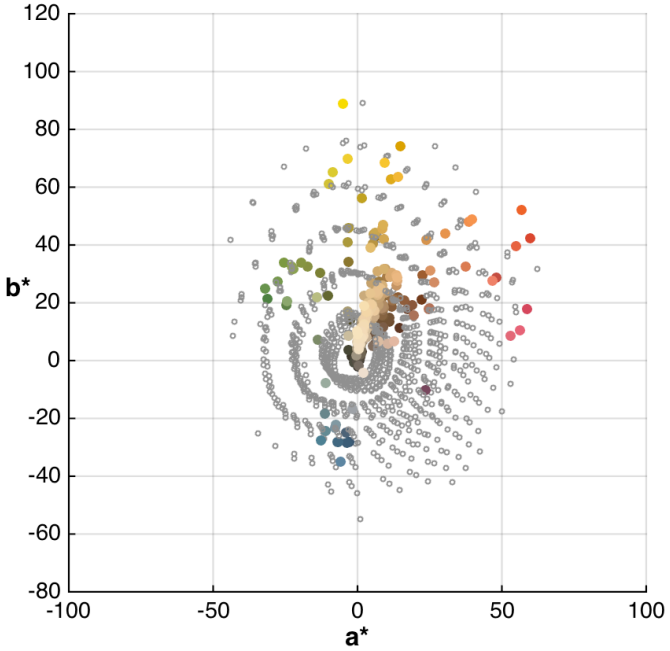
Report to

LIBRARY OF CONGRESS

Creation of Color Analysis Target

Task B: Define the coordinates for cultural heritage materials by logical category



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Executive Summary

In support of the digitization efforts of the Library of Congress, a solicitation, *Creation of Color Analysis Target*, was issued and subsequently awarded to Avian Rochester, LLC for the design and fabrication of a Next Generation Target (NGT) for color camera calibration. The NGT will be designed to address the shortfalls in commercially available targets. For the purposes of this report, those shortfalls are limited color gamut, and a lack of durability for typical laboratory usage. The lack of durability has a direct impact on the accuracy of the calibrated values for the target. Any physical damage to the target surface requires calibration to reassert the color coordinates for each patch, meaning the cost of operations for a target is directly tied to its durability.

The previous report, documenting the effort in Task A of this project, proposed an initial set of colors for inclusion in the NGT. These colors considered existing color targets and color systems of historical importance.

The present report addresses the requirements of Task B of the project, *Define the coordinates for cultural heritage materials by logical category*. The goal of Task B is to propose additional colors representative of culturally relevant materials. As a basis for determining these additional colors, a set of approximately 1700 samples were measured, encompassing the range of available culturally relevant materials. These samples included: books, periodicals, photographic prints, and others. From the distribution of these measured colors, the additional NGT color are proposed to complement those proposed in task A. The total set of proposed colors now considers both the available color targets and includes an emphasis on areas of color space representing culturally relevant materials.

Subsequent tasks will identify the specific physical materials that will be used to create the NGT. In particular: substrate and pigment systems that will fulfill the other requirements of the NGT.

Introduction

The Library of Congress (LC) supports an ongoing effort to digitize materials. The requirements for high quality imaging include controlling the system for accurate color, meaning that imaging devices must be characterized for accurate color capture. One critical need identified by LC is for a robust color target to facilitate this color characterization. Towards this end, Avian Rochester, LLC responded to Solicitation Number: LCOSI15Q0058, *Creation of Color Analysis Target*, was subsequently rewarded the contract. This report is the secomd part of the fulfillment of that contract, specifically Task B: "Define the coordinates for cultural heritage materials by logical category."

The general requirements identified for the next generation target (NGT) are:

1. it will better fill the appropriate color space;
2. it will have increased durability, and be suitable for regular laboratory use;
3. it will be able to be lightly cleaned;
4. it will be compatible with existing software systems (LabviewDICE and OpenDICE).

This is the second report addressing the first of these: filling the appropriate color space. The Task A report, considering existing color targets and color description spaces, was submitted in November 2015. The present report extends the work to include the measurement of materials that are specifically selected for their relevance to cultural heritage.

The balance of this report will address the measured colors found in the following logical categories:

- Books: including covers, spines, end papers, interior pages, imagery, page edges, etc. The measurements include books of as wide a variety of age and printing process as possible.
- Periodicals: magazines, journals, newsletters, newspapers, etc. The measurements include all aspects of each individual periodical: covers, imagers, interior pages, etc.
- Photographic prints, including as wide a variety of age and printing process as possible.
- Other materials, including at a minimum handwritten manuscripts and maps.

