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Thinking Outside the Color Profiling Capture Box

Don Williams and Peter D. Burns; Image Science Associates and Burns Digital Imaging

Abstract

Color-capture systems use color-correction processing operations to deliver expected results in the saved image files. For cultural heritage imaging projects, establishing and monitoring such operations are important when meeting imaging requirements and guidelines. To reduce unwanted variations, it is common to evaluate imaging performance, and adjust hardware and software settings. In most cases these include the use of ICC Color profiling software and supporting measurements. While advice on the subject by experts can be deftly persuasive, discussions of color goodness for capture are clouded by many imaging variables. This makes claims of a single, color-profiling approach or engine moot in the context of a greater workflow environment. We suggest looking outward and considering alternative profiling practices and evaluation methods that could improve color image capture accuracy and consistency.

Introduction

An underlying theme of this paper is the emphasis on the statistical variability inherent in any digital image capture workflow, and how it strongly affects the color encoding image performance at image capture. Rather than glibly assume a *what-could-go-wrong* attitude we urge the readers to think *anything-can-go-wrong*. We illustrate this, at a high level, in Fig. 1. It shows the component items in a typical digital imaging workflow, where color variability can be introduced. (Yes, even the lens can be a factor).

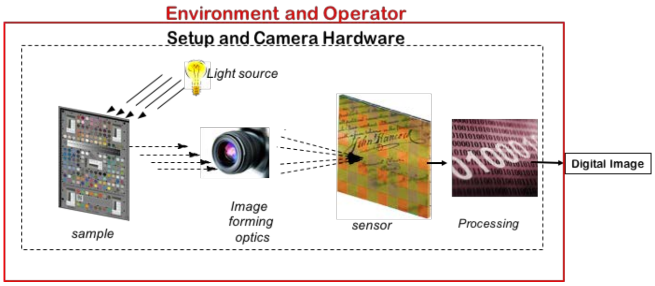

Figure 1: The different ways an image is modified at capture

Many users are, perhaps, not aware that any of these steps can influence the color capture performance of their systems. Others may dismiss these items as stable hardware entities that are accommodated in initial calibration, or are comfortably managed by their system providers. Our experience has been otherwise.

Even outside the direct camera calibration setup there are the environment and operator variables. Given the many interface options presented to an operator at the calibration point, all sorts of divergent selections can be made. What follows are suggestions of better ways to measure and manage color imaging performance for capture that are not often considered in the mainstream These are largely derived from 10 years of experience working with users striving to achieve FADGI* color conformance. [1-3]

Color Ground Truth

The starting point for any color profiling exercise is some form of colorimetric ground truth, that is, a color reference target. The popular ones used in serious cultural heritage capture applications are the Color Checker Classic (24 colors), and ColorCheckerSG (96 unique colors). Over the last several years color reference targets specifically tuned to the color demographics of cultural heritage content (vela, parchments, etc.) or artist's colors have emerged. All of these have a significantly greater number of unique color patches than those cited above, with the goal of improving color specificity and encoding accuracy for collection materials.[4]

Whatever color target is chosen though, each one should be individually measured for its colorimetry *(L*a*b*)* or ideally for spectral reflectance. Doing so helps eliminate the variability often seen with different generations of manufactured color targets, possible fading, or very simply random manufacturing variations. Do not rely on batch averages of color target colorimetry for color critical image capture. For the conditions under which a given target is measured, it is unlikely that the colorimetry would change under normal operational or environmental conditions over the long term.

With this target specific colorimetry on hand and the RGB camera data from that target, a color profile can now be created with the preferred profiling engine and selected parameters. This color profile can be thought of as a color dictionary that translates between camera RGB data and CIELAB (*L*a*b**) colorimetry. A simple illustration of this process is illustrated in Fig.2 below.

It is worthwhile noting that even for a given color target, differences in colorimetry can exist based on several factors. These are; illumination geometry, measurement mode, and instrument manufacturer. The best policy to take in such cases is to maintain consistency in each of these for a particular project or application.

