

# ‘Cyber-Digitization’: Pushing the Borders of Film Restoration’s Ethics

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**ABSTRACT:** What is the outcome if we combine current digital technologies with the restoration of historical analog color films? Could we guarantee a better reproduction of the original color aesthetics? In the framework of the project ERC Advanced Grant FilmColors at the University of Zurich, we investigate new approaches that help bridge the gap between the aesthetics of analog color film processes and their transfer into digital form(at)s. By showcasing three highly topical case studies, the paper argues for a broader understanding of film restoration ethics in order to create new digital versions of analog films. The presented methods are informed by a profound knowledge of historical color film processes on the one hand, but they also consider the shortcomings of contemporary modes of digitization on the other hand. By overcoming previously established ethical limitations, we highlight the original color film technologies’ broader potential, suggest reinterpreting the concept of authenticity to allow the display of historical color films in a guise that no one could have ever seen in the analog era.

## 1. INTRODUCTION

What new applications do current digital tools provide us with in the field of film restoration and with which ethical considerations are these connected? In the framework of the *FilmColors* project at the University of Zurich, financed by an ERC Advanced Grant, we investigate new approaches that help bridge the gap between the aesthetics of analog color film processes and their transfer into digital form(at)s. The present paper reports three cases that leave open some room for interpretation on how the ethical principles of film preservation can be followed.

On the research platform *Timeline of Historical FilmColors*, created by Prof. Dr. Barbara Flückiger, we classify the film color processes into two big functional groups: applied film colors (e.g. toning, tinting, stencil coloring) and mimetic processes (e.g. screen processes, chromolytic multilayer, chromogenic monopak) [1]. Whereas the colors of the first category were added to the silver image on the film strip after its development, the color image in the second category is produced by chemical or optical

principles through additive or subtractive color mixing during processing or screening of the films. Mimetic processes aim to match human color perception to reproduce the colors that we see around us. The color film stocks and the technical equipment used for this purpose should enable this reproduction as its primary objective.

The manufacturing process of every single analog color film technology is shaped by a number of consecutive steps: In order to obtain a tinted or toned monochromatic color image on the screen, first you have to print the developed black and white negative to a black and white positive and then immerse it in a dye bath (tinting) or replacing the silver with metallic compounds (toning). In the case of the chromogenic monopak, the filmmakers and cameramen were relying on a highly complex color film technology, but with the most effort executed in the film laboratories. They had to guarantee the correct processing of the camera negative and subsequently choose the adequate printing lights for the final positives. All of these intermediate or simultaneous steps while printing or projecting the analog film strips were necessary for the final colorful images.

With the introduction and the expanding application of elaborate digital tools in film restoration we are able to implement new strategies in otherwise established and critically discussed workflows [2-4]. In contrast to mechanical or photochemical methods, we can perform multiple digital methods at the work stage of the so-called color grading. By combining different approaches and interdisciplinary knowledge in the realm of digital restoration and digital humanities we obtain a result from a kind of—as we are suggesting here—‘cyber-digitization’. In the following, we present three cases in which we bypassed traditional routes in film restoration and which now call for ethical reconsiderations. The first example 1.) *The Effect of Light Sources on Toned Images* explores the interrelationship between the illumination geometry and the color appearance of a tinted and toned nitrate print. The color image of the Kodacolor film presented in 2.) *Reproducing the Colors of Lenticular Film* was imitated with the help of digital technologies. The concluding example, 3.) *Chromogenic Positive Looks for Digitized Negatives* sheds light on how to combine the aesthetic of a film print with the image structure of its corresponding negative.

## 2. THE EFFECT OF LIGHT SOURCES ON TONED IMAGES

Beside the early mimetic color film processes, applied film colors were the most widespread film color techniques at the beginning of the 20th century. Metallic toning transforms the silver image in a colored metal-salt compound, while film tinting is the immersion of a positive black-and-white print into a dye that confers a uniform coloration to the gelatin. During the early period of cinema, tinting and toning were popular and often combined together to obtain composite effects [5].

There can be a remarkable color difference between a toned film directly observed with diffuse backlighting and its image projected on screen. In some cases, these discrepancies bothered filmmakers, as documented by the following brief excerpt from a course book: “Many practical methods have been worked out from time to time for the toning of lantern slides and photographic papers. When these are applied to the toning of motion picture film, the toned film obtained in most cases although apparently satisfactory when viewed

in the hand, appears substantially black on projection” [6].



