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Next Generation Camera Calibration Target for Archiving

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Abstract

The desired features of a new camera characterization target are described. Any new target must minimally be justified by meeting or exceeding the characterization performance targets used in current imaging processes. Additionally, a target should be physically robust against normal laboratory handling, including the ability to be cleaned after being soiled. To be less sensitive to illumination and camera geometry, all patches in the target should have identical gloss and more generally the same BRDF characteristics. Finally, some colors should be included that are similar to those in anticipated materials to be imaged. These features will allow a more productive and continuous workflow without interruptions imposed by inadvertent target mishandling, and bring cost and time savings by eliminating unnecessary recalibrations. After describing the process for selecting the colors of such a target, the target camera characterization performance is compared against targets in common use.

Introduction

Pressure to increase productivity of digitization activities in the archiving community has forced the evaluation of all aspects of the calibration, processing, storage, and transmission of imaging data. One important aspect is the calibration process which ensures accurate image capture, and the reference materials that enable that accuracy. Considerable expense is invested in these materials, typically color charts, for both their purchase and subsequent measurement. The proper calibration of the imaging devices must assume the reference measurements of the materials remains valid over time, and any change in the physical properties of those materials can reduce the accuracy of the color digitization data.

The first requirement of any proposed reference color chart is to have patches of sufficient color distribution to facilitate accurate capture profiles of digitization devices; this should include a general filling of available gamut as well as increased sampling in regions known to be of interest for the specific application. To address productivity pressures, the chart should be as impervious as practical to typical laboratory handling, and be able to be cleaned when soiled; such cleaning should not affect the reference measurement data.

Selection of Color Distribution

There are many color systems that could be used as suggested distributions for a color chart. This study focused on two, published by Pointer [1] and Newhall *et al* [2] ("Munsell"). After analysis, the Pointer distribution was rejected due to its essentially unattainably chromatic colors, made available by printing inks. The proposed target is limited to available paints, and therefore the somewhat less chromatic gamut provided by Munsell was used as the basis for aim colors in the proposed target. To ensure the target colors were based on the latest Munsell formulations, in particular for high-chroma colors unavailable in 1943, a modern Munsell

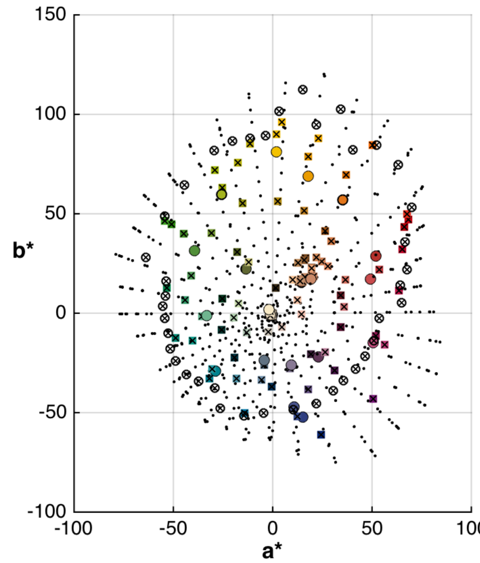

Figure 1. CIELAB b vs. a* projection of target high-chroma glossy Munsell (⊗); ColorChecker Classic (●) and SG (☒). Pointer Gamut is shown for reference (•).*

