Colorimetric Characterization of a Positive Film Scanner Using an Extremely Reduced Training Data Set

Jean-Baptiste Thomas; University of Bourgogne; LE2I; Dijon, France
Clotilde Boust; C2RMF; Paris, France

Abstract

In this work, we address the problem of having an accurate colorimetric characterization of a scanner for traditional positive film in order to guarantee the accuracy of the color information during the digitization of a movie. The scanning of a positive film is not an usual task, however it can happen for cultural heritage purpose. Art-movies, are often created and stored as positive-film in museums. One of the problems one can face for a colorimetric characterization is to have a reasonable number of measurements from an item. In this work we succeeded in having a reasonable accuracy with just a few number of measurement (typically 4 to 7 ΔE^*_{ab} units with 2 to less than 10 measurements).

Introduction

While the common process for digital cinema tends to scan negative films, in some cases it can be necessary to scan positive films, such as for cultural heritage conservation. Indeed, museums own positive copies that are sometimes the only original still available. A recent research thematic at the C2RMF (Centre de Recherche et de Restauration des Musées de France) is to address problems linked with film obsolescence in contemporary art [1, 2, 3]. Within this thematic, we are focussing on art movies digitization and rendering through a digital media. The goal is to evaluate the differences between an original artist's film projection and its digital copy. We then want to quantify the impact of these technological changes on film reception from an art history point of view and study how to minimize those differences if necessary. The possibility of using a digital copy for exhibitions or for conservation could then be seriously discussed.

Films in museum collections can be several decades old (sometimes from the beginning of the 20^{th} century). While working on their digitization, one of the major problems faced is the lack of information on the substrate (type of film, dyes, speed, use, etc.) because these silver halide films are now obsoletes and their technical characteristics are forever lost. We could measure those films to refind a part of the technical data, but there is no color chart on them to do it properly and the risk of damaging a unique artwork while manipulating is too high so we would limit action to the minimum. Moreover, most movies are printed on different films. That makes the color characterization of the couple scanner - artist film difficult.

Colorimetric characterization of scanners has been widely studied the last twenty years, and different valid solutions have been proposed [4, 5]. One of the remaining challenge is to reduce the amount of measurement required.

Some works have been performed in order to design the optimal set of spectral stimulus (data set) to measure and acquire in order to limit the number of measurements [6]. However, these data set are mostly purpose dependent, and can be different from one goal or method to another. Nevertheless, these works have given birth to some charts that are now widely used for scanner characterization, such as the $KODAK\ Q-60^{TM}$ chart.

In parallel, some works addressed the problem of having different configurations (changing in papers, inks, etc. of the input to the scanner) working with the same color characterization model, which is specific to a given set-up [7].

On another hand, some works have been completed the last years in order to transform the colorimetric characterization of printers using a reduced measurement number, depending on the configuration used (changes of paper, ink, toner, etc.). Balasubramanian and Maltz [8] proposed to use a local linear transform to modify the model, reaching good results. Littlewood and Subbarayan [9, 10] studied different global transforms.

The model proposed by Noriega et al. [11] is the only cinema scanner specific work we are aware of. It proposes to design first a physical model to pass from a negative density to a positive film density. The second step is the establishment of a 3D LUT (Look Up Table) based model with different interpolation methods. However, the problem of changes between dyes and films is not addressed.

In this work, we present a simple mean to reach a reasonable colorimetric accuracy while digitizing film movies. It is based on the establishment of a generic 3D LUT model based on one given film, which is then transformed through a linear application to fit with the film of the movie. This transform is based on only a few number of measurements, typically 2 to 10 homogeneous area taken on the actual film were enough to see the convergence of the algorithm.

In the following, we first introduce our colorimetric characterization model, then we show how we decided to transform the model. We evaluated the feasibility of our method, we used two positive films of the Gretag Macbeth DC Color Chart chart taken with the same camera and scanned with the same desk scanner.

Method used to build the generic model

We first need to build a generic colorimetric characterization model from a color data set measured on a film and their corresponding digital RGB values after scanning.