**Figure 1:** Different appearances of a tinted and toned film (“Tänze”, 1920 from the Deutsches Filminstitut - DIF) when projected (top) and when observed in diffuse illumination (bottom).

We provided a scientific explanation to this kind of color discrepancy in a forthcoming publication [7].

In the example reported in Fig. 1 the very diverse color shift between the dancers and their background radically alters the chromatic composition. It is fair to speculate that the film strip was toned in blue with the intention to obtain a blue background. As a result there is a conflict between aesthetic intention and appearance in the cinema projection.

In the code of ethics of film digitization, the contemporary intentions and circumstances play an important role in guiding the actions of archivists and conservators [8]. Therefore, even though the colors in the top half of Fig. 1 represent the proper reference to reproduce the image as it was seen on cinema screens, choosing as reference the colors of the bottom half can have some solid justification, as it conveys the appearance as originally intended. In this regard, it is important to consider that film scanners use diffuse illumination and, therefore, are prone to render the chromatic composition of the lower half-image of Fig. 1 [7].

## 2. REPRODUCING THE COLORS OF LENTICULAR FILM

During the first half of the twentieth century, besides multiple subtractive color film processes, several additive inventions for motion picture films were developed. Kodak and Agfa implemented the principles of the *lenticular screen* process in 16 mm motion picture products (marketed as *Kodacolor* and *Agfacolor* respectively), which were used by amateur filmmakers mostly during the 1930s. In a lenticular film the plastic support is embossed with a vertical array of cylindrical lenses [9]. Images were captured with a tripartite red-green-blue filter in front of the camera lens cooperating with the embossed lenticules. After exposure, reversal processing created positive silver-based images with spatially-encoded color information (see Fig. 3-b).



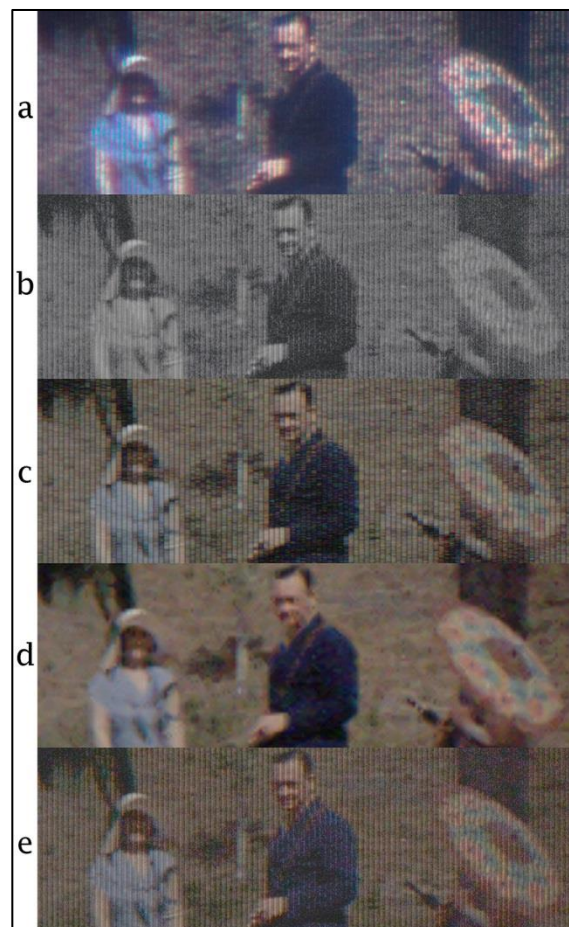
**Figure 2:** Filter used by Kodacolor projectors to display lenticular film.

In the original technique, the filmmakers needed a special projector equipped with a filter similar to the one used during image capture (Fig. 2) to display the captured colors. The resulting projected image was rather small and dim, so the movies could be only presented in small spaces to a limited number of spectators. The difficulties in obtaining enough screen brightness are documented in an investigation undertaken by the Kodak Research Laboratories [10].

Digital technologies provide a new possibility to screen movies shot on lenticular film. A high-resolution scan of a lenticular film produces a detailed reproduction of the silver image. In the framework of the *doLCE* project [11], software has been written to extract the encoded color from the scan. The software localizes the vertical pattern of lenticules, extracts from each lenticule the digital numbers of the side-by-side silver densities corresponding to the red, green and blue components. The way the extracted information is translated into color, and the way the color is combined with the image brightness to build up the final image file can be accomplished following a variety of

different approaches. These lead to very different visual results, both in terms of colors and image structure.

