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Report of the CIE Technical Committee on Archival Colour Imaging

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Abstract

This is the latest in a series of progress reports from CIE TC8-09, the CIE Division 8 Technical Committee on Archival Colour Imaging. The current focus of the committee is a multi-institution study to assess and compare the performance points of the protocols and methods that participating cultural heritage institutions use to capture representative materials that are within scope for the committee. As part of the study the committee is assessing the color accuracy of different color capture and encoding approaches with the goal of establishing a knowledge base and set of techniques which an institution can reference to either select or confirm the approach to color capture that is most compatible with its goals and capabilities. This report focuses on the tone capture and error performance of the capture of a standard test targets and sample prints across multiple institutions.

Introduction

The starting point in an imaging chain is the capture or creation of an image. Memory institutions, such as archives, museums and libraries that are traditionally entrusted with the care of physical objects, are and have been digitizing the objects in their collection. The value of accurate color capture to them seems obvious. When materials such as historic documents, prints and photographs are scanned to provide digital surrogates for scholarly study, online access or preservation, it is important to capture the properties of the object, including its color or spectral content, so that they are faithful to the original and support the intended use cases, which can include reproduction on a wide range of media. It is also important to get it right the first time around to avoid the need for re-scanning, which is expensive.

This is the context for the study being conducted under the auspices of CIE TC8-09, the CIE Technical Committee on Archival Color Imaging.TC8-09 was formed with the following terms of reference:

> *To recommend a set of techniques for the accurate capture, encoding and long-term preservation of colour descriptions of digital images that are either born digital or the result of digitizing 2D static physical objects, including documents, maps, photographic materials and paintings.*

An objective of capture in the context of CIE TC8-09 is creating a use-neutral master image, which can then be rendered or reproduced according to the requirements of the use case or reproduction medium [1]. This is implicit in the terms of reference for TC8-09, which mentions capture but not reproduction. In other words, this implies a focus on input- or original-referred color encodings rather than output-referred ones. While some institutions may archive display-rendered images, others archive images that can serve as common and neutral starting points for subsequent media- and organizational-specific rendering choices. A use-neutral archival master also suggests an institution-neutral archival master, which would enable inter-institution sharing and production of archival masters. Previous presentations have described the background of this study and related work [1,2].

The Study

For the study described in this paper, participating institutions captured a common set of study materials using their existing color image capture methodology.

The study materials consisted of three commercial targets (Figure 1) and four sample prints (Figure 2) representative of the materials within scope for TC8-09. For each sample print there was a mask or sleeve that isolated small regions of interest (ROIs) with approximately uniform color representative of the print. Figure 3 shows Print A with and without its mask. The prints had between five and twelve ROIs.

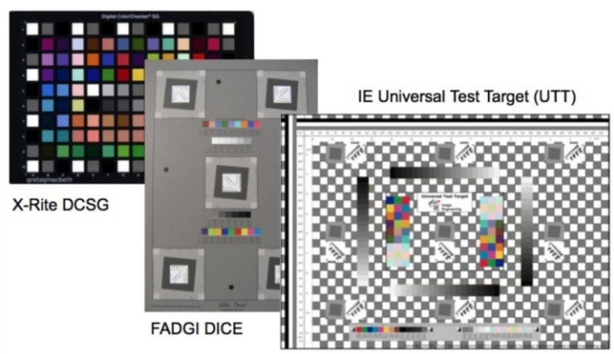

***Figure 1**. Test targets used in the study (L to R): X-Rite Digital ColorChecker® SG; Library of Congress DICE (Digital Image Conformance Evaluation) Object Target (same as the Device-Level Target from Image Science Associates); and Image Engineering Universal Test Target (UTT)*

***Figure 2**. Sample prints used in the study: (A) Hand-colored photo-gravure; (B) hand-colored etching; (C) hand-colored albumen photograph; and (D) chromogenic print*

The assembled package of study materials was passed from one participating institution to the next. Each institution was asked to capture the three targets and four sample prints, both with and without their masks, using their existing color image capture methodology, and provide TIFF files with the captured RGB data for analysis by the authors. Some institutions used the Metamorfoze or FADGI guidelines [3,4] although this was not a requirement. Besides providing image files, each institution was also asked to fill out an online form with questions about their capture methodology.