The color data set can be created either in shooting series of color patches with a camera generating a positive film, or using a cinema imaging device to create directly a positive film from digital data. The resulting positive film is then measured with a spectroradiometer to obtain spectral transmission curves and also scanned to obtain RGB corresponding data.

A colorimetric characterization model can be established based on the computation of the CIEXYZ tristimulus values from the spectral measurements with the choice of an illuminant (here D65), with an interpolation based on polyharmonic splines, a subset of Radial Basic Functions.

The use of this interpolation technique is not new in color imaging, and has been studied and used successfully with printers [12] and displays [13] color characterization in the past decade.

To evaluate the result of this model, we considered two films with different characteristics, a KODAK Ektachrome 400 EPL 5075 and a FUJI RM 135 Sensia 200 (referred as film A and film B in the following). We used the same camera, an Olympus OM1 with a macro lens, to shoot a Gretag Macbeth DC Color Chart with the same illumination in a Gamain viewing booth.

Then, we used the about 180 color patches from the Gretag chart to build the models and we evaluated the results on each film using a leave one out approach. Results are presented on Table 1. We observed that the Maximum error is high, 30 ΔE^*_{ab} (referring to ΔE 1976). This is due to the leave one out process. This situation could happen in a practical situation if the chart is not covering enough of the "gamut" [1] of the camera or scanner. However, the mean and median results are low and good enough, considering the few number of measurements we used, to show that this model can be used in practice.

Model adaptation

Since we want to evaluate the colorimetric values of the colors of an art movie, we need to have a model that characterize this movie. To get measures from these movies is a tough task, either because of the lack of uniform color patches and because of the difficulties to manipulate these films since they are fragile. Thus we could measure at the most only a few data on each movies.

We first evaluated the use of a generic model established on another substrate, performing simply a scaling of the CIEXYZ data. The scaling process is just based on the normalization of the two data set in XYZ color space. However, as one can see on Table 2, this process leads to an error that is not acceptable for our purpose. In using only a scaling of the data, the model is showing an average error of about 10 ΔE^*_{ab} units while applied on another film.

The leading idea of this paper is to use a really small amount of data to modify a generic model, based on a film with possible different features (age, dyes, etc.), in order to make it to fit with the film we need to consider.

Such methods have been explored for printers. In different works, methods to transform models have been explored. Littlewood and Subbarayan [9, 10] have shown that a global transform is a good mean to transform the model. Looking at their results, it appears that a linear transform is the best among the methods they tested and does not require too many data to be designed.

Following them we consider to use a linear transform.

We decided to work in CIEXYZ color space for its linear behavior considering additive and distributive properties.

We first normalize our colorimetric values, so we perform an intensity linear scaling.

We then design a colorimetric transform based upon a 3 matrix and on an offset modification. We retrieve the parameters through an optimization process.

A colorimetric value output of the model will then be modified such as follow:

$$\mathbf{C} = \mathbf{P}\mathbf{C}' + \mathbf{O} \qquad (1)$$

such as:

$$\begin{bmatrix} X \\ Y \\ Z \end{bmatrix} = \begin{bmatrix} a & 0 & 0 \\ 0 & b & 0 \\ 0 & 0 & c \end{bmatrix} \times \begin{bmatrix} X' \\ Y' \\ Z' \end{bmatrix} + \begin{bmatrix} O_a \\ O_b \\ O_c \end{bmatrix} \qquad (2)$$

with $\mathbf{C} = [X,Y,Z]^T$ the predicted tristimulus colorimetric values and a linear transform applied to $\mathbf{C} = [X',Y',Z']^T$ the predicted values from the generic model. a,b,c,O_a,O_b,O_c, parameters that are resulting of an optimization process based on a few number of measurement.