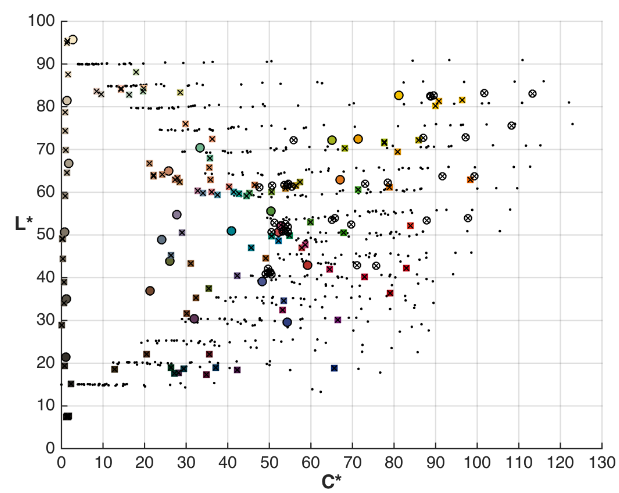

Figure 2. CIELAB L vs. C* of identical colors to those in Figure 1.*

Book of Color, Glossy Edition was measured. For this project, only the maximum chroma color from each hue leaf was measured. Figures 1 (b* vs. a*) and 2 (L* vs. C*) show the distribution of these high-chroma Munsell colors, the Pointer colors, as well as the color targets described below.

Consideration must be given to existing color targets in common use. This study included the X-Rite Color Checker SG and the X-Rite Color Checker Classic [4]. Figures 1 and 2 also include the color of both Color Checkers.

In addition to the Munsell colors, a series of measurements were completed to assess the colors that would be of interest to the archiving community. Approximately 1700 samples were measured, including books, periodicals, photographic prints, maps, and other materials. These *archival colors* were used to supplement the regular spacing of Munsell colors and oversample the gamut in these culturally significant regions. The distribution of the archival colors is shown in Figure 3.

As can be seen, the archival colors are reasonably sampled by the Munsell colors (gray circles in Figure 3) with the exception of the low chroma yellow region. This makes sense, as many materials fade from white to a light yellow or tan. Therefore emphasis should be placed on this region of color space when considering the final distribution for the next generation target.

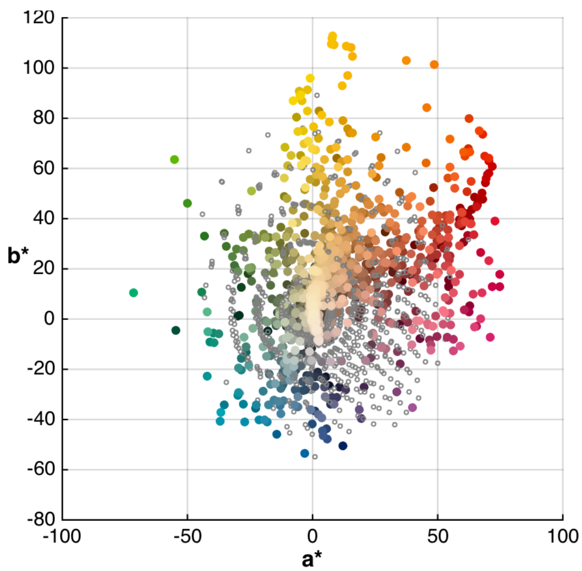

Figure 3. Measured color of materials of interest to the archiving community (colored circles) with target Munsell colors for reference (gray circles).

Actual Distribution of Colors

After considering the commercial paints available, as well as the target distribution of the Munsell and archival colors, 118 colors were selected and formulated. The CIELAB for these colors is shown in Figures 4 and 5, along with the Munsell colors for reference. The distribution can be seen to reasonably cover the Munsell gamut, and the addition of representative archival color is apparent in the first quadrant of Figure 4.

Physically, the patches are distributed across 130 locations in a 10x13 patch Next Generation Target (NGT). These locations are shown in Figure 6. Distinct color groups are denoted: "familiar" (red) "extended neutral" (green) and "archival" yellow, and are arranged in related rectangular regions to allow the user to select a desired subset of the entire color target for profile optimization. The entire color set will usually be appropriate for deriving a profile, but the selection of a smaller region for optimization permits the use of other regions as profile verification colors.

In addition to the 118 unique colors, extra white patches are included in each corner as well as the center of each edge. This is the same white as found in the lower left corner of the familiar colors. These white patches allow the simple estimation of light distribution in lieu of an actual flat fielding image. Further, an approximately N5 neutral patch is included near the center of each edge.

