Effects on Color Management when using a Glass Platen to Flatten Book Pages or Documents while Capturing Images with a Digital Still Camera

Paul Howell and Miranda Howard; Western Michigan University Libraries; Kalamazoo, Michigan/USA

Abstract

An increasing number of libraries and archives continue to initiate digitization projects where new equipment and updated technology make it practical to digitize books and documents in color. In the past, much of the work being done with book scanners and camera-based systems captured only black and white or grayscale images primarily for their content. In the past few years, systems and cameras have evolved and the capturing of color images depicting additional context of the selected materials has become desirable and affordable. Many of the systems used for this work including overhead book scanners, commercial book cradles and specially designed holding devices used with photographic copy systems, use glass or other transparent material to hold the page or pages of a book or document flat for image capture. As there is no readily available information on the specific effects that an intermediate element in the digitization process has on the accurate color management of an image captured in this manner, this paper will provide an analysis of those effects on the color profiles created.

Although there are types of glass advertised as being optically clear as compared to ordinary glass, the metal oxides in standard commercially available sheet glass of any type generally impart some tint or color (normally green) to the glass itself. Therefore, these optical properties have the possibility of adversely affecting the actual color of an image being captured when a glass platen is used to hold or flatten documents in the digitization process. This research investigates the associated effects of capturing images through transparent materials of various types in an attempt to determine how accurately the color profile generated can compensate for any color shift. Image capture was performed with both high frequency fluorescent copy lamps as well as photo strobes to determine any advantages or disadvantages to the lighting system used.

A high quality digital camera optimized for copy photography was used along with standard color calibration targets to create the digital images used in the investigation. International Color Consortium (ICC) Profiles were generated and analyzed with commercially available software tools to determine the relative accuracy of their transformation and the resultant color gamut. The analysis compares the results of the images captured through glass platens of various commercially available forms to that of a control target captured without any intermediate element. Lighting uniformity and intensity were standardized for the sample sets with both systems used. All variables associated with the camera copy system and processes used to capture the images and the profiling processes were minimized to the maximum extent possible.

The conclusions derived from the analysis, including the variables noted due to the use of the alternate lighting systems and how the color accuracy of the digitized images were affected, are detailed. Recommendations are made as to the suitability of the various transparent materials when they are used as platens to flatten pages of a book or document.

Introduction

As the digitization of materials held in archives, libraries and special collections has increased, the costs associated with image capture have decreased. Along with this is the ever-increasing capability to produce high quality images of the selected materials. The capability to capture high quality digital images in color makes it possible to depict more than just the textual and graphical "content" of a particular item but also allows to some extent the "context" of the item to be represented.

Many factors should be taken into account during the image capture process for digital still cameras. In addition to resolution requirements and exposure, the accuracy of colors in an image needs to be considered. To obtain the most consistent and predictable colors, the introduction of color management into the workflow is required. [1] When properly applied, this technology can improve the quality of the captured image by more accurately representing the actual color of the original object. Although a captured image does not always represent the original exactly, the goal for both access and preservation should be to provide the end user with the most accurate reproduction possible utilizing the available technology.

Of specific interest, and for the purpose of this paper, is the process of image capture or photographing (copy photography) of pages from bound books, manuscripts and other documents with the aid of a digital still camera (as opposed to "scanning" with a flatbed scanner). A variety of book scanning systems, book cradles and other forms of book holding devices are used to achieve the requirement of properly positioning items during this method of image capture. Many of these systems and methods require that some type of glass platen or sheet of transparent material be placed over the item being photographed to hold it flat and in the correct position during the image capture process.

Color management workflows for digital cameras and the creation of color profiles for use with these systems are much more complex than those of other input devices such as flatbed and slide scanners. In addition to understanding the application of basic color management, consideration needs to be given to the effects of lighting balance and intensity, focus, exposure, lens focal length and camera position. Specific requirements, such as image neutralization, of the specific and normally proprietary software used in the image capture process also need to be applied. As previously noted, many of these copy systems use some form of transparent material as a means of positioning the original during image capture. This introduces yet another variable into the already complex requirements necessary for the proper color management of images created with this type of equipment.

