

# Targeting for Important Color Content: Near Neutrals and Pastels

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## Abstract

The elements of a successful imaging performance program should include; establishing of performance goals, efficient test plans, and periodic performance auditing. All three of these require the selection and adoption of test objects as references. In many cases the use of common color elements such as those of the ColorChecker® test target is sufficient. However for critical collections predominated by near neutrals (e.g. paper, vellum, parchments), limited color gamut (e.g., watercolors), or near singular hues (early photographic prints), the capture of small color differences is not only important but problematic, largely because the color targets used today to calibrate digital capture devices were not designed to discriminate the subtle color gradations of such content.

Recently [IS&T Archiving Conf, 2010], we described how the measurement and testing of color image capture performance for cultural heritage imaging could be adapted for special collections such as those indicated above. As a continuation of this effort, we now present both the methods and initial results of the selection of test target elements, testing/calibration methods and results. We start by characterizing the spectral reflectance characteristics of the collection materials. These are then compared with the corresponding properties for a database of practical, available color samples. For a given collection, the automated selection method of corresponding color patches is demonstrated. We then describe how color calibration and performance monitoring software can be designed to accommodate the flexible testing of special color materials. Aspects of the resulting system, color-patch selection, target assembly and analysis software are then described, as are criteria for the successful application of such a program.

## Introduction

One impediment to improved color image capture in the cultural heritage community is the adoption of color reference and calibration targets designed for a different imaging sector. The ColorChecker® target series is a good example. A casual reading of the original article [1] describing the rationale for this target reveals that seven of the 24 color patches were selected specifically for consumer and professional photographic film use, the kind of content found in outdoor scenes. These colors include blue flower, blue sky, dark and light flesh tones, foliage, oranges, and lemons. The remaining colors were selected with contemporary photographic film characteristics, and limitations, in mind.

The ColorChecker® SG is the modern day replacement for the original ColorChecker®. Instead of 24 unique colors it has 96, and is better suited for creating ICC color profiles, used by color management software. While no rationale document for its design was ever published, a inspection of the SG target reveals that the

color patches were chosen to (1) maintain a legacy to ColorChecker® design, and (2) emphasize important color content for the professional and consumer imaging sector, specifically flesh tone and foliage subjects. It is this latter design criterion, subject-specific colors, that has motivated this paper.

Figure 1 shows an example of the material that that we address, with a currently available object-level test target. This target includes the same color patches from the original ColorChecker® target, used to evaluate color image capture. In addition, there are elements used for measuring other imaging performance characteristics. The red arrow indicates an area used below in a spectral matching example.



Figure 1: Larks, *Das Buch der Welt* (Book of the World) a German encyclopedia. Hand colored engraving, 1859, with an object-level target.

## Why custom color test targets?

Though existing color targets serve a useful role, in some cases they appear to be selected for convenience rather than technical merit. While some targets provide near neutral colors, these colors are a small sampling of such colors encountered in cultural heritage imaging. Given the strong anecdotal evidence from practitioners of difficulty in capturing near-neutral collection content, an investigation of content-specific test targets was initiated. Previously [2] we reported on a effort aimed at historical photographic prints.

The topic of content-specific color performance evaluation testing for cultural imaging has been addressed from several perspectives. To understand these approaches and objectives, it is helpful to consider how color targets are used. The two principal reasons to use them for image capture are; (1) to establish accurate color image capture – part of a *calibration* function, and (2) to measure deviation from the desired capture of color image information – an *evaluation* function.

An example of the calibration function is the optimizing of image capture, display and printing components of a system as part of a color-management function. In this case the results of imaging a reference target are used to compute software parameters, part of ICC color profiles. If scanner and camera calibration targets have similar colorants to those of the collection, this reduces the influence of metamerism, often improving image capture. Berns and Haddock [3] reported on selection criteria for a color test target in an art museum environment. The purposes for their proposed test target included; selection of museum lighting, selection of pigments used for retouching (inpainting), and evaluating whether inpainting would be detectable when viewing or imaging. As a result, colorants were chosen from artists' paints that are known to present challenges. For example, pairs of paints that match under one illumination, but do not when it changes, and maximum chroma colors, were selected to be sensitive to changes in museum lighting.\*

Trumpy [4] also addressed the application of content-specific test targets for color calibration. Rather than include the spectral characteristics of the collection, as in [3] and our study, he focused on the improvement of colorimetric (3-color) color-signal processing in ICC profiles. In a practical demonstration for sepia prints, custom profiles resulted in significant improvements in the accuracy of color image capture. The target samples were chosen from a commercially available set, based on sampling the CIELAB region populated by the sepia prints.