The ideas and results from the *doLCE* project are now further elaborated under the auspices of the *FilmColors* research project. By developing and evaluating different transcode methods, comparing their resulting images with the image projected with the original historical equipment the team establishes a scientifically proven approach. To this end, the lens assembly and color filter of the historical projector have been used to focus color images of lenticular film directly on a color CMOS sensor (Fig. 3-a).



**Figure 3:** Frame detail of a lenticular film belonging to the collection of the Lichtspiel / Kinemathek Bern. Direct projection on color digital sensor (a), scan of silver emulsion (b) carried out by the FilmColors team. Three different color reconstructions from the scan (c, d and e) conducted by Joakim Reuteler.

The digital replica of a lenticular film is supposed to reproduce the visual impression provided by the original analog projection equipment. It is however possible to compute color images that retain the detail of the silver

grain from the original digital scan (e.g. the transcode in Fig. 3-e). These images have sufficient resolution to be displayed on a big screen with adequate brightness. Such a digital screening actually distorts the original representation of the lenticular film and does not adhere to ethical principles of film digitization.

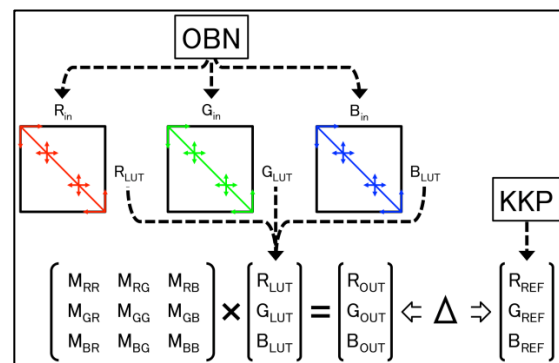
### 3. CHROMOGENIC POSITIVE LOOKS FOR DIGITIZED NEGATIVES

After the introduction of the chromogenic film processes, film production companies started creating several film elements for each cinematic work in color. In the second half of the 20th century, from the original camera negative to the final exhibition print, a couple of duplication processes were necessary, which inevitably entailed some image degradation. Only the projection print contains the final result of the color grading and is therefore the best reference to digitally recreate the contemporary aesthetics. Still, in film preservation practice it is common to scan the negative and correct the colors to match the print. In case the projection print is missing or drastically faded, scanning the camera negative or another film element (e.g. inter-positives, rush prints) is the only viable option. However, the appeal of higher sharpness and better preserved details in darks and highlights can persuade film restorers to scan the negative even when a well-preserved print is available.

In the framework of the research projects ERC Advanced Grant *FilmColors* and SNF *Film Colors. Technologies, Cultures, Institutions* we are carrying out an extensive case study in cooperation with the *DEFA Foundation* that is interested in merging the different aesthetic characteristics of chromogenic negatives and positives [12]. For this purpose, we digitized three different source materials of the short musical film *Das Film-Magazin Nr. 4, Teil 2 – Lea aus dem Süden* (GDR 1963, Gottfried Kolditz): the original camera negative (OBN), one intermediate negative (IMN) and one combined projection print (KKP). The chromogenic color film stock used for the negative and positive items is Agfacolor from the East German production plant in Wolfen. Two different sorts of negative materials were

used: an unmasked Agfacolor B negative for daylight illumination and a supposedly silver masked Agfacolor G negative balanced for Tungsten light [13].