Due to physical properties of intermediate materials, such as glass placed between the original object and a capture system or camera, there is the possibility of an adverse effect to the accuracy of the color being reproduced by the system. This investigation provides a basic analysis or test of the capability and accuracy of profile generating software to correct for these possible effects during the profiling process (generation of camera input profiles).

Commonly available materials, equipment and software were used for the tests so that the analysis would most accurately produce results consistent with normal working conditions and procedures available to the general library and archive community.

Procedures and Results

All of the equipment, software and the target used for the analysis are generally available through commercial sources. Except for the measurement and comparison of the corrected reference data, all lighting measurements and ICC profile generation were obtained with an i1Pro Spectrophotometer and i1Match software. Comparisons between reference data, images and attached ICC profiles were accomplished with CHROMiX ColorThink 3.0 Pro. Adobe Photoshop CS4 was used to manipulate images and attach the specific profiles. The availability of the type of equipment and software used to balance lighting and generate profiles should allow the average user to be aware of the requirements for color management and understand the required profiling procedures for this type of image capture.

A GretagMacbeth™ Digital ColorChecker® SG (semi gloss) color reference chart was used as the standard reference target. All color patches of the target were measured using MeasureTool 5.0.8 and the same i1Pro mounted in an i1iO Scanning Table. A target reference data file was generated using patch measurement mode and averaging of five samples from each color patch of the target. The reference data were saved in spectral form and used to replace the standard/default target reference file for i1Match and in all applicable comparisons in ColorThink. (For this analysis the measured reference data differed from the vendor supplied data by an average of 1.7 ΔE)

The copy stand setup for the analysis was a Kaiser rePRO RSP system with Kaiser HFB high frequency fluorescent lamps consisting of two sets of 2 x 55 Watt 5000K lamps. For the photo strobe testing component, the lamps were replaced with two AlienBees B800 flash units mounted on stands, with 32 inch bounce umbrellas providing a “soft white bounce” (the specifications for these units is 320 true wattseconds / 144,000 lumenseconds at 5600K).

The images of the ColorChecker target used in the analysis were captured using a Hasselblad H2 camera body with Hasselblad CF-39MS digital back and Hasselblad HC Macro 120mm lens. All images were captured with an aperture setting (f-stop) of 22. Exposure was initially checked with the aid of a Sekonic Flash Master L-358 light meter.

The latest version of the proprietary Hasselblad image capture software, Phocus version 1.1.3, was used to operate the camera in a tethered configuration and capture the target images. During the image capture process, all of the software adjustment tools were initially left in a neutral position or deselected. The exceptions to this were the default software settings for “Lens Corrections”, where the RAW processor increases the quality of the native Hasselblad images by providing “digital lens corrections for color aberration, distortion and vignetting”. [2]

For the purpose of the investigation, three readily available types of transparent material were obtained for analysis. For consistency and sufficient size to completely cover the color target, a 14 by 18 inch sheet as close as possible to .25 inch thick was selected for each. The samples consisted of standard “plate glass”, Starphire® Ultra Clear glass, and Cyro Acrylite® FF Acrylic.

Image Capture and Profiling

Initial setup for each lighting system consisted of using i1Match in the “Advanced” mode to “Check lighting equipment”. The i1Pro was calibrated with the ambient light head and used to balance the specific illumination (continuous or flash) of the target area, as it would be photographed. The relative color temperature and apparent intensity of illumination for each type of lighting is noted with the profile data tables that follow. The ColorCheckerSG target was then photographed uncovered and then with each of the transparent materials selected. Additionally, a QPCard 101 v2 was captured in the image area for consistency with each image and the middle gray patch was used to gray balance or neutralize each image with the neutralization tool in Phocus. [3] With an f-stop of 22 for all samples, the exposure of each image was held as close as possible to obtain a value in the white areas of the target of 210-245 (nominally 230-240), and a value of the black patches below 20 if possible (these values are required by i1Match to successfully create a valid profile in the advanced mode). Minor exposure (EV) corrections were necessary in the software for some of the basic exposures so that the white and black patches of the target fell into this required range for the profiling procedure. The relative International Standards Organization (ISO) rating used for the fluorescent lighting samples was 50, which is the default sensitivity of the charged-coupled device (CCD) sensor and recommended for the highest quality by Hasselblad. [4] The samples captured with photo strobe lighting required an ISO rating of 200 to allow for the standardized f-stop of 22 and still maintain the correct exposure for neutralization and proper values in the white and black patches of the target.