Identifying Culturally Relevant Materials

When considering which materials are relevant for the Library of Congress to archive, one quickly arrives at this somewhat daunting conclusion: *nearly everything*. "Culturally relevant materials" can be modern printed materials, handwritten materials predating the printing press, and nearly every type of recorded document in between. Therefore, rather than consider the large list of what is culturally relevant, we choose the more tractable problem of determining what culturally relevant materials are available for measurement. In addition to relevance, we hope to include materials which are also of significance, however, significant documents are often too fragile to permit safe handling.

Several institutions were identified and contacted, each specializing in a different segment of the relevant materials. These institutions that were engaged for data collection:

- Rochester Museum and Science Center, Rochester NY.
- Rochester Institute of Technology, Cary Graphic Arts Collection, Rochester, NY.
- George Eastman Museum, Rochester, NY.
- Library of Congress, Washington DC.
- Local libraries and person collections.

In total, approximately 1700 individual measurements were made. These included all of the materials identified in the introduction, and represent as good a cross-section of the target materials set that can be expected for the scope of the overall project.

Measurement Procedure and Documentation

All materials were measured with a KonicaMinolta FD-7. The FD-7[1] is a bidirectional spectrodensitometer, with the CIE 15.2004 geometry designation[2] of 45a:0. It reports spectral reflectance from 380 to 730nm, sampled every 10nm. It can also be configured to report CIELAB coordinates directly. For the measurements reported here, two different instruments were used: one by Avian Rochester and one in use at the Library of Congress. For the purposes of this report, we assume that the instruments function identically. Given the broad scope of materials, this is a

reasonable assumption; both instruments are in good working order, and any small performance differences will be inconsequential compared to the range of materials measured.[3]

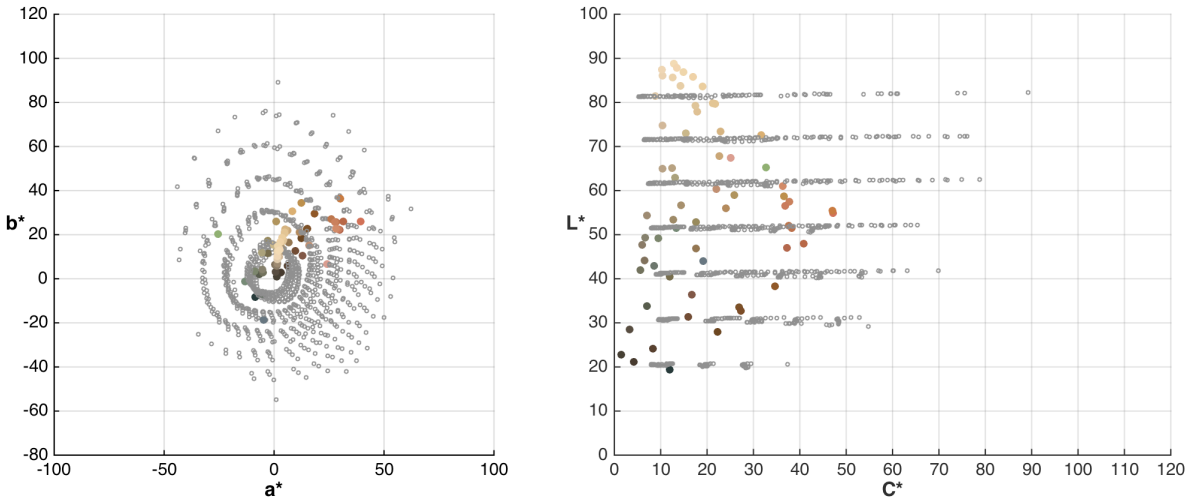
For all measurements, the following data were captured:

- Sample description
- Source
- Color data: CIELAB calculated for the 1931 2° CIE Standard Observer under CIE illuminant D50.
- Date
- Operator
- Optional comments