[1] The area of a color space where a camera does not show too much metamerism

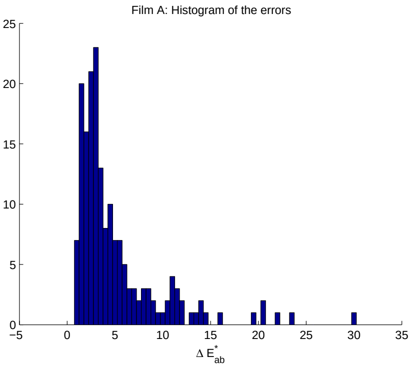

Figure 1. Histogram of the errors induced by the model on film A.

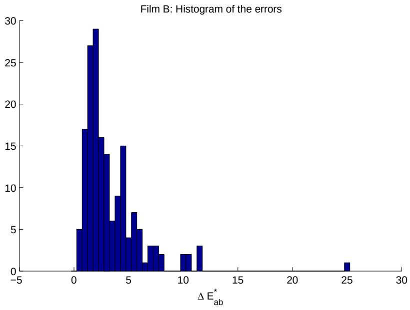

Figure 2. Histogram of the errors induced by the model on film B.

Results and discussion

We evaluated the original model using the leave one out method. The average error was found around 3. This error overestimate the inaccuracy of the model since the leaving data is not used to establish the model. The maximal error is misleading since some patches to evaluate the model can be out of the "leave one out model gamut" and use an extrapolation.

Table 1 : The polyharmonic splines model applied to film A and film B. We used a leave one out method to estimate the accuracy since we do not have too many data.

ΔE^*_{ab}	film A	film B
mean	5.08	3.41
median	3.23	2.46
max	30.10	25.90
std dev	4.68	2.92

While using this model to characterize the other film, we observed similar results than on printers. In using only a data intensity scaling and the same characterization model, we obtain a ΔE^*_{ab} average error of around 10. Results are shown in Table 2 and on Figures 3 and 4.

This error is reduced to an average error of 5 to 7 ΔE^*_{ab} or a median error of 4 to 6 ΔE^*_{ab} while adjusting the model with a linear transform based on a few number of measurements (See Table 2, Figures 5, 6 and Figures 7, 8).

Figures 7 and 8 show the convergence of the process while increasing the number of measurements. We converge with 2 to 6 measurements in both tested cases. We still observed a maximum error really high for patches outside of the gamut of the

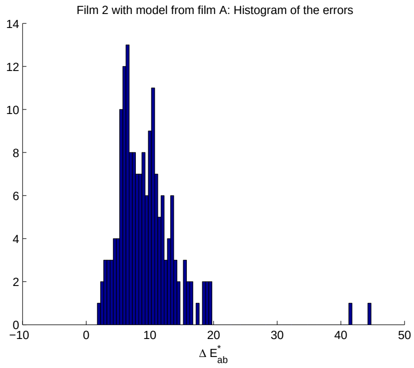

Figure 3. Histogram of the errors induced by the model on film B while applying the model generated from film A.

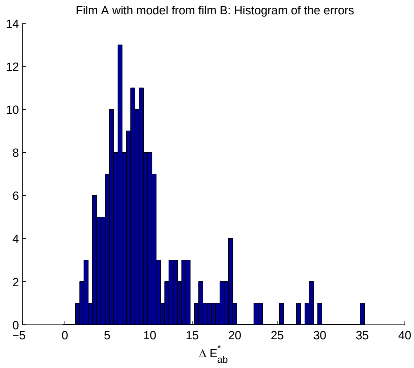

Figure 4. Histogram of the errors induced by the model on film A while applying the model generated from film B.

Table 2 : The polyharmonic splines model generated on film A (film B) and applied to film B (film A) with or without transforms.

