Analysis of Color Management of RGB Laser COM for Image Archiving Applications

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Abstract

An RGB laser COM system – the Eternity – has been developed to provide high-resolution and high-speed recording of image data on color microfilm. Experiments were performed to analyze the color accuracy of the Eternity on Cibachrome Micrographic Master (CMM) film. Targets included Color Checker SG as well as a set of specific test charts for white point and gray scale calibration. The targets were measured with a photospectrometer (SpectroSwing RT) and the results were analyzed with commercial software (Profile Maker).

The average and maximum CIEDE2000 was 2.23 and 5.05, respectively, for the ColorChecker SG target. According to the FADGI guidelines, a four star performance has an average CIEDE2000 below 3 and maximum below 6. This clearly demonstrates the excellent color reproducibility of the Eternity RGB laser system and its suitability for producing authentic archival images of historic manuscripts, books, graphic illustrations, maps, plans, photographs, and aerial photographs.

Introduction

In an archive image department, accurate color reproduction is of prime concern for both digitizing and reprographics of cultural heritage objects such as historic manuscripts, books, graphic illustrations, artwork, maps, plans, photographs, and aerial photographs. From a color management perspective, image recording devices should be colorimetric, that is, color differences should be small between the original image data and data obtained by spectrophotometry on reprographic prints.

Although the Ilfochrome microfilm with its life expectancy (LE) of 500 years is the medium of choice for long-term preservation of color documents [1, 2], its rather low sensitivity of about 0.4 ASA and its strong non-linearities in its sensitometric curves [3] is challenging classical camera- and display-based photographic exposure devices.

In contrast to classical exposure devices, RGB laser COM systems are based on red, green and blue lasers at their core and enable to address a high number of quantization steps along the sensitometric curves of the film and hence to address virtually the full color gamut of the film.

RGB Laser COM

The RGB laser COM system – the Eternity – which has been used for image recording on Cibachrome Micrographic Master (CMM) film in this study has been described elsewhere [4].

Calibration Procedure

In order to provide optimum image recording capability an innovative color calibration procedure has been implemented for the Eternity. The calibration procedure includes three steps:

- White point calibration;
- Gray scale profiling;
- ICC profiling.

A set of specific digital color targets is recorded on color microfilm and is measured using a spectrophotometer. The white point calibration target consists of 126 unique color patches (near neutral). An iterative procedure then allows determining the exact RGB laser power levels for recording a neutral white on the CMM film (with an optical density of typically 0.2). The gray scale calibration target consists of 252 gray patches. In a second iterative procedure, a look-up table (LUT) for the Eternity is determined providing gray scale profiles. Finally, a suitable color target such as the ColorChecker SG [5] with a total of 140 patches including 96 unique colors is recorded and analyzed to obtain an ICC profile using color profiling software (Profile Maker).

Performance Metrics and Measurements

The spectral transmission factor of each sample was measured with a spectrophotometer (SpectroSwing RT from Barbieri). Colorimetry was calculated for the 1931 standard observer and illuminant D50. Two color-difference formulas were used: CIEDE2000 (ΔE00) – recommended by the CIE – and ΔE^*_{ab} (still widely used in the community).

Results and Discussion

The color reproduction performance of the Eternity recorder on CMM film evaluated from the ColorChecker SG target is listed in Table I.

With a CIEDE2000 (ΔE_{00}) average of 2.23 and a maximum of 5.05, respectively, the results of our analysis are very satisfying. According to the FADGI guidelines [6], a four star performance has an average CIEDE2000 below 3 and a maximum below 6.

In terms of ΔE^*_{ab} we find an average and a maximum value of 2.96 and 7.67, respectively, which fulfils the guidelines set up by Metamorfoze [7]. Although both FADGI and Metamorfoze were set up as guidelines for digitizing cultural heritage materials, it might also be adapted for classifying the reverse process, e.g. digital image recording on color (micro-) film.

For further analysis, we have plotted the CIELAB coordinate b* versus a* and lightness L* versus chroma C^*_{ab} of the reference and measured values of the ColorChecker SG target in Figure 1 and Figure 2, respectively. The data indicates a quite random orientation of the delta vectors (although not shown in the plot).

Figure 3 shows the color performance CIEDE2000 versus chroma C^*_{ab} of the Eternity RGB laser recorder based on spectrophotometric measurements of the ColorChecker SG target.