Measurement Data

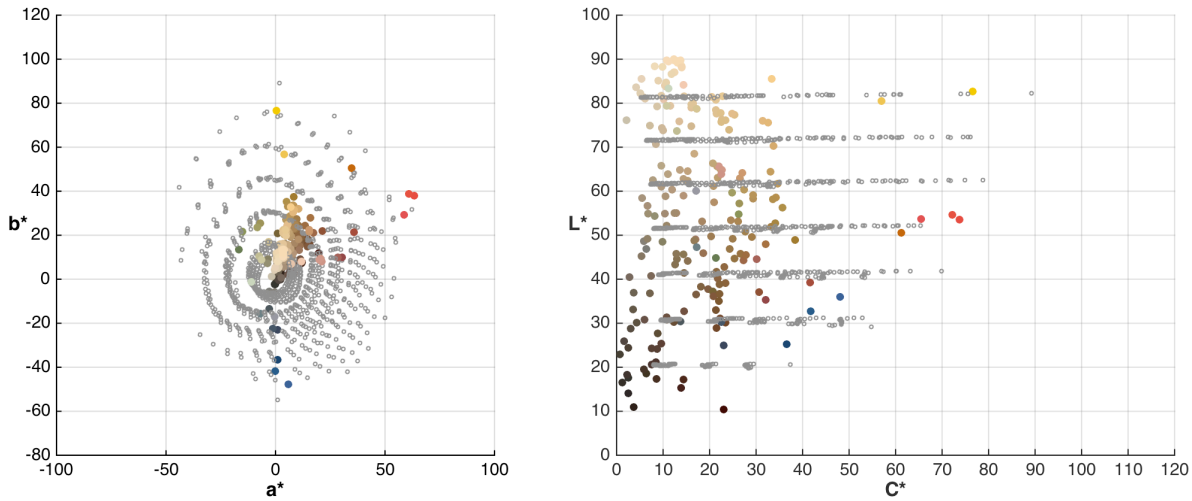
One conclusion from the report on Task A was that the Pointer Gamut[5] represented colors unattainable in samples that met the other important criteria for the Next Generation Target. In particular, the Pointer Gamut includes printed materials consisting of ink on paper. This printing technology can achieve highly chromatic colors, in many cases more chromatic that are otherwise achievable using glossy paints. Glossy paint samples, however, retain other physical properties required of the NGT: uniform, high gloss; and robust surface permitting light cleaning hen necessary. Therefore, as with the final recommended colors from Task A, the measured data here will be plotted against colors in the Munsell Book of Color, Glossy Edition.[6] The Munsell color distribution represents the attainable colors that will meet all the NGT requirements.

To understand how the color in cultural materials has evolved over time, the plots below are divided into the following datasets by year: pre-1800; 1800-1900; 1900-1950; and all measured data. For each dataset. there are two plots: one b* vs a* projection and one L* vs C*. Combined, the plots provide a reasonable 2D picture of a 3D distribution. Note that samples of unknown or indeterminate age we included only in the final plot of all measured data.



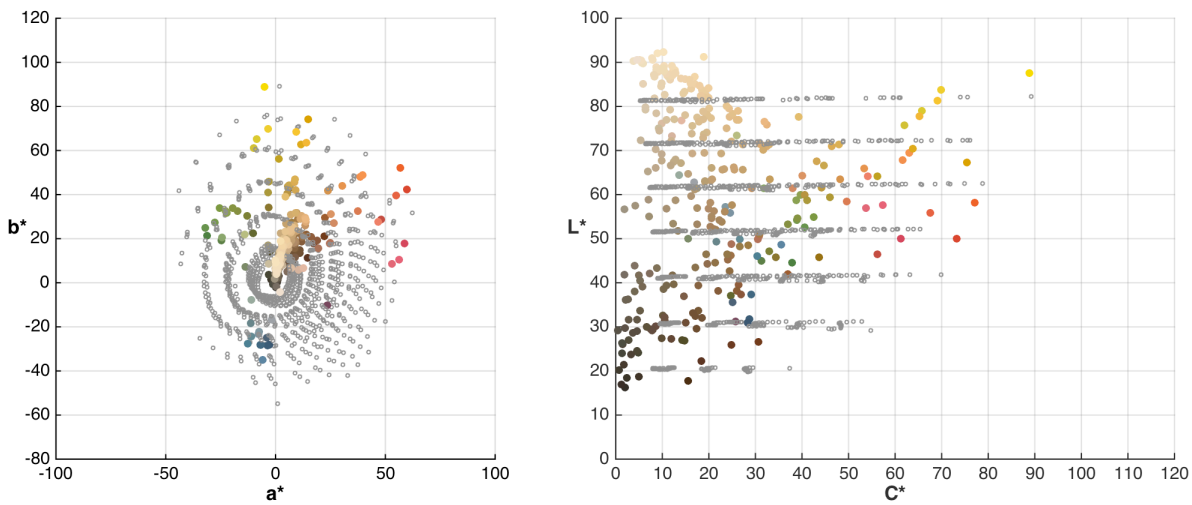
(a) (b)

Figure 1. Distribution of pre-1800 measurements (colored circles) and Munsell colors (gray circles).