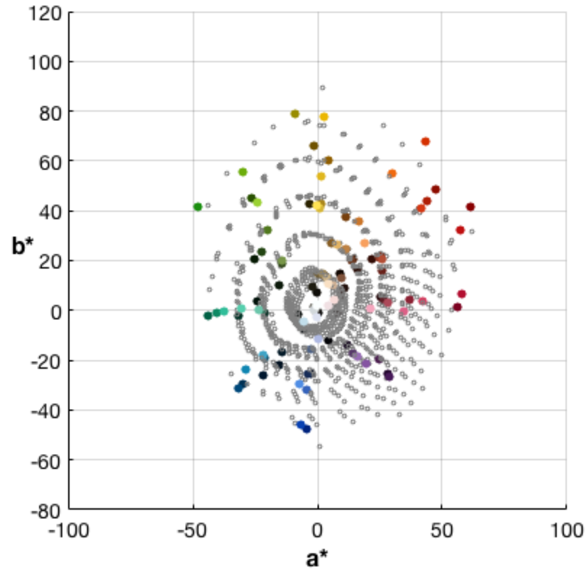

Figure 4. Measured CIELAB colors (b vs. a*) of NGT (colored circles). Munsell color are shown for reference (gray circles).*

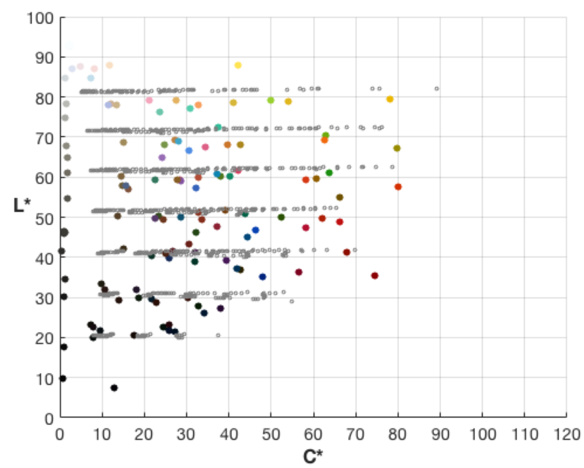

Figure 5. Measured CIELAB colors (L vs. C*) of NGT.*

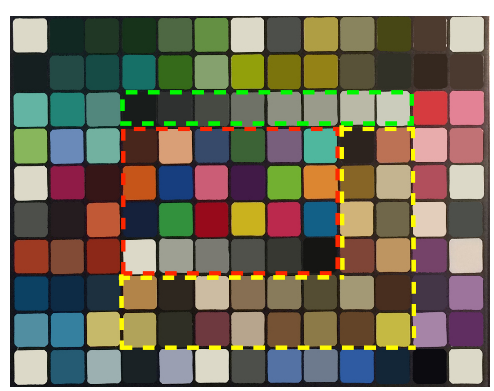

Figure 6. Physical distribution of NGT colors. Green box indicates extended neutral scale; red box indicates familiar colors; yellow region denotes representative archival colors.

Effect of Cleaning the Patches

To meet the requirements of durability, uniform gloss, and the ability to be cleaned, paints were applied to the second surface of a clear substrate. This exposes the durable substrate to handling and keeps the color protected. This has the added benefit of ensuring that every patch has identical gloss. Figure 7 shows the layering used in the NGT construction.

Given the importance cleaning for the target, experiments were made to determine the color and gloss differences resulting from a cleaning procedure. Results showed that for a representative set of colors, repeated cleaning resulted in a mean ΔE^*_{ab} of 0.1 or lower. Gloss differences (60°) were at most 3 units after repeated cleaning.

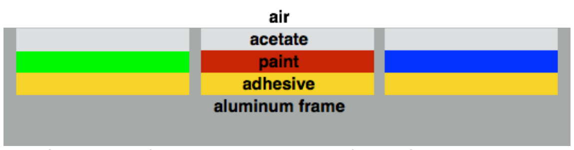

Figure 7. Schematic of laminate construction of the NGT.