* US Federal Agencies Digital Guidelines Initiative

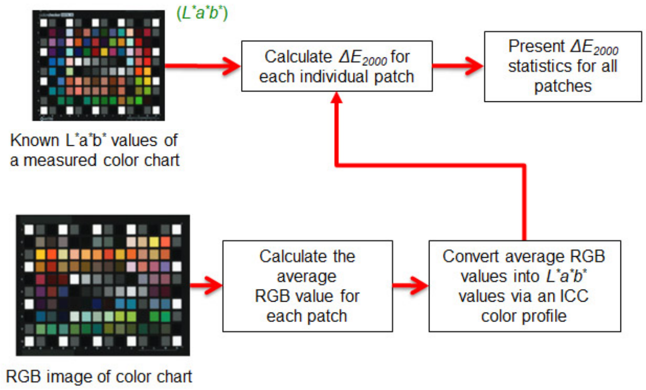

Figure 2: Evaluation of image capture color using reference chart

Profiles with Frequency as Panaceas

Up to two years ago we were not generally in favor of treating color profiles as panaceas for all exposure, white balance (WB) and color encoding ills for image capture. However, with some qualifications and exceptions, recent experience indicates the value of such custom color profiles. If computed properly and frequently, color profiles can be excellent tools in achieving FADGI 4-star performance for exposure, white balance, color encoding. We offer three key qualifiers.

- The initial target (image) capture from which the color profile is generated must be well behaved. By this we mean no clipping or near-clipping of the highlights and shadows (i.e. white and dark patches), and that the target image is uniformly illuminated
- A sufficient number of unique color patches (> 120) be used in the reference target image and that they reasonably represent the color demographics of the content to be digitized.
- The capture hardware, software and lighting settings are stable and not dramatically changed between the capture of the color target and actual capture of content in the workflow.

The last item is important because it minimizes the session-to-session variability. Adopting a 'microfilm' QA model is a good approach. In order to insure consistent imaging from beginning to end of a role of microfilm, target captures were made at the beginning and end of a role of microfilm. We suggest a similar approach.

Assuming the first two suggestions above are followed, capturing a color target at the beginning of every session will allow a custom color profile to be embedded or associated with all images captured during that session. As along as the operator is confident of a well-behaved exposure of the color calibration target in the beginning, the associated color profile can perform the appropriate exposure, WB, and color corrections. While there is still a chance that capture conditions may change during the session, it is unlikely they will do so dramatically.

These suggestions, of course, rule out the use of any 'canned' (pre-computed) profiles or those generated once and used over the lifetime of a project. As noted in our introduction, things go wrong. Generic or canned profiles are insufficient for color critical image capture. We suggest using whichever profiling software, targets, or data are preferred. However, be sure color profiling is done often in order to manage the inevitable variability.

Statistical Assessment of Color Difference

The most current, and popular, objective measure of color difference from an aim for a single color is ΔE_{2000}. For multiple color patches (in a color target) some central tendency (e.g. average or median) and dispersion (maximum value, or % value) of the target's color population is reported. This is usually the average and maximum value. Such basic summary metrics for a small number of patches (24 – 50) may be acceptable. However, such basic statistics for the large population of colors used in targets of cultural heritage applications are often insufficient.

We were inspired, in fact, by the tools in BasICColor Input software where a more rationale 90-percentile ΔE_{2000} value is reported in place of the maximum value. This is a good first step and is being considered in updated specifications for color error reporting in the FADGI guidelines. Too often, we find that a single outlier color in a large population of color patches will indicate a FADGI star level failure in an otherwise well color managed system.

Another alternative to presenting such color error data is through a ΔE_{2000} histogram. This is illustrated in Fig. 3 for both ΔE_{2000} and $\Delta E(a^*b^*)_{2000}$. The left side is a temperature map of color errors (green = low error, red = higher error) with the right side showing target colors themselves. In the middle are the ΔE_{2000} histograms along with a percentile color error slider. There are only four color patches out of 168 possible that are contributing ΔE_{2000} values greater than 10. Note too that the statistics and histograms of the ΔE_{2000} and $\Delta E(a^*b^*)_{2000}$ are nearly equivalent. This suggests that most of these errors are due to the chroma values (i.e., a^*b^*) themselves and not the L^* components

These graphing tools provide much better diagnostic context of where color errors lie, and whether these errors can be considered significant based on the collection content being digitized. These tools provide a choice to allow rational and adaptable guideline selections, based on the job on hand rather than simple statistical reports.