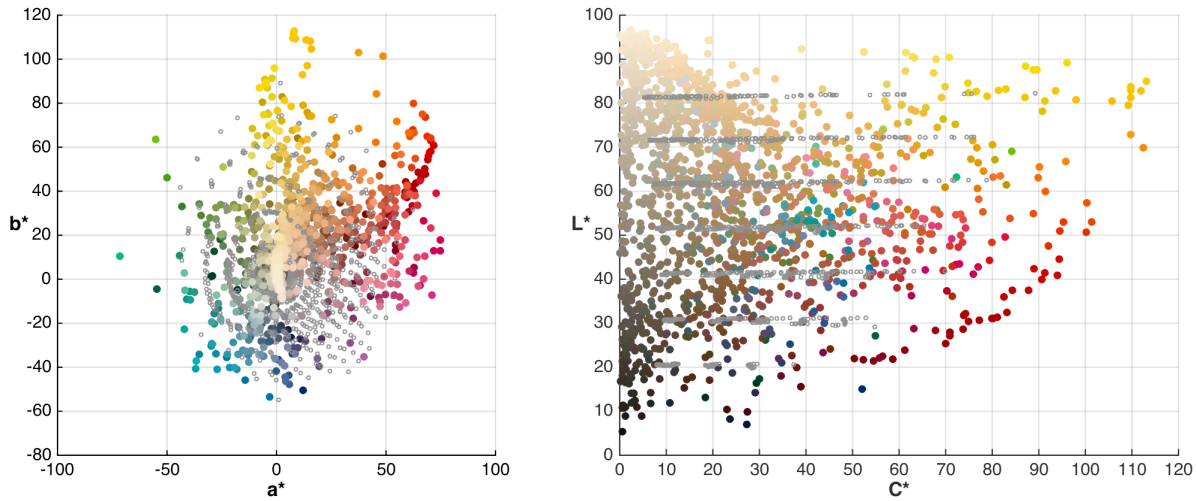
(a) (b)

Figure 2. Distribution of measurements from 1800-1900 (colored circles) and Munsell colors (gray circles).



(a) (b)

Figure 3. Distribution of measurements from 1900-1950 (colored circles) and Munsell colors (gray circles).



(a) (b)

Figure 4. Distribution of all measurements (colored circles) and Munsell colors (gray circles).

Discussion

Figures 1-4 show that older samples are much less chromatic. This is due to many factors, such as aging or the unavailability of more chromatic pigments, but the reasons are outside the scope of this report. What is clear is that the colors trend towards lighter, and yellower regions. This is not surprising given the sample set available for this project: most are some form of printing onto paper, which in general will yellow over time. If a digital imaging systems is required to differentiate among these potentially important colors, the test target should present these colors as well.

The measured modern samples were nearly all printed with high-chroma inks that extend beyond the Munsell colors, and are unattainable within the constraints of the physical properties of the NGT.[4] This is seen in Figure 4(b) where measured colors are higher (lighter), lower (darker), and further to the right (higher chroma) as compared to the Munsell colors.

Estimate of Next Generation Color Distribution

Figure 5 shows b* vs a* projections for each of eight L* (lightness) planes. Each figure shows the respective measured data, the Munsell data, the NGT colors proposed in the Task A report, and the proposed color for the NGT that emphasize the regions of color space covered by the culturally relevant colors.

Much of the range of measured colors was already adequately addressed by the proposed Task A colors. For the present report, 25 additional colors were selected that filled gaps in the Task A proposed distribution identified by the measurements. These colors are enumerated in the appendix.

It is important to note that these proposed NGT colors, as well as those from the Task A report, still have to be formulated in a real paint system, and therefore represent only estimates at this time.