Profile Creation

The most fundamental requirement of a calibration target is its performance in aligning camera output (RGB) with measured color (CIELAB). To verify the performance of the new target, the following experiment was completed:

1. Configure a digitization system (scanner or camera).
2. Image each of three characterization targets (CC, IT8 [4], and NGT).
3. Develop a camera profile based on the measured data of each characterization target.
4. For each test image attach one of the three profiles developed in step 3. This results in three versions of each image: one with the profile based on each of three profiling targets.
5. Render the RGB imaged to CIELAB by applying the profile.

The experimental imaging was performed by Library of Congress personnel using a Metis imaging system, which generated the RGB images and the ICC profiles. The CIELAB data were rendered using Adobe™ Photoshop™ CS3 software, and the mean CIELAB patch data were calculated using custom routines written for Matlab™ R2015a. The analysis below compares these mean rendered CIELAB values with the actual measurements of each target.

Characterization Model Performance

Table I shows the average color difference between rendered and measured CIELAB data. All color differences apply the CIEDE2000 formula [5]. Columns indicate the target used to develop the profile, and rows are the performance of each target under that profile. The first aspect of the data to note is that on average the profiling targets predict their own colors better than the colors of other targets (diagonal italicized entries). This is neither a surprise or a concern, but simply an artifact of the profile optimization. The non-italicized entries in each column show how well the profile rendered the other two targets. From these data we can conclude that the performance of the NGT is close, but certainly not exceeding that of the other two profiling targets.

Table I. Results from OpenDICE Profiling (ΔE_{00})

Test Target (# of patches)	Profiling Target (mean, std dev)		
	NGT	CCSG	IT8
NGT (130)	*3.26, 0.63*	2.51, 1.27	7.11, 1.58
CCSG (140)	3.96, 1.71	*1.76, 0.79*	7.32, 1.57
IT8 (477)	3.78, 1.30	3.21, 1.47	*6.08, 1.46*

To visualize the effect of the various models, the following plots show the component color changes for each of six pairs of profiling and test targets. For brevity the results using the IT8-derived profile are omitted since the profiling performance of that target was significantly worse than the other two. For each combination there are two plots: b* vs a* and L* vs C*. The circles are the measured colors, and are rendered to approximate that measured color. The tips of the arrows indicate the rendered color. In the plots below the IT8 is used only as a verification target.

As mentioned above, these plots confirm that both the CCSG and NGT perform well when used with their respective profiles. This is shown for CCSG in Figure 8(a) and (b) and NGT in plots (k) and (l). In general the largest color differences for the IT8 are in the lightness channel. This is seen by the longer arrows in plots (d) and (j). The high surface gloss of the IT8 may be contributing to this L* difference.

The best test for comparing the CCSG and NGT is how well they each can reproduce an identical third target, in this case the IT8. Table I shows the average ΔE_{00} of 3.78 (NGT) and 3.21 (CCSG) color difference for rendering the IT8. While the CCSG shows better mean performance, the distribution of those difference is slightly greater than that of the NGT (1.47 vs 1.30 standard deviation). These differences and the spread can be visualized in Figure 8(c) and (d) for CCSG rendering of the IT8, and (i) and (j) for the analogous data from the NGT rendering of the IT8. The CCSG appears to render the IT8 dark colors less accurately, while the NGT color differences are more uniformly distributed.

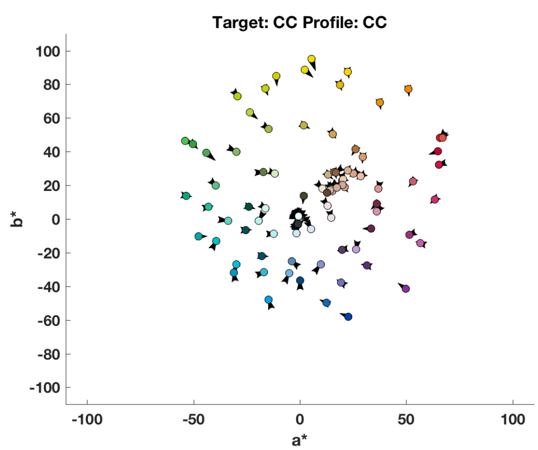

Figure 8(a). Rendering results for the CCSG profile applied to the CCSG.