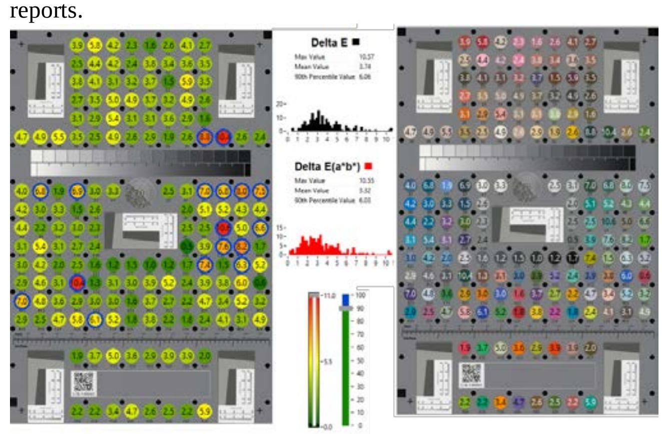

Figure 3: Color chart ΔE_{2000} Histogram examples

Applying content specific criteria to color patches has already been tested and is being used in OMB/NARA Memorandum Transition to Electronic Records (M-19-21).[5] This memorandum is based on the FADGI Technical Guidelines but has been modified to exclude any patch values with $L*$ values less than 20. This was done because the type of records being digitized under this memo do not have $L*$ values so low. Thus, such color patches were excluded from consideration when assessing color goodness for those projects.

Color Profile Smoothness

One technique for assessing posterization or gradient artifacts introduced by color profiles is the use of smoothness gradients or color blends.[6] Such tools have been frequently used in the printing and display side of digital imaging to evaluate stepping artifacts introduced when converting from RGB to CMYK color. Fig. 4 illustrates an example drawn from the camera color profiling software SpectaCore by ColorBurst®. Shown are continuous gradients of different hues and lightness. The top half are the original test gradients. In the theme of this paper these can be considered synthetic color test targets. The bottom portion shows the exaggerated stepping that could occur with aggressive or poorly transformed data.

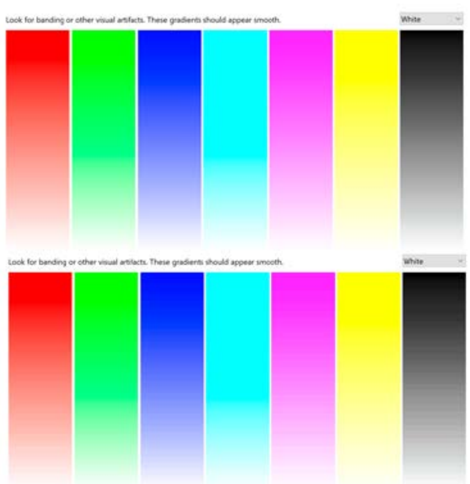

Figure 4: Color gradients with posterization artifact (bottom)

Typically, these artifacts are judged visually by inspecting for such stepped behavior. With respect to input color profiling these too can be evaluated quantitatively by comparing before/after transitions. With row/column averaging calculations these artifacts could more easily be detected computationally than they could visually.

Conclusions

We have addressed several ways to reduce variability inherent in color digital image capture for cultural imaging. We propose the use of traceable colorimetric measurement for (each) reference test chart. These can be used to color-correct digital objects, using ICC color profiles when needed. However, consideration should be given to color-error statistics other than the simple mean and maximum, currently in common use. The elements of the test chart can be selected to best represent the content of collections being photographed. In addition, a corresponding interpretation can be given to measured color errors. The signal transformations provided by color profiles can introduce unwanted artifacts, usually based on the degree of correction needed. Evaluation of these is aided by processing and examining of computed ramp images.

References

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Author Biographies

Don Williams is founder of Image Science Associates, a digital imaging consulting and software group. Their work focuses on quantitative performance metrics for digital capture imaging devices, and imaging fidelity issues for the cultural heritage community. He has taught short courses for many years, contributes to several imaging standards activities, and contributes to the US Federal Agencies Digitization Guidelines Initiative, FADGI.

Peter Burns is a consultant supporting digital imaging system and service development, and related intellectual property efforts. Previously he worked for Carestream Health, Eastman Kodak and Xerox Corp. He is a frequent conference speaker and teaches courses on these subjects.