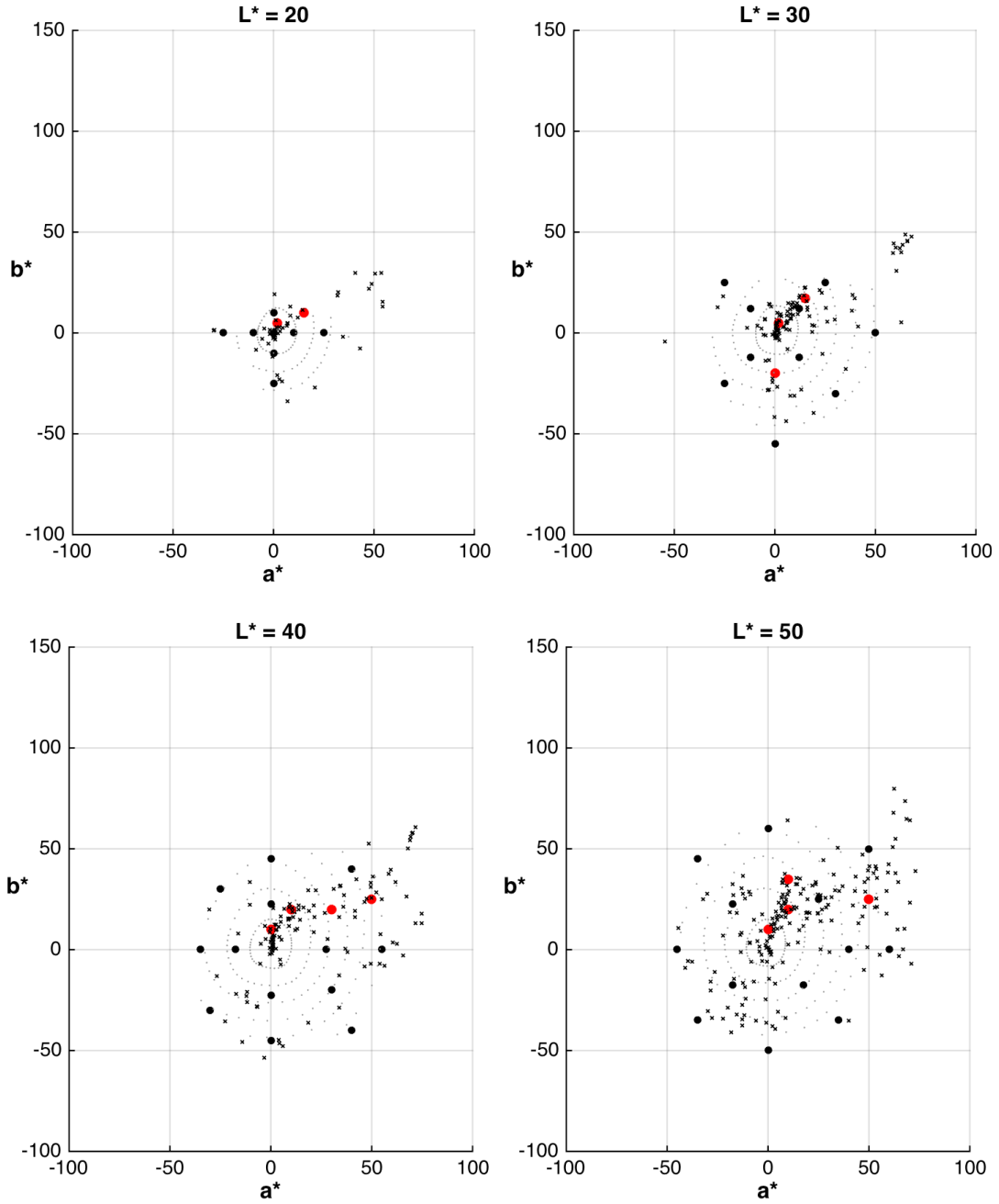


Figure 5a-d. Lightness planes showing the location of Task A proposed NGT colors (black filled circles), and Task B proposed colors (red filled circles) shown in as a*-b* projections in each lightness plane. Measured colors (dots) are and the measured colors (x) are shown for reference. The Task B colors are enumerated in the appendix.