***Figure 3**. Sample print A without and with its mask showing the 11 selected color areas or regions of interest.*

The accuracy of the color capture was assessed by calculating the color differences between the measured and captured values for the target patches and sample print ROIs. The measured CIELAB values (2-degree Standard Observer, D50 illuminant) were obtained using an X-Rite 530 spectrodensitometer with a 3.4 mm aperture. Although the capture and measurement illumination-sensor geomtries are different, using the values measured with a spectrodensitometer for assessing the capture accuracy provides a common reference point for assessing the results from a given institution and comparing the results from multiple institutions. Further, spectrodensitometers measurements of test charts such as the X-Rite Digital ColorChecker® SG chart are normally used for profiling color capture devices.

This paper will report on the results from 15 participating institutions:

1. Art Institute of Chicago
2. Harvard Library
3. Library of Congress
4. Metropolitan Museum of Art
5. National Archives and Records Administration
6. National Gallery of Art
7. National Library of the Netherlands
8. Rijksmuseum
9. Stanford University Libraries
10. Studio Buitenhoff
11. Van Gogh Museum
12. Royal Library of Denmark
13. Beinecke Library, Yale University
14. Museum of Modern Art
15. George Eastman House International Museum of Photography and Film

Results

Participating institutions used digital camera and planetary and flatbed scanners for capture, with manufacturer's or custom profiles and in some cases post-capture image processing. Some institutions had multiple options for capture and used them to provide multiple sets of TIFF files, one for each capture scenario. Altogether results were obtained from over two dozen institution-scanner combinations across the 15 participating institutions.

All the institution-scanner combinations generated TIFF files with embedded ICC profiles for RGB encodings, with one exception that contained no calibration data. RGB data without an ICC profile or calibration data was interpreted as sRGB. The combinations that exported TIFF files with ICC profiles used the RGB encodings as follows:

- 8 used eci RGB v2 (both 48-bit and 24-bit)
- 15 used Adobe RGB (1998) (both 48-bit and 24-bit)
- 2 used ProPhoto RGB (48-bit)
- 1 used sRGB (24-bit)

While these are all output- referred color encodings, they are used here as input- or original-referred color encodings without regard to the viewing environment defined in their specifications.

Figure 4 shows the Tone Capture Curve (TCC) for three institution-scanner combinations. The TCC plots captured L* values versus measured L* values for the 12 gray patches at E5:J6 on the X-Rite Digital ColorChecker® SG chart. The straight line on the plot in Figure 4 is the aim curve for accurate capture in an original-referred encoding.

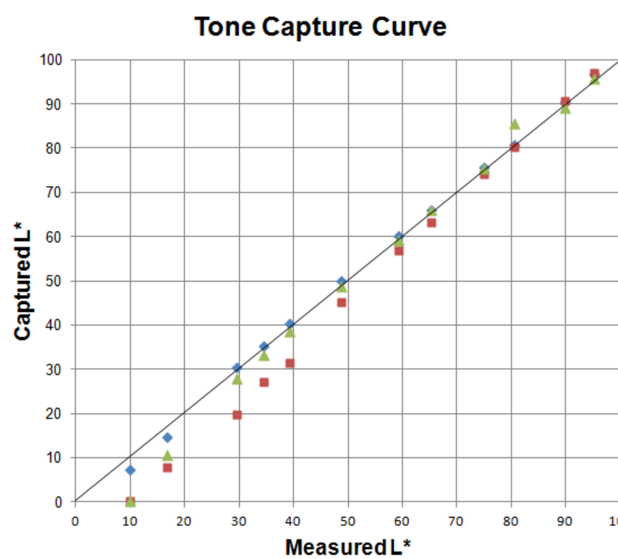

Figure 4. Tone Capture Curves for Insitution1-Scanner B (green triangles), Institution 2-Scanner B (brown squares) and Institution 3 (blue diamonds)

Institution 3 follows the Metamorfoze guidelines [3], which are intended to create a master image from which output-rendered images destined for print or the Internet can be derived in a separate step. Institutions 1B and 2B follow the FADGI [4] guidelines, which are intended to create an image ready for display.