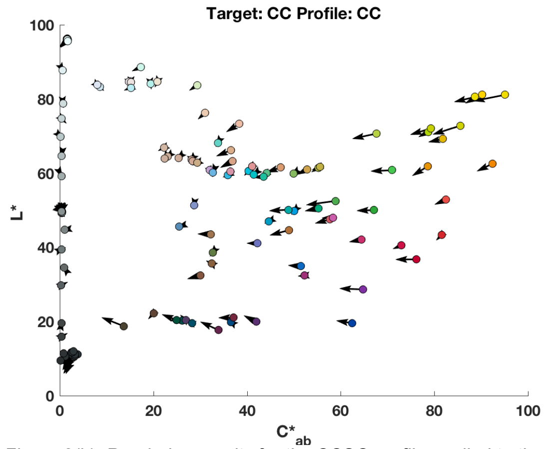

Figure 8(b). Rendering results for the CCSG profile applied to the CCSG.

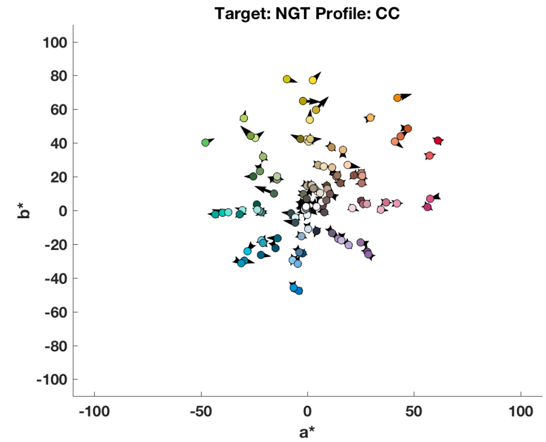

Figure 8(e). Rendering results for the CCSG profile applied to the NGT.

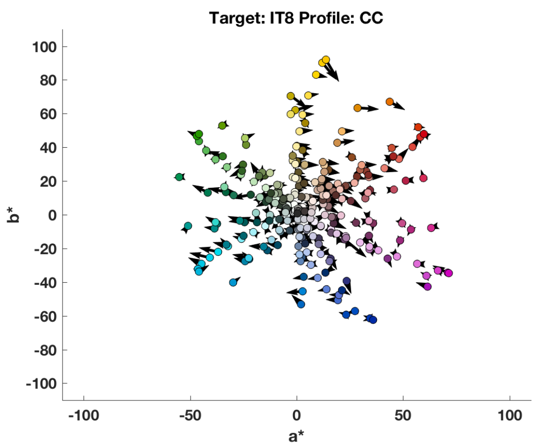

Figure 8(c). Rendering results for the CCSG profile applied to the IT8.

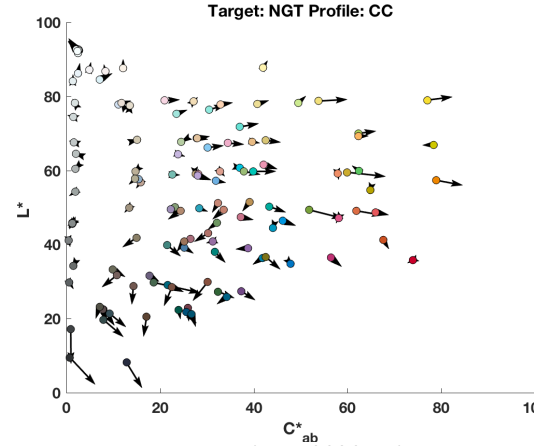

Figure 8(a). Rendering results for the CCSG profile applied to the NGT.