The objective of our study is to support improved calibration and evaluation functions for image capture. Our approach is to include the spectral characteristics of the collection. We investigate if and how a target can be constructed from candidate colorants from commercially available paint formulations, to economically and reliably manufacture such a target. Practical target design considerations will also be addressed, and suggestions given for its use in color performance benchmarking and color-profile building.

## Color Census

The focus on our study was on material from historical collections that include hand-colored prints, letters, books and maps. In the initial phase of this project, reported on here, spectral reflectance and colorimetric measurements were made on a collection of 358 objects. The earliest work was a medieval manuscript (vellum) by the Italian writer, Dante Alighieri (1265-1321), courtesy of The Morgan Library and Museum, New York.

The regions chosen for color measurement were selected from a variety of historical and rare documents in the collections of the participating institutes. When soliciting these institutes for sample objects to measure we asked them to identify content that they found particularly difficult to image or render in the past, especially parchment, vellum, or aged paper. By their nature these documents contained a predominance of near-neutral, off-white, and pastel colors that are critical to the essence of the object. Four to ten regions were selected per object.

Often there were also moderately high chroma spot color regions. We included these colors too as part of our spectral database to the extent that our measurement equipment allowed. Some examples of the type content and selected regions are shown by the circles in Figs. 1 and 2.

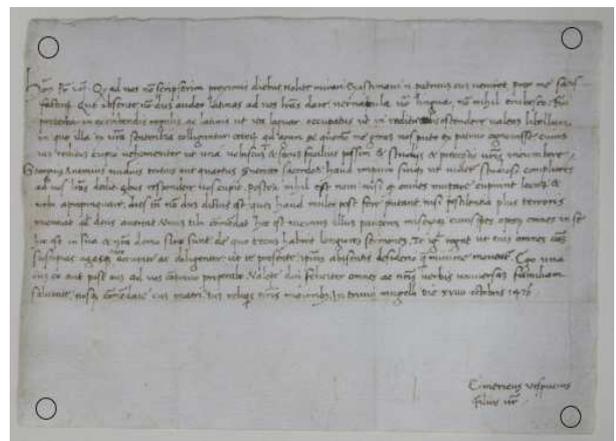


Figure 2: Measurements taken in the corners of a letter by the explorer, Amerigo Vespucci, 1476 (courtesy of The Morgan Library and Museum).

Fig. 3 illustrates a sampling of the reflectance factor values from the identified regions of Fig.1. From the set of spectral curves over all items measured, CIELAB values were derived.