The differences in tone reproduction are evident in Figure 5, which shows a screen capture of a portion of Sample Print A. The tone reproduction in the two images on the right, corresponding to capture curves 1B and 2B in Figure 4, is usually preferred. The tone reproduction in the image on the left, corresponding to curve 3, is in fact more faithful to the original but has not been rendered for a pleasing reproduction on a monitor and looks washed out.

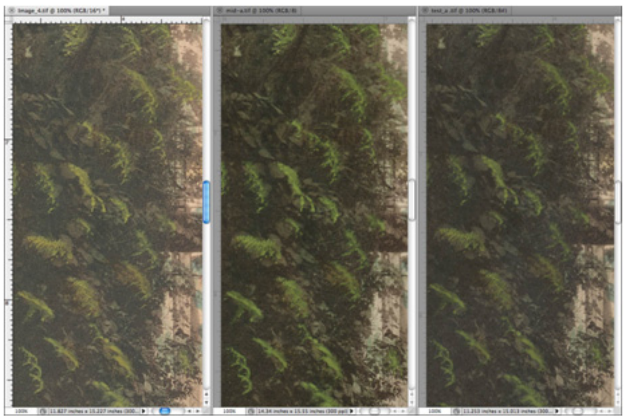

Figure 5. Screen capture of Sample Print A with the tone capture curves shown in Figure 4; see text for explanation.

Figure 6 shows the distribution of average color difference, given as DE2000, for the capture of the X-Rite Digital ColorChecker® SG chart by 25 institution-scanner combinations from the study. The 90% percentile point is at a DE2000 value of around 4; the median DE 2000 value is about 3.25.

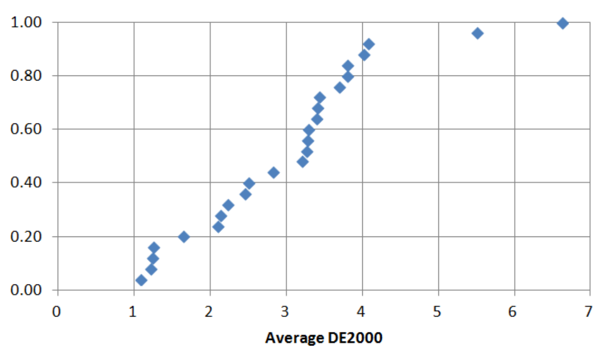

***Figure 6**. Distribution of CIE DE2000 values for the test patches of the X-Rite Digital ColorChecker® SG chart.*

Figure 7 plots the maximum DE2000 value against the average DE2000 for several institution-scanner combinations capturing the X-Rite Digital ColorChecker® SG chart. (The institutions are identified by numbers; the different scanners or capture scenarios they used are identified by letters.) Figure 7 shows that the maximum color error value is roughly proportional to the average error value. A check showed that the maximum errors were not due to out of gamut colors but rather to a few "problem" colors. Also shown on the figure are the different RGB encodings used by the different institution-scanner pairs. While one might be tempted to conclude the eciRGBv2 is a more accurate encoding than sRGB, the more appropriate interpretation is that the differences have more to do with profiling and calibration practices and about using an original-referred encoding. Future charts will plot the 90th percentile against the median error for the capture of the X-Rite Digital ColorChecker® SG chart.