	ΔE^*_{ab}	film B through model A	film A through model B
Scaling	mean	9.54	9.69
	median	8.84	8.22
	max	44.54	34.97
	std dev	5.27	5.86
Linear transform 10 data	mean	5.22	6.40
	median	4.07	5.04
	max	42.24	29.83
	std dev	4.95	4.88
Linear transform with offset 10 data	mean	5.18	6.39
	median	4.03	5.17
	max	42.11	27.63
	std dev	4.91	4.80

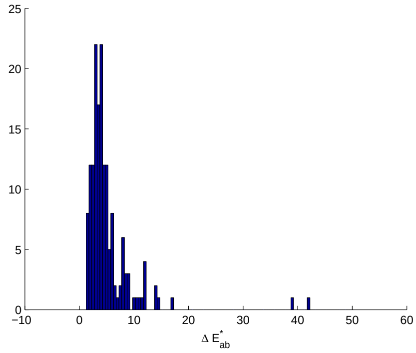

Figure 5. Histogram of the errors induced by the model on film B while applying the model generated from film A modified with 10 measures taken on film A.

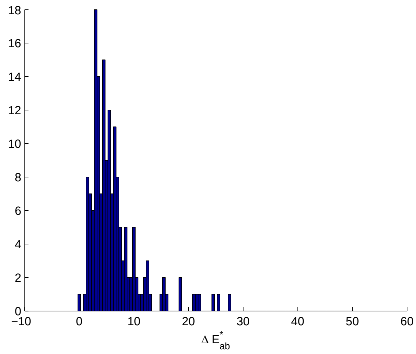

Figure 6. Histogram of the errors induced by the model on film A while applying the model generated from film B modified with 10 measures taken on film A..

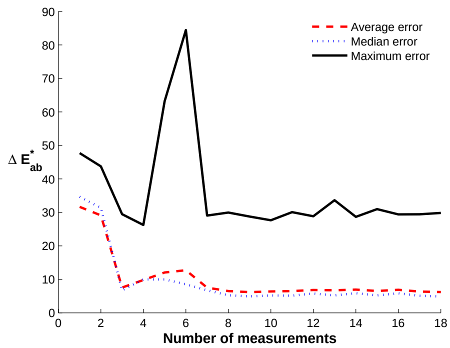

Figure 7. Graph showing the evolution of the accuracy of the refined model for a linear + offset transform for the model based on film A and applied on film B. The average error decrease and converge after a fitting based on 2 measurements. The maximum error is stable.

original couple scanner/positive film data set. We can notice that the maximum error is following in one case a smooth behavior instead of on the other case, where it oscillates. We can also notice an effect at the level of 3-4 measurement, where we can see an increasing error. This is due either to the optimization process and to the choice of measurements. There is some investigation to make on the choice of the color samples to measure in order to get a good fitting.

Table 2 shows also that adding an offset is not necessarily making the model fitting better. We do not discard this considering that with some scanner or some films it can have an impact on the result.

Conclusion

We demonstrated that it is possible to have an accurate colorimetric calibration of a positive film using just a few number of measurements to adapt a general model to a given positive film. The required number of measurement was typically 4 to 6. Our method is robust with a changing of dyes, quality of film, etc. We reduced the error from 10 ΔE^*_{ab} using a simple intensity scaling and a generic model to around 5 ΔE^*_{ab} when using a linear transform to fit the generic model to a given film, which is reasonable for our application.

In a next step, we will test this method on other scanners to assess the robustness of this method. Our near future work will

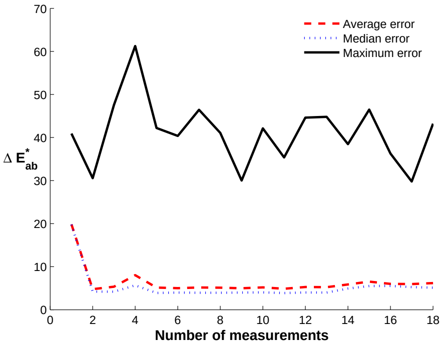

__Figure 8.__ Graph showing the evolution of the accuracy of the refined model for a linear + offset transform for the model based on film B and applied on film A. The average error decrease and converge after a fitting based on 4 measurements. The maximum error is unstable and oscillate between 30 and 40.

then show that it can be applied in practice to the digitization of art movies in museum collections.