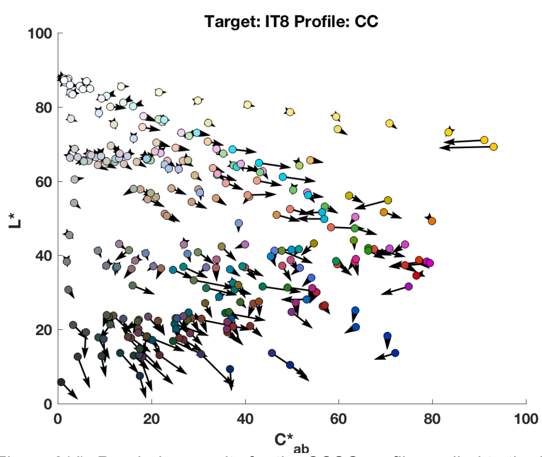

Figure 8(d). Rendering results for the CCSG profile applied to the IT8.

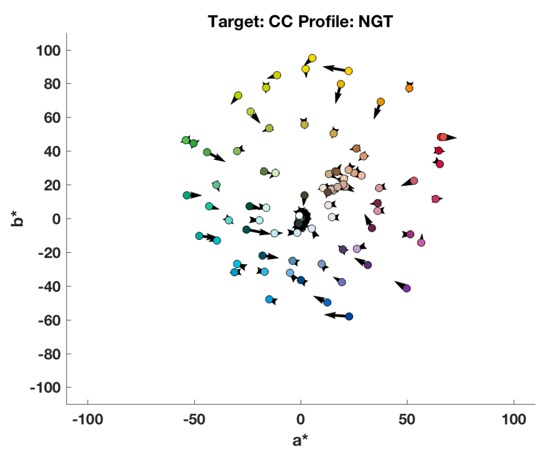

Figure 8(g). Rendering results for the NGT profile applied to the CCSG.

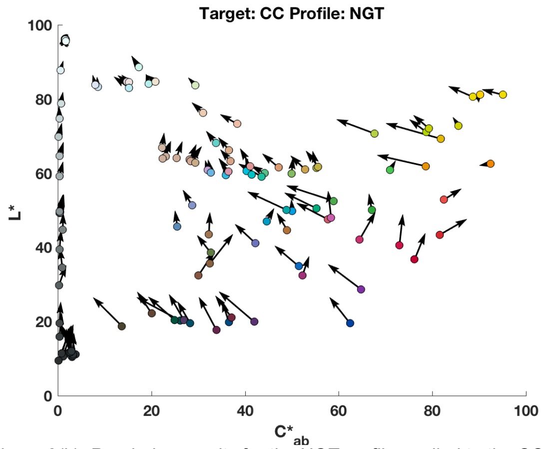

Figure 8(h). Rendering results for the NGT profile applied to the CCSG.

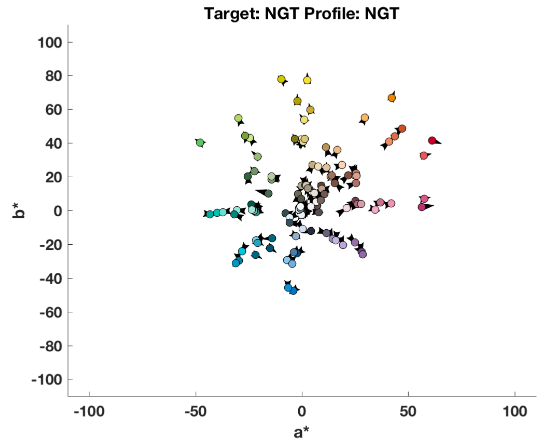

Figure 8(k). Rendering results for the NGT profile applied to the NGT.

