based workflow and a CMS-based workflow were differentiated. In a legacy-based workflow, the user pays little attention to device calibration and profiling. A typical scenario in a legacy-based workflow: (1) an image is captured by a digital camera and downloaded to a computer, (2) the image is adjusted by the user and output to a printer, (3) the digital file is tweaked in the image editing software based on visual feedback of an existing output, (4) the tweaked file is sent to the printer. The desired image quality eventually is achieved after several such iterations and is a function of the user’s skill.

In a CMS-based workflow, the user has to calibrate imaging devices used and ensure that devices stay in calibration. A typical scenario in a CMS-based workflow: (1) an image is captured by a digital camera and downloaded to a computer, (2) the image is converted from the camera RGB space to the internal RGB space of the image editing software, (3) Image-dependent adjustments, such as cropping, image size, spatial resolution, sharpness, etc., are performed; (4) the image is converted from the internal RGB space of the image editing software to a printer space and output to the printer. The print-ready digital file requires no tweaking if the source image is desirable. The desired image quality depends on the proper use of the CMS technology and less on the user’s skill.

3. EXPERIMENTAL
The objective of the study was to compare image quality from digital photography to RGB-printer under two digital imaging workflows: legacy-based and CMS-based. Image quality is defined in two ways: reproduction quality and picture quality. Reproduction quality is the visual assessment of the image quality in relation to a reference, e.g., a printed image of an oil painting in comparison with the original painting. Picture quality is the visual assessment of the image quality with the observer’s own criteria as to what’s pleasing.

Key technologies used in the study were a Kodak DC290 digital camera capable of producing more than 2 mega-pixel RGB images, a Mac G3 with a 21” Studio Display color monitor, Photoshop 5.02 capable of image adjustments and ICC implementation\(^2\), and an Epson SP5000 ink jet printer. A number of ICC-based color management technologies were used for device calibration and profiling. Among them, Kodak Colorflow Profile Editor was used to build profiles for the digital camera under controlled lighting conditions; Colorflow Profile Editor was also used for printer profiling along with
GretagMacbeth’s SpectroScan (an automatic color measurement and data entry device); OptiCal 3.0 was used for monitor profiling along with X-Rite’s DTP 92 colorimeter.

To test for reproduction quality, a 2-dimensional oil painting and a three-dimensional still life scene were photographed. The initial reproduction plus two iterations (labeled as A, B, and C) were designed to represent the legacy-based workflow. For the CMS-based workflow, only the initial output using perceptual rendering intent (labeled as D) was allowed. A paired comparison method was used to collect psychometric data from 20 observers. All 20 observers are college students majoring in either photography or printing technology. These students were asked to select one of the two images (A vs. D, B vs. D or C vs. D) as to which image, while viewing under standard graphic arts standard viewing conditions, was closest to the original painting or the still life scene.

To test for picture quality, four digital images containing memory colors (broccoli, a school bus, fruits and a brick building) were prepared. In this case, only the images from the third iteration of the legacy-based workflow and the initial output from the CMS-based workflow were compared. The same 20 observers, made up of college students studying photography and printing, took part in the paired comparison test.

Figure 1 summarizes the design of experiment. Raw digital images were captured by a Kodak DC290 digital camera under controlled interior lighting conditions. This was the common starting point for both workflows. The authors were experienced ICC CMS users and Photoshop users. The entire experiment was carried out in a laboratory environment at RIT’s School of Printing Management and Sciences. For ICC-based CMS workflow (right-hand-side of Figure 1), the DC290 camera profile and the Epson SP5000 printer profile were applied to raw images in Photoshop’s Profile-to-Profile conversion prior to color hard copy output. For legacy-based workflow (left-hand side of Figure 1), color hard copy of the raw image was used as a visual aid for image adjustments using many Photoshop’s image adjustment tools. A total of three color output was allowed for each of the images tested.

![Figure 1. The experimental design conducted in the study](image)

4. DATA ANALYSIS

For reproduction quality testing, Figure 2 illustrates the outcome of the paired comparison of the oil painting. To recap, reproduction quality means the visual assessment of image quality in relation to a reference. As can be seen, the initial output
of the oil painting from CMS-based workflow out performs all three images from legacy-based workflow. The same can be said for the still life scene (Figure 3).

Without any further statistical analysis, Figure 2 and 3 suggest that CMS-based workflow offers higher reproduction quality than legacy-based workflow. In addition, CMS-based workflow offers higher productivity than legacy-based workflow because it is capable of matching the source images without iterations.

![Figure 2. Paired comparison of the oil painting for reproduction quality](image)

![Figure 3. Paired comparison of the yarn scene for reproduction quality](image)

For picture quality testing, Figure 4 illustrates the outcome of the paired comparison of four different images. Here, picture quality means the visual assessment of the image quality with the observer’s own criteria in mind. About one-half of the observers preferred memory colors from the third iteration of the legacy-based workflow to the initial output of the CMS-based workflow. No further statistical analyses was applied. We can not conclude that there is a significant difference between the two workflows in producing pleasing color images. But we’re confident that (1) CMS-based workflow offers higher productivity than legacy-based workflow despite the fact that it also requires more efforts in device calibration.

![Figure 4. Paired comparison of four digital images for picture quality](image)
5. SUMMARY

In digital imaging practices, it's strategic to account for device-dependent variables prior to addressing image-dependent variables. Legacy-based systems fail to recognize this point since they address both sets of variables through image adjustments. Even if legacy-based workflow can achieve the desired outcome, e.g., pleasing color reproduction, the cost of iteration is high and the adjusted image is bound to the device at the image editing stage. On the contrary, CMS technology separates device-dependent parameters from image-dependent variables. By adopting CMS-based workflow, a user can produce consistent image quality from digital photography to color hard copy without iteration.

Due to the difference in judging criteria, the study shows that legacy-based digital imaging workflow, with iterations included, can produce pleasing images comparable to a CMS-based workflow. But ICC-based CMS, requiring no iteration, outperforms legacy-based workflow in matching the color appearance of source images. This is a welcome feature in direct mail catalogs where printed images need to closely match the appearance of the merchandise.

6. FURTHER STUDY

It would be valuable to show how to convert legacy-based workflow to CMS-based workflow for increased image quality and productivity. In this regard, the role of the monitor and the selection of the internal RGB working space at the image editing stage are critical.

The case study focused on the advantages of the CMS method when using an RGB-printer as the output device. A PostScript RGB-printer accepts RGB data in various file formats and uses its internal color management mechanism to convert the RGB data to CMYK (or more than CMYK) data prior to raster image processing and hard copy output. The simplicity of the process makes it ideal for designers and photographers. But an RGB data file is considered not press ready. Therefore, a similar study could be performed using a CMYK-printer, i.e., either a CMYK digital proofer or a printing press. The objective would be to compare legacy-based workflow to CMS-based workflow to provide further evidence that the imaging and publishing industries can benefit from CMS-based workflow.

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