After images were captured with the Phocus software, and EV corrections made if necessary, the RAW image files (Hasselblad 3F format) were converted into Tagged Image File Format (TIFF) images that could be processed with the i1Match software. It was important to note the following statement from updated information about the current version of the Phocus software. “When generating the input file to be used by your profiling tool it’s important to export with an output preset where the profile is set to Source since this means that no ICC transformations will be applied to the data in the file.” [5] This setting is important so that the default input profile, Adobe RGB (1998), is not attached to the file changing the source color space data.

Each target image was loaded into i1Match and the actual target area cropped as required. The light source selected was D50, once again for consistency, and the profile was generated (built).

The advanced mode of i1Match makes it possible to "modify and fine tune" the profile and requires that a reference picture be loaded. For this step, the original target image was loaded and no modifications were made to the profiles. Verification of this was indicated by the procedure "Summary" indicating no corrections to the profile data had been made. Subsequently, each profile was saved with a descriptive filename.

Because of the requirement to use an ISO rating of 200 for the photo strobe lighting, it was decided at this point to also capture an additional set of target images at ISO 200 with the fluorescent lighting setup. Profiles were generated from these images using the same procedures as with previous samples so that any variances could be noted during the analysis.

Data Analysis

For the purpose of this investigation the ColorThink 3.0 Pro software was used as a basis for data comparisons. All ΔE values are recorded using the ΔE76 standard for profile accuracy. [6] The overall average ΔE values for all 140-sample patches of the ColorChecker chart were used for comparison. Target reference data referred to is the same measured spectral data file used to generate the ICC profiles for each of the samples.

Initially, each of the profiles were analyzed using the "ColorSmarts Guide" component of ColorThink that can recognize and extract the reference and measurement data used to generate the profile (when it's embedded in the profile) and compare the data to evaluate the accuracy of the profile. A report was created for each sample and the average ΔE76 was recorded in the table. Each profile was also opened with the "Profile Inspector" component and the gamut volume recorded. Comparison of the profiles in the "Grapher" component for each of the two lighting systems showed little variance between each of the four (4) profiles of each setup. The comparison of fluorescent to strobe lighting profiles showed a difference in larger LAB +b values (yellow/orange) for the strobe lighting, and larger LAB –a values (green/blue green) for the fluorescent lamps. Figure 1 shows the Grapher display of LAB values for the Starphire Glass profiles for both lighting systems where (red/gray = fluorescent / blue/black = strobe).

The ColorThink "Color Worksheet" component was used to compare color values of the patches in each target image file to the values of the original measured reference data file. A report was generated for each comparison and the ΔE76 values were recorded. Two comparisons were made for each image file, one for the basic file as it was converted, with the source Hasselbald RGB color space, [7] and one with the appropriate ICC profile attached/applied for color correction.

Because ColorThink does not read the reference data file measured in MeasureTool (a color list) in the same order as it interprets the color data from the image file of the ColorChecker target, all of the image files needed to be transformed before a comparison could be made and a report created. In Photoshop, each image needed to have applied the Image Rotation functions "90º CW" and "Flip Canvas Horizontal". The images were then saved in the rotated form, both without and with the appropriate ICC profile attached. In the Color Worksheet, the Reference file data was compared to that of these two sets of image files by using the Target Marquee tool to select the 140 patches of the target with a "custom" 10 x 14 Target Resolution grid. A report of ΔE values was then generated for each target comparison and the overall average ΔE76 values recorded.