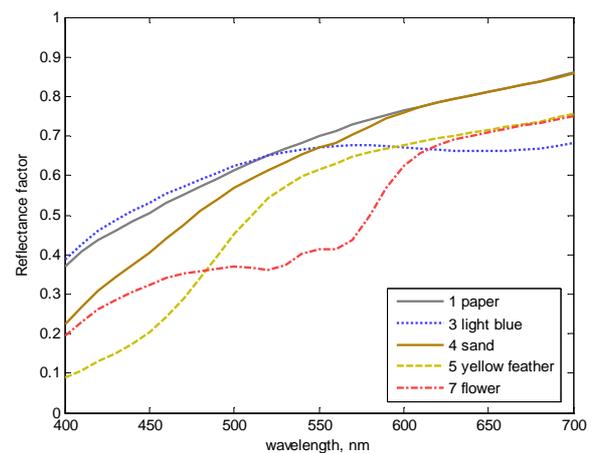
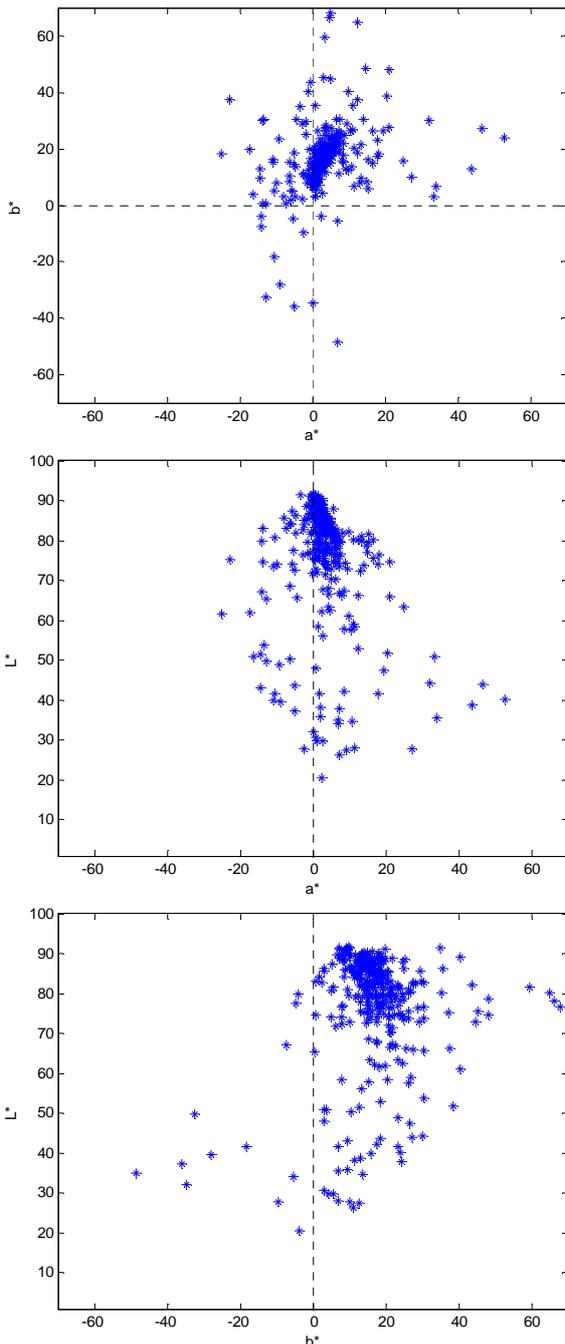


Figure 3: Several spectral reflectance factor measurements from the example of Fig. 1. Numbers indicate locations

\* Such test charts are sometimes referred to as 'killer targets' because they can emphasize small differences between systems when used in a commercial context.

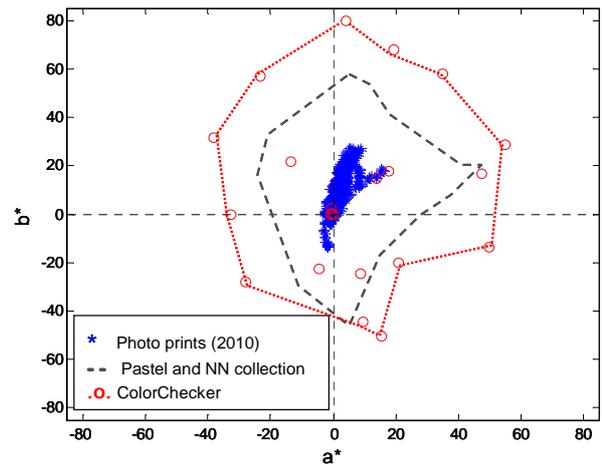


**Figure 4:** CIELAB coordinates for Pastel and Near-neutral collections in three, two-dimensional cross-sections ( $N=358$ )

The  $L^*a^*b^*$  census data is depicted in Fig. 4 with three cross sectional views of the CIELAB volume. There are several notable features of these scatter plots. Primarily, notice in the top  $a^*b^*$  plot that most of the data is centered with a positive  $b^*$  bias. This indicates a near neutral color population with a yellow tendency, indicative of aged papers and parchments. The second and third plots of Fig. 4 both show how these are distributed in luminance. The greater population is above an  $L^*$  of 50, or less than a density

of 0.73. This suggests populating the target with higher reflectance samples.

Fig. 5 shows compares the  $a^*b^*$  regions that is populated by three data sets. The measurements in this study are well within the color perimeter defined by the standard ColorChecker® and provide evidence that perhaps a stronger consideration toward the center of the color space is appropriate when doing color profiling and performance evaluation [4]. Note particularly the strong central tendency from the Photoprint study [2] performed previously.



**Figure 5:** CIELAB color coordinates ( $a^*, b^*$ ) for the previous photographic prints (2010), current pastels and near-neutral, and Macbeth ColorChecker test target measurements.