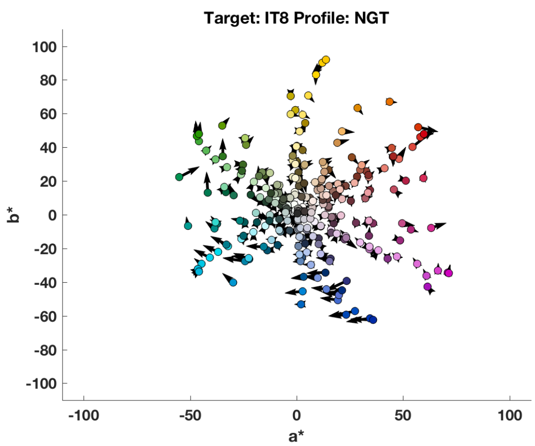

Figure 8(i). Rendering results for the NGT profile applied to the IT8.

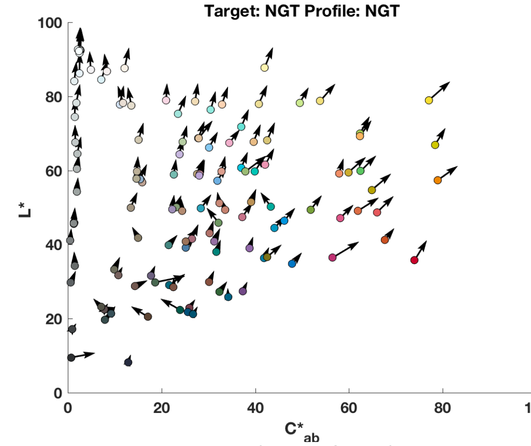

Figure 8(l). Rendering results for the NGT profile applied to the NGT.

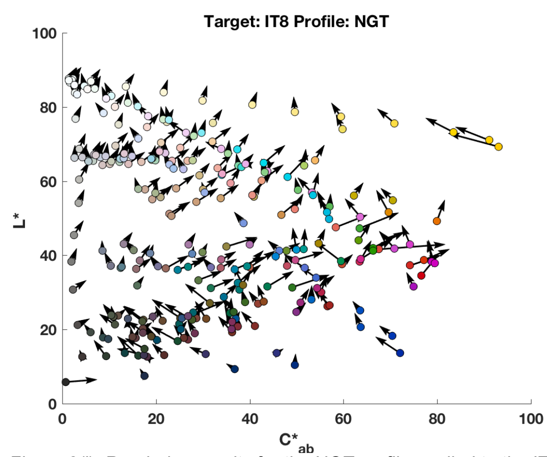

Figure 8(j). Rendering results for the NGT profile applied to the IT8.

Conclusions and Future Work

The desired features of a new digitization profiling target have been described, and such a target has been analyzed for its physical robustness and ability to profile digital cameras. The target has been shown to be robust against cleaning, with both gloss and color change being negligible after repeated cleaning. The new target has been shown to approach traditional targets in terms of the ability to accurately profile a digitization system. We feel that the performance is sufficient for most applications, especially considering the other attributes offered, such as robustness and uniform gloss.

To extend this study, future work will evaluate the use of alternative profiling techniques, camera systems, and verification targets with a variety of color and physical properties. The goal will be to better simulate the typical production workflow of a scientific studio, where a wide variety of targets and configurations must be accommodated.

The specific properties of the NGT will also be evaluated. An analysis should be made of the effect of target gloss and BRDF and its relationship to the sample gloss and BDRF. Also, a more specific analysis of the utility of the archival colors included in the

NGT should be made, as well as an investigation into other colors that might be included for archiving or other applications.

References

[1] M.R. Pointer, "The Gamut of Real Surface Colors," Color Res. and Appl. 5, 145–155 (1980).

[2] S.M. Newhall, D. Nickerson, D.B. Judd, "Final report of the O.S.A. subcommittee on spacing of the Munsell colors," Jour. Opt. Soc. of Am. 33, 385-418 (1943).

[3] These two and other ColorChecker targets are available from X-Rite Incorporated, Grand Rapids MI. www.xrite.com.

[4] The ITS is a film based target, available from LaserSoft Imaging, www.silverfast.com.

[5] Luo MR, Cui G, Rigg B. The development of the CIE 2000 Colour Difference Formula. Color Res Appl 2001;26:340 –350

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