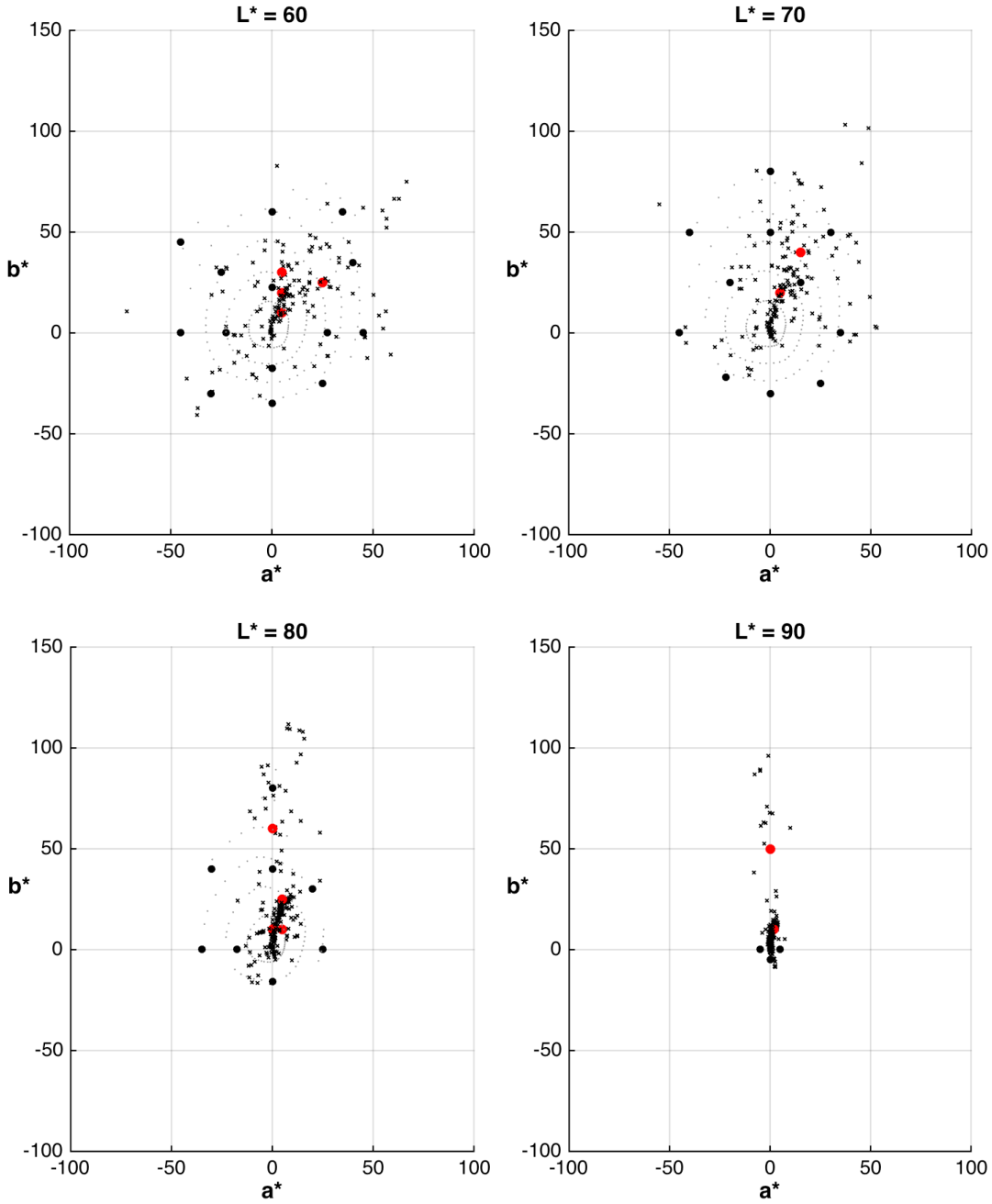
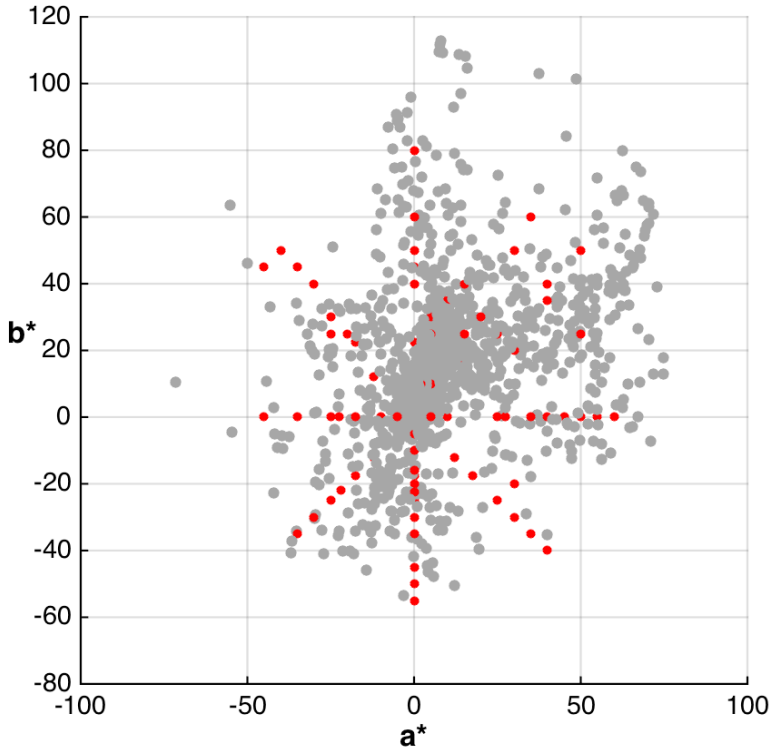
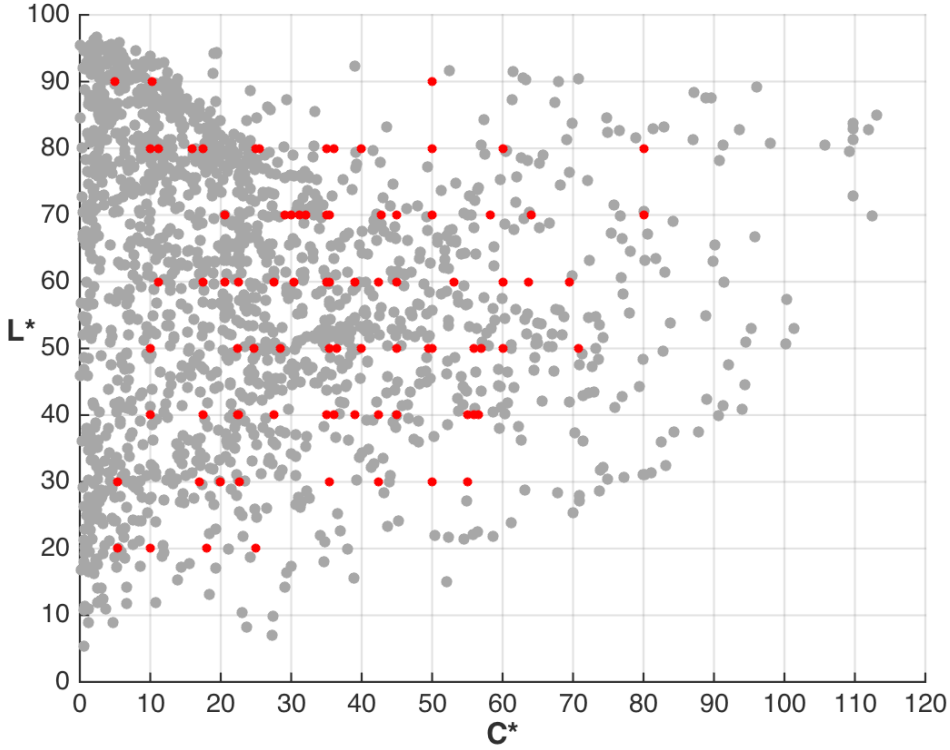