## Target Design

Besides accommodating more representative collection color-samples, the candidate target should also be efficient and useful in everyday workflows. So a number of other items are considered. In order of importance, the items considered are:

- Color palette selection,
- Form factor and spatial layout,
- Number of color elements,
- Supplemental performance metric elements.
- Administrative elements.

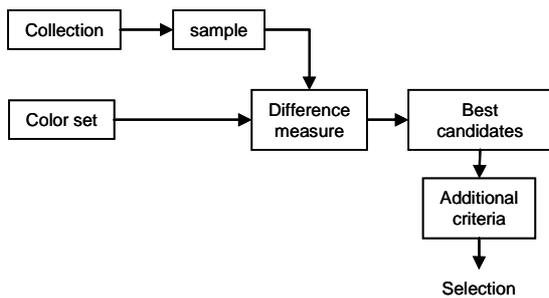
Each of these is discussed briefly below.

## Color palette selection

Having measured the reflectance factor characteristics of our collection, the next step is to select the test target components that share important characteristics with the collection population. Here we outline a method that can be adapted to many types of content. As indicated above, we start with a set of commercially available color samples. For this we chose a large set of Munsell colors that have previously been measured [5], and developed an automated selection method. This is outlined in Fig. 6, where the first step is selection of a representative item from the collection in terms of its color/spectral characteristics. In our case we chose this to be the spectral reflectance factor values. The number of representative samples is normally number of color patches that are needed for

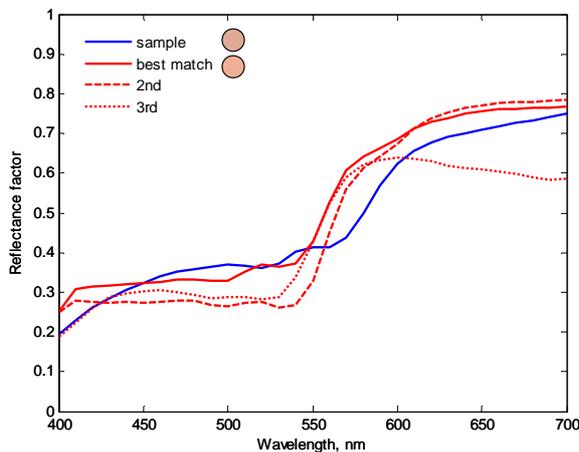
the color target. These samples may be drawn from measurements the collection, but could also be generated as potential members of the population based on a Principle Component Analysis of the population statistics [2].

This sample is then compared with the corresponding data from the set of available samples (color set). This is typically done by computing a difference measure. In our case this was an un-weighted mean absolute difference calculation, however this can also be weighted by a function of wavelength (e.g. illuminant or luminosity). Selecting the members of the sample set with the minimum difference measure identifies several candidates.



**Figure 6:** Outline of selection from a set of available color samples based on the characteristics of a collection

From the set of best candidates, additional criteria can be invoked, such as non-duplication of previous selections, and illuminant-specific considerations that may be important for a particular project. For our demonstration, an example of which is shown in Fig. 7, we chose the best candidate following the difference measure. Note that several close candidates from the Munsell set were found for this sample.



**Figure 7:** Results of spectral matching of the sample area 7 in Fig. 1 to the set of Munsell color samples. The colored circles are rendered as the sRGB values corresponding to the sample and best match.

### Form factor and spatial layout.

A brief survey of the aspect ratio of several popular color targets in use today revealed an aspect ratio (7:10) remarkably consistent with standard ISO paper sizes. We decided to use the

A4 size (210 mm x 297 mm). It is only slightly larger than the very popular ColorChecker® SG chart (204 mm x 290 mm) in use today, is handled simply and can be easily stored in most office and studios. It is also of sufficient size to place a large number of reasonably sized (~ 1cm square) color patches.

As for most targets, we have chosen to place the color patches in a simple row/column grid design. Targets with such designs are easier to manufacture and are compatible with most software analysis and profiling tools.

Perhaps one of the biggest differences in the look of color reference targets has been the way the colors transition over the extent of the target field. While the luminance levels for a particular hue or chroma are often grouped together, the way in which the reds transition into greens and in turn the violets seems somewhat random. We will attempt to make this transition with the hues changing with angle and circular symmetry chroma values, similar to the standardized  $a^*b^*$  circle shown Fig. 5. Maintaining this type of layout should make it easier for the user to quickly identify important color content by hue and chroma regions and to better select their associated luminance levels.