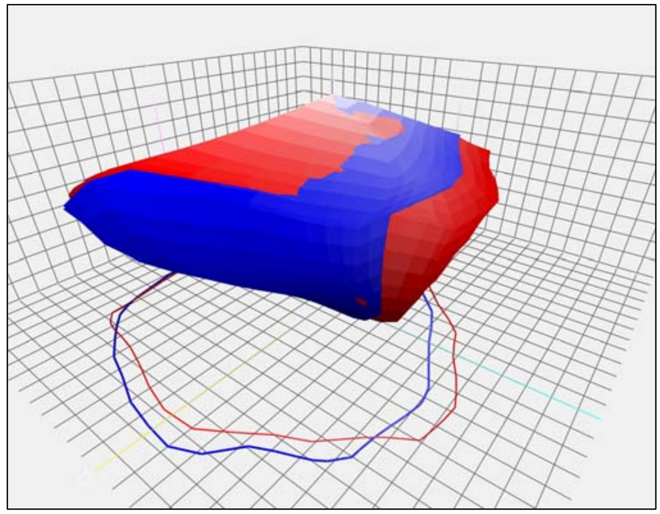

Figure 1. *ColorThink 3.0 Pro 3D comparison of Starphire Glass profiles*

The following tables list the results from the reports made during the data analysis of the previous discussed comparison procedures. An individual table is shown for each of the lighting system setups and the specific variations of each are annotated. The first two columns list the information extracted from the specific ICC profile generated for the specified target. The second two columns list the comparisons made between the measured reference data file and the image files with source color space (Hasselbald RGB) and with the specific ICC profile applied.

HF Fluorescent (i1Match / 4900K / 3000 Lux / ΔE76 Average)

f-stop 22 ISO 50	Profile	Gamut Volume	Source Space	Profile Applied
No Glass	2.98	972,522	7.03	3.02
Plate Glass	2.87	983,303	7.11	2.90
Starphire Glass	3.02	990.270	7.83	3.06
Acrylic Sheet	3.01	986.577	7.59	3.04

Photo Strobe (i1Match / 7800K / 900 Lux / ΔE76 Average)

F-stop 22 ISO 200	Profile	Gamut Volume	Source Space	Profile Applied
No Glass	2.66	973,539	6.59	2.71
Plate Glass	2.76	985,095	6.24	2.78
Starphire Glass	2.96	956,482	6.58	2.98
Acrylic Sheet	2.74	960,461	6.45	2.76

HF Fluorescent (i1Match / 4900K / 3000 Lux / ΔE76 Average)

f-stop 22 ISO 200	Profile	Gamut Volume	Source Space	Profile Applied
No Glass	2.99	916,974	7.23	3.08
Plate Glass	2.93	923,734	6.90	2.95
Starphire Glass	2.86	927,532	6.76	2.90
Acrylic Sheet	2.91	920,955	6.96	2.98

Discussion

This investigation was initiated to obtain an understanding of the possible effects imparted on the color correction of images captured through a transparent material, such as glass, by a digital camera. Practices involving this method of positioning materials for image capture are common, but in an effort to provide the highest quality image capture this specific factor required analysis in more detail. In addition to the data that was recorded during accomplishment of the procedures described, a number of factors were noted that affected specific results associated with use of the lighting equipment and the transparent materials analyzed.

In configuring the equipment and two lighting systems the high frequency fluorescent lamps proved to be the most easily arranged to obtain the required balanced and even illumination of the target. Ambient light measurements were very consistent and any required adjustments were not difficult to make. Because the target object was continuously illuminated at full intensity it was much easier to obtain proper object positioning and camera adjustments for framing and focus. Continuous lighting also allows exposure adjustments to be based on a fixed aperture setting allowing for more control of depth of field by increasing the length of exposure.

The use of the two photo strobes proved to be more complex and a number of factors needed to be resolved before the desired balanced and even lighting was achieved. Initially an umbrella "soft box" configuration was tried where the photo strobe light was directed toward the target with translucent material in front of the strobe diffusing the light. This configuration provided more light on the target, and color temperature measurements of 6300K were closer to the strobes advertised 5600K output than the final configuration. Although it was possible to obtain balanced ambient light readings of the target area, numerous adjustments to the configuration failed to provide sufficient distribution of light to obtain a target image that could be properly processed by i1Match.