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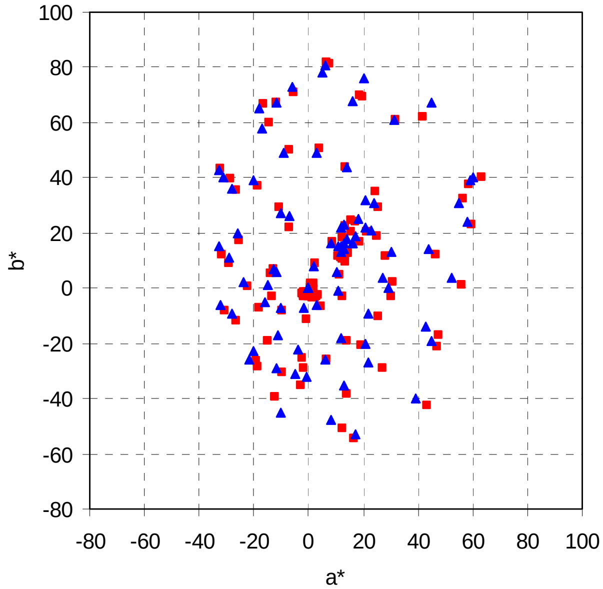

Figure 1. CIELAB color coordinates (a, b*) of the ColorChecker SG target on CMM film where the blue triangles and red squares represent the reference and measured values, respectively.*

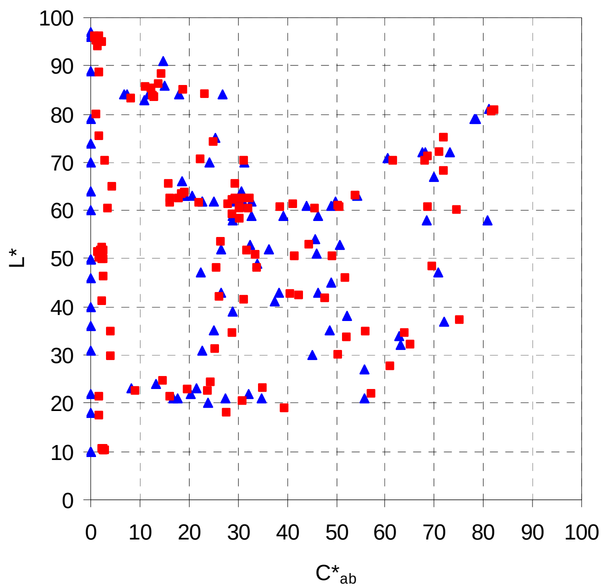

Figure 2. CIELAB color coordinates lightness L versus chroma C^*_{ab} of the ColorChecker SG target on CMM film where the blue triangles and red squares represent the reference and measured values, respectively.*

Except of three ΔE_{00} values at low chroma, the color reproduction accuracy for the ColorChecker SG target is better than 4.7 for all chroma values and is quite uniformly distributed (neither showing a systematic deviation nor a tendency).

Figure 4 shows the color performance CIEDE2000 versus lightness L* of the ColorChecker SG target. Again, we find a quite uniform distribution in this data plot.

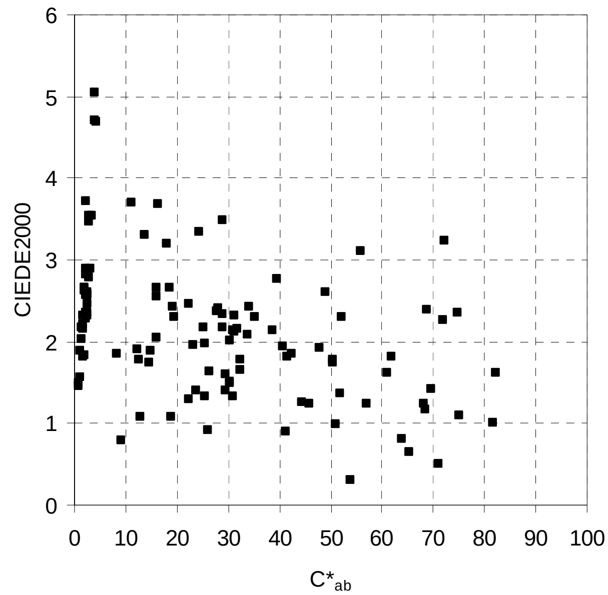

Figure 3. Color performance CIEDE2000 versus chroma C^*_{ab} of the Eternity RGB laser COM based on spectrophotometric measurements of the ColorChecker SG target on CMM film.