Figure 5e-h. Lightness planes showing the location of Task A proposed NGT colors (black filled circles), and Task B proposed colors (red filled circles) shown in as a*-b* projections in each lightness plane. Measured colors (dots) are and the measured colors (x) are shown for reference. The Task B colors are enumerated in the appendix.



(a)



(b)

Figure 6. All measured colors (shown gray) and all proposed color (Task A and Task B, shown in red).

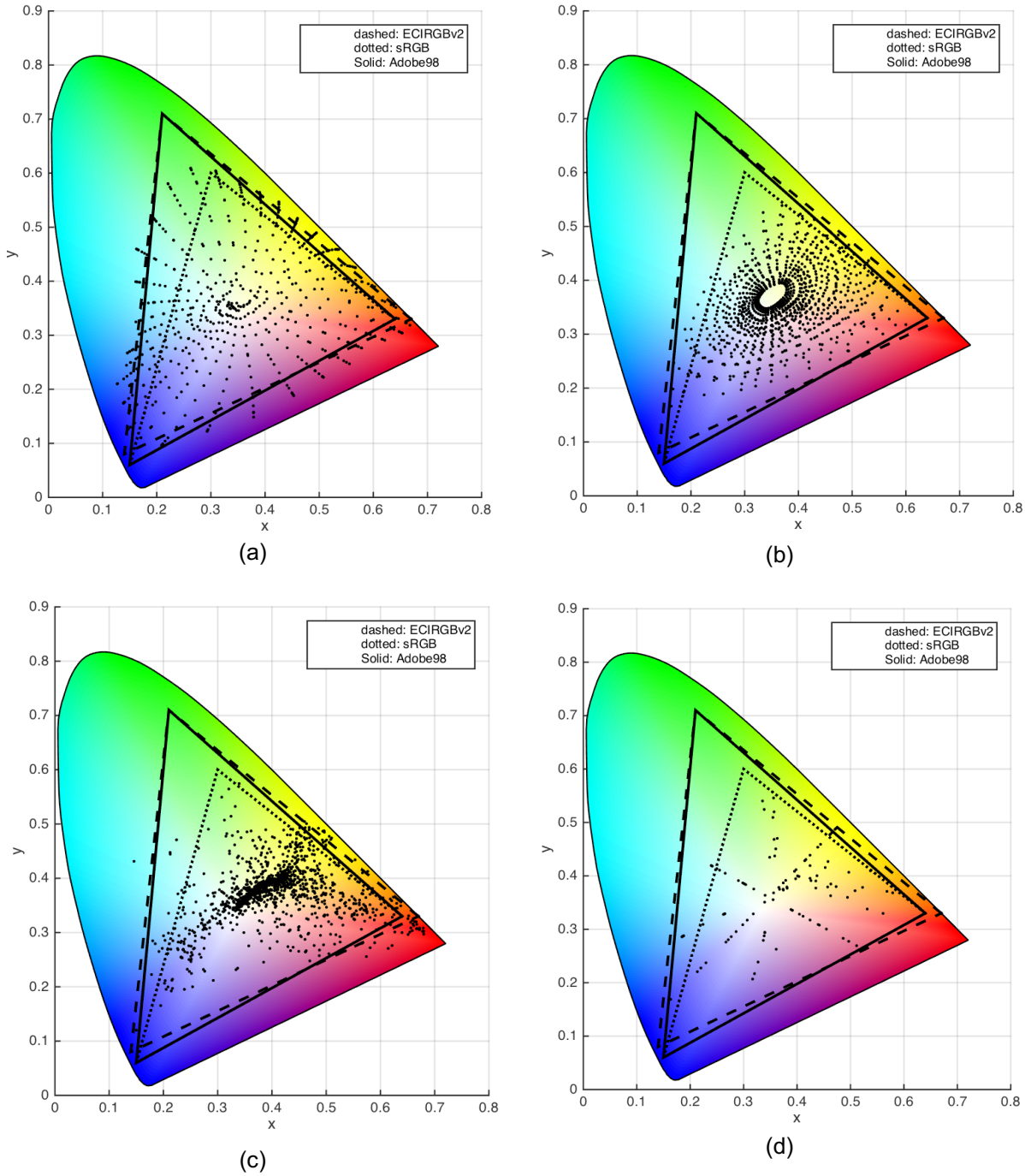


Figure 7. Distribution of various object color data sets (black dots) and the three relevant RGB gamuts: (a) Pointer Gamut; (b) Munsell colors; (c) Measured colors; (d) Propose NGT colors.