Acknowledgments

This research is hosted by the C2RMF and won several research projects from the CNRS ISCC and the French Ministry of Culture PNRC that we would like to thank for their founding. We would like to mention our direct collaborators in C2RMF, Cécile Dazord, curator of contemporary art at C2RMF, Matthieu Dubail engineer on this project and the photographers Jean-Louis Bellec and Daniel Vigears for their help. We would like to thank also the two main institutions we work with, the National Museum of Modern Art Georges Pompidou for the work and access to artist films and the cinema post production firm Mikros for their participation on film scanning.

References

[1] Matthieu Dubail, Cécile Dazord and Clotilde Boust, Study of contemporary art preservation with digitizations, Archiving IS&T, Arlington, USA, Vol. 6 , pp. 47-52, (2009).

[2] Clotilde Boust, Matthieu Dubail and Cécile Dazord, Contemporary art and technological obsolescence : Film digitization and color rendering in avant-garde and experimental cinema, Contemporary art : who cares ?, INCCA, Amsterdam, Nederland, (2010).

[3] Research blog, Contemporary art group, Centre de Recherche et de Restauration des Musées de France - C2RMF : http://obsolescence.hypotheses.org/

[4] Tony Johnson, Methods for charaterizing colour scanners and digital cameras, Displays, 16, 4 (1996).

[5] Gaurav Sharma, Targetless Scanner Color Calibration, J. Imaging. Sci. and Technol., 44, 4, pg. 301-307 (2000).

[6] Maier, T.O. and Rinehart, C.E., Design Criteria for an input Colour Scanner Evaluation Test Object, The Journal of Photographic Science, 38, pg. 169-172 (1990).

[7] Pan, Zhihong and Noyes, Ying X. and Hardeberg, Jon Y. and Lee, Lawrence and Healey, Glenn, Color scanner characterization with scan targets of different media types and printing mechanisms, Proc. SPIE, 4300 pg. 58-63. (2000).

[8] Raja Balasubramanian and Martin S. Maltz, Refinement of printer transformation using weighted regression, Proc. SPIE, 2658, pg. 334-340. (1996).

[9] Littlewood, David and Subbarayan, Ganesh, Maintaining an Accurate Printer Characterization, CIC 12, IS&T / SID, pg. 179. (2004).

[10] Littlewood, David and Subbarayan, Ganesh, Updating a CMYK Printer Model Using a Sparse Data Set, J. Imaging. Sci. and Technol., 50, 6, pg. 556-566 (2006).

[11] Leonardo Noriega and Jan Morovic and Wolfang Lempp and Lindsay MacDonald, Colour characterization of a digital cine film scanner, CIC 9, IS&T / SID, pg. 239-244. (2001).

[12] Gaurav Sharma and Mark Q. Shaw, Thin-Plate Splines for Printer Data Interpolation, Proc. European Signal Proc. Conf., (2006).

[13] Philippe Colantoni and Jean-Baptiste Thomas, A color management process for real time color reconstruction of multispectral images, 16th Scandinavian Conference, SCIA, Lecture Notes in Computer Science, vol. 5575, (2009).

Author Biography

Jean-Baptiste Thomas received his Bachelor in Applied Physics in 2004 and his Master in Optics, Image and Vision in 2006, both from the Université Jean Monnet. He received his PhD from the Université of Bourgogne in 2009. After a stay as a researcher at the Gjøvik University College and then at the C2RMF (Centre de Recherche et de Restauration des Musées de France), he is now Maître de Conférences (Associate Professor) at the Université of Bourgogne. His research focuses on color science and on color and multi-spectral imaging.

Clotilde Boust received her engineering degree in photography from the École Nationale Supérieure Louis Lumière, France in 1998. After working for three years as a color consultant, she received a Ph. D. in perceptual image quality from Paris VI Uiversity in 2004, with Océ Print Logic Technologies. She is now associate professor and leading research projects at the Research and Restauration Center for French Museums (Centre de Recherche et de Restauration des Muses de France C2RMF) about color imaging for art conservation.