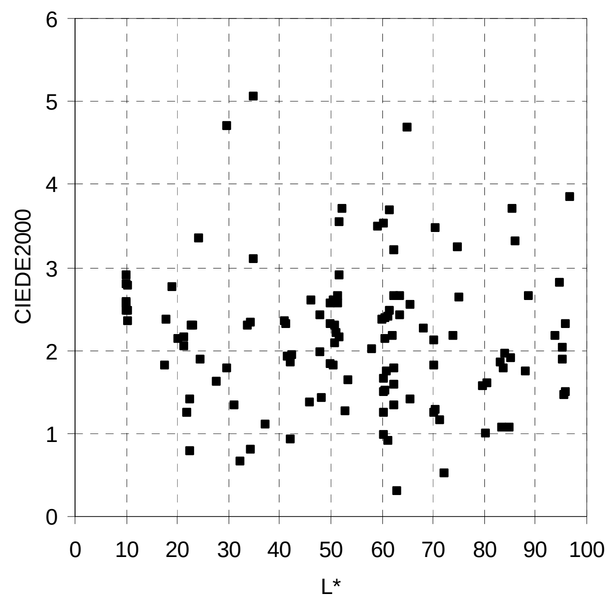

Figure 4. Color performance CIEDE2000 versus lightness L of the Eternity RGB laser COM based on spectrophotometric measurements of the ColorChecker SG target on CMM film.*

In Figure 5, we have ploted the measured color coordinates of the ColorChecker SG target together with the color gamut of the CMM film. As we can see, all the colors of the ColorChecker SG target are inside the gamut. Hence, it is no surprise that the colors of the ColorChecker SG target can be colorimetric reproduced as has already been demonstrated by the results of the spectrophotometric measurements (see Table I).

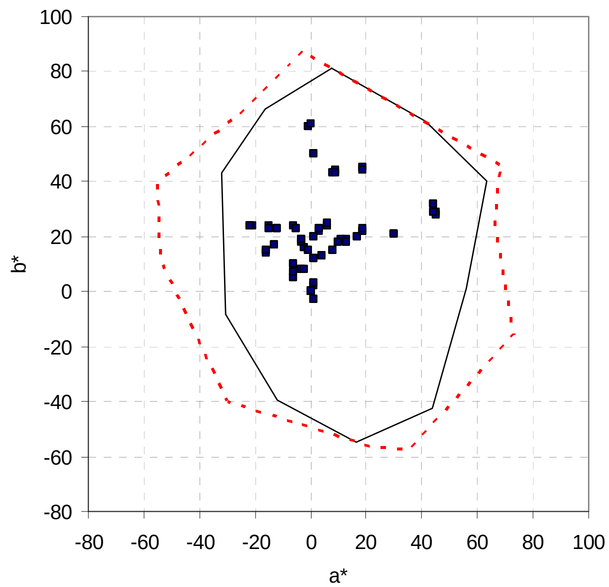

Figure 5. CIELAB color coordinates (a, b*) of the image of an historic map together with the perimeter of the ColorChecker SG target colors (black line) and the CMM film gamut (dashed red line).*

Table I. Average, average of best 90%, and maximum color difference for the ColorChecker SG target and a sample image of a historic map recorded on CMM film with the Eternity RGB laser system.

Test Target	Statistics	ΔE_{00}	ΔE^*_{ab}
ColorChecker SG	Mean	2.23	2.96
	Best 90%	2.04	2.67
	Max	5.05	7.67
Sample Image of Historic Map	Mean	2.08	2.77
	Best 90%	1.91	2.52
	Max	4.78	7.28

From a practical point of view, the interesting question is about how precise the archival copy on CMM film reproduces the colors of an historic image or document. In a recent archiving project, historic hand-colored maps were to be recorded on color microfilm. The analysis of the colors in these images revealed that their corresponding gamut was quite restricted as is shown in Figure 5. Therefore, we decided to use the ColorChecker SG target for final ICC profile calibration.

In order to quantify the color reproduction accuracy for these historic maps, we selected 31 colors from the images (trying to get an appropriate color palette selection [5]) and designed a reference color target. The target was then recorded on the CMM film and measured with the spectrophotometer. The color reproduction performance of the target is also listed in Table I. Finding an average ΔE_{00} of 2.08 and a maximum of 4.78, we conclude that the Eternity records these historic images on CMM film with an excellent colorimetric reproduction.

Conclusion

The Eternity RGB laser system enables to record digital images in excellent colorimetric accuracy on color microfilm. The ColorChecker SG is an adequate target for CMM film calibration because all of its reference colors can be accurately (calorimetric) reproduced on the film and, - based on our experience in color microfilm recording of digitized image data over the last five years - it also covers the typical color gamut of historic image collections. We have demonstrated that historic image collections (such as maps) can be recorded on CMM film with excellent colorimetric reproduction. According to the FADGI criteria, the Eternity achieves a four star rating.

Thus, archives, libraries, museums, publishers and other public and non-public organizations are provided with a high-quality image recording service which allows them to implement image preservation concepts based on color microfilm for archiving beyond digital.

References

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Author Biography

Daniel Fluck, born 1963, studied physics at the Swiss Federal Institute of Technology (ETH) in Zurich and received a Ph.D. in physics in 1995. He has more than 15 years of research and development experience in the fields of optics and lasers. He is inventor and co-inventor of several patents. In 2005 he founded the company Pro Archive AG.

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