At this point, a different configuration was tried where the light from the photo strobe was "bounced" off a white reflective umbrella back to the target area. This configuration provided less actual light to the target area and a measured color temperature of 7800K for the reflected light. After a number of adjustments to the position of the strobes, images could be captured that had adequately even lighting and patch densities for the profiling process. Images captured with this configuration also displayed various reflections from the camera and surrounding environment when photographing through the transparent materials and adjustments had to be made. Black foam core board was used to surround the camera lens and block reflections from reflective materials on the ceiling thus eliminating these reflections.

Although difficulties were encountered in configuring the tests for photo strobe lighting, results of the ICC profiling provided slightly better ΔE values. For effective results, the use of this type lighting will require additional factors be taken into account. In the specific environment tested, more powerful photo strobes would possibly allow for a broader range of the exposure settings. Additionally, the use of four strobe lamps should provide more even and consistent illumination of the target area. A good reference for this is section 62.2 Illumination of the original, in *Applied Photographic Optics.* [8]

The data for the image files with the source color space (Hasselblad RGB) indicate relatively consistent and low ΔE values (6-8 ΔE) for all images analyzed. It can also be seen that with the specific equipment used, the ICC profiles generated will provide for a correction of approximately three (3) ΔE or less for each of the targets profiled. Gamut volumes for the first two configurations used are also relatively close (<3.6% difference). Analysis of the TIF image files show minimal variance between the ΔE values of the profile evaluation and those of the ΔE values calculated from the target image with the profile applied and measured in ColorThink.

The additional set of data for the high frequency fluorescent lamps, captured with a relative ISO of 200, indicate ΔE values in the same range for the other samples. The primary difference is the somewhat smaller gamut volume recorded (<7% difference). This may be a factor accounted for by the previously mentioned default sensitivity of ISO 50 for the CCD image sensor, in combination with the lighting method used. Further investigation of the photo strobe lighting system with more powerful lamps or larger aperture settings may be of interest to evaluate any possible differences in this area.

Conclusion

Color management of digitized materials with systems and equipment similar to those used in this investigation is of interest if the most accurate representation of the original item is desired. This analysis provides an indication as to the suitability of three possible materials that could be used as platens to flatten/position pages of a book or document. Within the accuracy and capability of the image capture and testing procedures, the data indicates there are minimal differences between an uncovered target and one covered with any of the three tested materials. This is providing that the lighting equipment used is correctly adjusted and an ICC color profile is properly generated and attached to the captured image. Of interest is that the Starphire "Ultra Clear" glass generally returned values of the largest variance. Also of interest is the fact that ordinary "plate glass", which generally has a visible green tint, proved to function as well or slightly better for this purpose. Acrylic sheet is also a suitable alternative, for specific requirements, although it's increased susceptibility to scratching and attraction of dust needs to be taken into account.

References

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[2] Phocus by Hasselblad User Manual (Victor Hasselblad AB & Hasselblad A/S, 2008) pg. 2.

[3] Phocus by Hasselblad User Manual (Victor Hasselblad AB & Hasselblad A/S, 2008) pg. 22.

[4] Hasselblad CF User Manual (Victor Hasselblad AB & Hasselblad A/S, 2006) pg 32.

[5] Phocus 1.1.3 read me (Victor Hasselblad AB & Hasselblad A/S, 2009) http://hasselblad.com/statsproxy?Group=Phocus%201.1.3%20Mac%20-%20PDF&File=http://www.hasselblad.com//media/1631187/phocus%201.1.3%20read%20me.rtf

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[8] Sidney F. Ray, Applied Photographic Optics, Third Edition (Focal Press, Woburn, MA, 2002) pg. 535-538.

Author Biography

Paul Howell has a B.S. in Industrial Science and Education from Colorado State University. He served as an officer with the United States Air Forces in Europe, and worked in the printing and publishing industry before returning to the United States. Currently is the Digitization and Systems Manager for the University Libraries at Western Michigan University. He is concluding graduate studies in Imaging with a research concentration in color management for digital imaging and preservation.

Miranda Howard holds a MALS in Library Science from Dominican University, a MA in Art History from Northern Illinois University, and a BA in Art (studio) from Rockford College. She worked for fourteen years as an art and visual resources librarian gaining experience with digitization before becoming Head of Technical Services, Waldo Library at Western Michigan University. Professor Howard also has classroom teaching experience in the areas of Art History and Family and Consumer Science