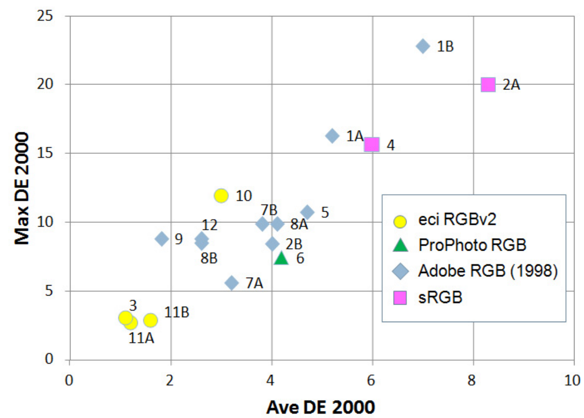

***Figure 7**. Plot of maximum versus average CIE DE2000 values for the test patches of the X-Rite Digital ColorChecker® SG chart.*

Figure 8 is the Print A analog of Figure 7; it plots the maximum DE2000 value against the average DE2000 for the eleven ROIs in Print A. The number and range of colors which are compared are smaller for Print A than for the X-Rite Digital ColorChecker® SG. The median values of the average color difference between measured and captured values are the same for both; the spread of the average color differences between institution-scanner combinations, as given by the standard deviation, is smaller for the ROIs in Print A. It is also apparent in Figure 8 that the differences in color difference performance between the institutions that use eciRGBv2 and the ones that use sRGB are not as great for Print A as they are for the X-Rite Digital ColorChecker® SG chart. The final report of TC8-09 will contain the equivalent analysis for the other sample prints.

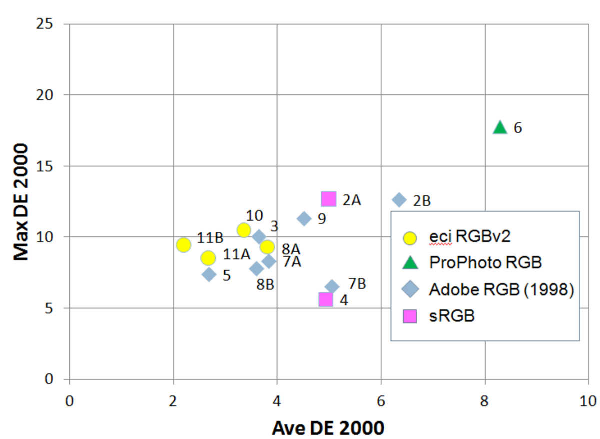

***Figure 8**. Plot of maximum versus average CIE DE2000 values for the ROIs on Print A.*

It should be noted that the average color differences plotted in Figures 6, 7 and 8 were calculated using reference values obtained with an X-Rite 530 spectrodensitometer and captured CIELAB values obtained using a variety of tools: the delt.ae website for Figure 6, the ColorGauge SG Analyzer for Figure 7 and Adobe Photoshop for Figure 8.

Conclusions

This round of the study represented a relatively broad range of capture approaches in regards to equipment, color encoding, and corresponding range of color accuracy across a variety of institutions. Our analysis has confirmed results previously reported, where we observed more accurate and less variable color imaging with the use of digital cameras in the way they were used and with well calibrated and color managed approaches to color capture.

The performance differences that have been reported here reflect the differences in approaches to capture across the participating institutions. Each data point on the plot reflects an institution's capture methodology, based on its particular mix of use cases, skills, budget, equipment, materials and schedule and the result of an implicit cost-benefit analysis. One side effect of this study will be to expose aspects of this cost-benefit analysis so that an institution will be in a position to confirm or select a performance point on the curve that best meets their requirements and constraints.

CIE TC8-09 is planning to complete the analysis and issue a final report in late 2013 or early 2014.

Acknowledgments

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References

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Author Biographies

Robert Buckley is a Senior Scientist in the Department of Electrical and Computer Engineering at the University of Rochester and the founder of NewMarket Imaging, a consulting firm which works with clients on the adoption of rising imaging technologies, especially for the capture, preservation and interchange of digital color images. He is the chair of the CIE Technical Committee on Archival Color Imaging and a member of the Advisory Board of the Still Image Working Group of the Federal Agencies Digital Guidelines Initiative.

Steven Puglia is a Manager Digital Conversion Services at the Library of Congress. Previously he worked as a Preservation and Imaging Specialist at the US National Archives and Records Administration for over 22 years. He coordinates the Still Imaging Working Group of the Federal Agencies Digitization Guidelines Initiative.