### Number of color elements

Overall, we propose approximately 300 unique color patches. About twenty of these will be neutral gray patches heavily populated toward the high luminance end of the scale. Approximately 50% of the center field will be populated by high luminance near-neutrals and pastels dictated by our color census data. Current targets populate only about 15% of the color patches, at most, with these colors.

The remainder of the target will likely be drawn from uniform sampling of higher chroma colors. These colors will provide an option to assess color imaging performance for less populated, but often important high chroma objects found in collections. A candidate configuration of the target is presented in Fig. 8.

### Supplemental imaging performance elements

While the primary purpose of the proposed target is for improved color management and performance evaluation it is worthwhile to also include elements to judge other imaging performance metrics [6-8]. For instance placing a single spatial frequency response (SFR) element in the center would allow for an evaluation of resolution and color channel misregistration.

Lighting non-uniformity or shading could also be measured by placing several identical gray patches throughout the target field. Alternately, shading could also be measured by evaluating the grid pattern overlay that separates the individual color patches.

Some form of English and metric ruling, in both the horizontal and vertical directions, will be included to aid in manually determining the sampling rate of the captured image. Sampling rates can also be determined automatically through the use of registration features placed at known distances. These are discussed further in the following section on administrative elements.

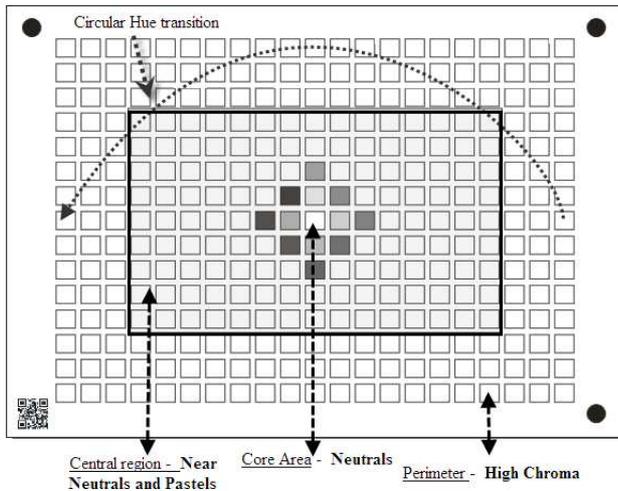


Figure 8: Candidate target layout

### Administrative elements

A number of additional elements are necessary to help in data tracking and automated evaluation. Among these is a row column annotation. In all likelihood this would consist of a simple alpha (row) – numeric (column) labeling, similar to that of the ColorChecker® SG. Some barcode or QR code scheme is helpful in identifying unique color, usage, and manufacturing data for individual targets. Finally, some form of registration features, such as crosshairs, circles, or wedge segments are advisable in order to accommodate automatic target detection for more efficient workflow.

### How to use the target

The proposed target can be used like any of the currently available ones; for better color profiling or for imaging performance benchmarking and monitoring. We propose going further though and suggest a more focused, content important use of the target. Instead of the user considering the totality of the target's color content for these purposes, we urge the reader to consider a color importance strategy for profiling or performance tasks. Why should out of gamut, or high chroma colors be considered for evaluation when in fact they are not part of a collection being scanned? How would this work?

One way would be to have complementary performance evaluation software (currently being developed) that allows the user to weight important colors, based on the task at hand, more or less than others. This could easily be done through target description files (TDF) that would contain aim color values and their degree of importance, set by the user or client. A TDF for illuminated manuscripts might have high weightings for the occasional high chroma colorants and the predominance of yellowed neutrals of the paper or parchment. These weights could be determined by visual comparison of the target and collection

content or through analytical means. Some colors samples could be 'turned off' completely (i.e., zero weighting) if they were not representative of the collection being considered. Whatever the choice, it provides a more meaningful approach to performance evaluation and color profiling. It is also likely to be more economical.

### Conclusions

A collection-specific color image capture calibration and measurement strategy have been proposed as a flexible and efficient way to improve color imaging of near neutral and pastel colors. The use of such a color target, however, requires compatible color-management and imaging performance evaluation software. Strategies that allow adjusting the use of a general target (including the kinds of near neutrals, pastels color subsets focused on here), however, are likely to strike a balance between flexibility and simplicity of testing.

### Acknowledgements

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### Authors' 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 is a member of the Advisory Board for the interagency US Federal Agencies Digitization Guidelines Initiative, FADGI.*

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