Other Important Color Spaces

While CIELAB is an important color space, and perhaps the most relevant for representing the perceptual distribution of colors, other color spaces are important for the target end user of the NGT. The three spaces to be highlighted here are: sRGB, Adobe1998, and ECIRGBv2. The following plots each show a pseudocolor CIE 1931 chromaticity diagram and the triangular gamuts of the three spaces. The chromaticity distribution of color from Pointer, Munsell, measured, and proposed data sets are shown in Figure 7(a)-(d), respectively.

Figure 7 compares the object colors described in this report with the various important working color spaces. Figure 7(a) clearly shows that many of the high-chroma Pointer colors are simply too chromatic for these encodings. If the

NGT were to include such highly chromatic colors, there would necessarily be clipping when those colors were imaged and transformed into any of these working spaces. Likewise, even many of the measured colors in Figure 7(c) are also out of gamut for all three spaces. In Figure 7(b) the Munsell colors can be seen to extend beyond sRGB, but lie comfortably within ECIRGBv2 or Adobe98. The propose NGT colors, in Figure 7(d), are with a few exceptions inside sRGB, but all are well inside the other two spaces.

Conclusion and Future Work

In support of the digitization needs of the Library of Congress, a project has been initiated to design and produce a new target for color camera characterization. The requirements for this Next Generation Target (NGT) are to better meet the needs of the library imaging community: better represent cultural heritage materials in terms of color; better general coverage of the range of available colors; and a more durable target for laboratory use. Previously, an analysis considered the range of colors in existing physical samples. The present report adds to that the colors from measured samples representing culturally relevant materials. From this measured dataset, an additional set of proposed colors is made for the NGT. As with the previous work, considerations on the proposed distribution of colors were based on the requirements of the NGT: primarily the physical durability, and color and gloss uniformity. Combined with the previous proposed colors, this set represents the best estimate of the aim colors for the NGT.

The next tasks of the project involve creating the physical samples that will constitute colors in the NGT. The real colors will necessarily differ from the estimated depending on the substrate and color mixing system selected. These will be addressed in Task C and Task D, respectively.

Acknowledgements

The data in this report were collected from several sources. We acknowledge the following people for their gracious support of this project by providing access to relevant materials for measurement:

- Steven K. Galbraith, Curator, RIT Cary Graphic Arts Collection, Rochester NY.
- Amelia Hugill-Fontanel, Assistant Curator, RIT Cary Graphic Arts Collection, Rochester NY
- Lea Kemp, Librarian/Archivist, Rochester Museum and Science Center, Rochester NY.
- Ross Knapper, Collection Manager, George Eastman Museum, Rochester NY.
- Sophia Lorent, Curatorial Assistant, George Eastman Museum, Rochester NY.
- Taina Meller, Conservator in Charge, George Eastman Museum, Rochester NY.
- Library of Congress staff: Steve McCollum and Taren Ober.

Notes and References

[1] Complete specifications can be found at the KonicaMinota web site (accessed Feb 1, 2016):
`<sensing.konicaminolta.us/products/fd-7/>`

[2] CIE Publication 15.2004, *Colorimetry*, Third Edition, Vienna (2004).

[3] The stated inter-instrument agreement is $0.3\Delta E_{00}$, which is well within the needs of this project.

[4] Refer to the discussion regarding the Munsell Limit Color Cascade in the Task A report.

[5] The Gamut of Real Surface Colors, M.R.Pointer, *Color Research and Application* **5** (1980).

[6] Newhall SM, Nickerson D, Judd DB. Final report of the O.S.A. subcommittee on spacing of the Munsell colors. *Journal of the Optical Society of America*, **33** (1943).

Appendix

Table A1. Enumeration of proposed colors for the Next Generation Target (Culturally relevant colors only)

Sample ID	L*	a*	b*
1	20	2	5
2	20	15	10
3	30	0	-20
4	30	2	5
5	30	15	17
6	40	10	20
7	40	30	20
8	40	0	10
9	40	50	25
10	50	0	10
11	50	10	20
12	50	10	35
13	50	50	25
14	60	25	25
15	60	5	30
16	60	5	10
17	60	5	20
18	70	5	20
19	70	15	40
20	80	0	10
21	80	5	10
22	80	5	25
23	80	0	60
24	90	2	10
25	90	0	50