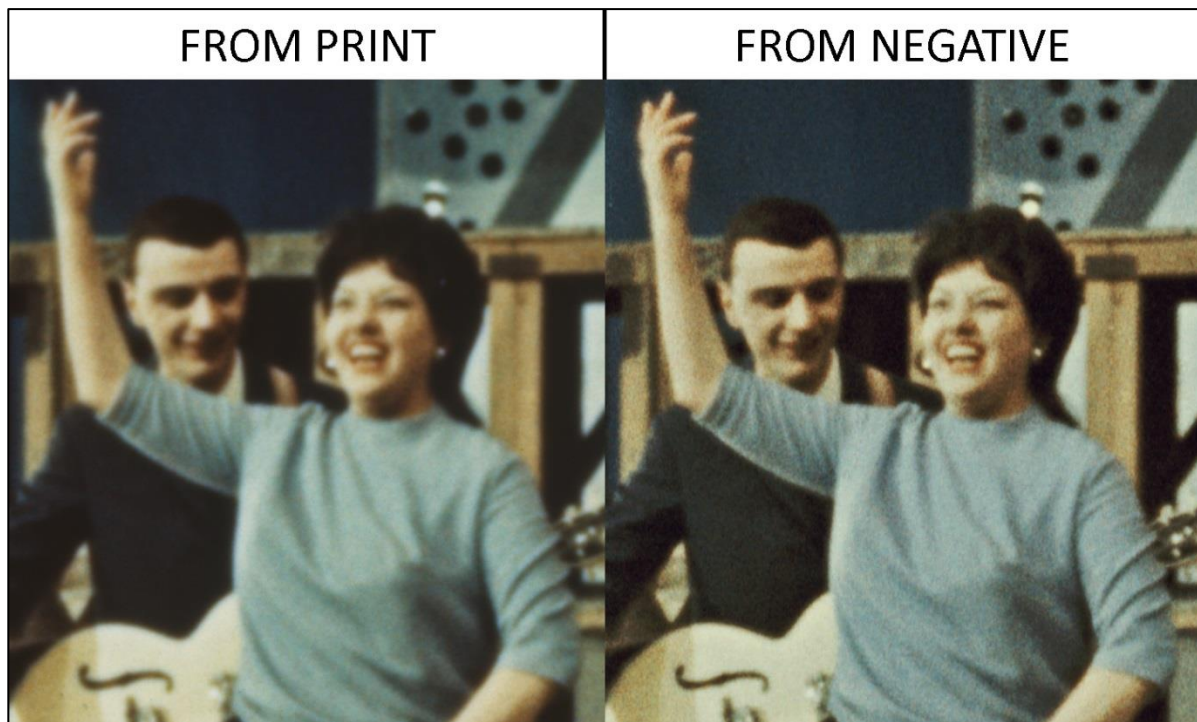
To automatize the color correction process that matches the scan of a negative to the colors of its print, we developed a specialized image processing routine. The *LUTgenerator* takes the RGB images from the negative and from the print as input, and outputs a 3D-LUT that minimizes their color difference. A prior feature-based image registration [14] is necessary for a pixel-to-pixel comparison. The digital image of the negative is processed with four structures: three 1D-LUTs (one for each color channel) and a 3-by-3 matrix that adjusts color saturation (see Fig. 4).



**Figure 4:** Constituent structures of the 3D-LUT: three 1D-LUTs and a 3-by-3 matrix ( $M$ ). The input values ( $R_{in}$ ,  $G_{in}$  and  $B_{in}$ ) are first processed by the 1D-LUTs, and then multiplied by the matrix. The *LUTgenerator* routine minimizes the difference  $\Delta$  between the output values and the reference values.

Each 1D-LUT is a curve defined by its black value (one variable), its white value (one variable) and two midpoints that can move up/down and left/right (two variables each). The total number of variables is eighteen for the 1D-LUTs, plus nine for the matrix. The routine finds the optimal values for the twenty-seven variables though a multistep minimization process based on the Nelder–Mead simplex algorithm [15]. The resulting four structures are “enclosed” in a  $33^3$  sized 3D-LUT and saved as a .cube file [16]. All professional color grading applications recognize this file format and can easily apply the 3D-LUT to the film scan.





**Figure 5:** Frame details of *Das Film-Magazin Nr. 4, Teil 2 - Lea aus dem Süden* (GDR 1963, G. Kolditz) from digital scan of the print and from digital scan of the negative (color corrected to match the print).

The LUTgenerator routine was run on the scans of the film material of *Lea aus dem Süden* (OBN and KKP). The example in Fig. 5 reports a detail of the resulting images of a frame. The image on the left reproduces the film appearance as it was supposedly seen by the audience in analog cinemas, so it is the ethically justified image. The image on the right, however, is definitely sharper and has more elements in the darks (see for instance the blazer of the guitarist and the singer's hair). This raises the question if it is 'ethically wrong' to retain these image features if they were not seen in cinema projection at the time of its circulation?

### 3. CONCLUSION

In this paper, we presented selected film restoration methods for which digital tools were used in ethically challenging ways. Considering three different color film technologies, we showed in what ways the demonstrated approaches have an impact on the visual characteristics of the digitized results: changing the original geometry of illumination and hence the hue of toned films, reconstructing the colors of lenticular films with a higher resolution and increased brightness, and finally generating a hybrid between an Agfacolor negative and positive material. These 'cyber-digitizations' adapt to the contemporary aesthetic preferences and

have the potential to reach a bigger audience, fulfilling one of the fundamental missions of a film digitization, namely to make the film heritage visible again. With this knowledge in mind, we invite archivists and researchers to engage critically in the following up debates.

### 4. ACKNOWLEDGMENT

We would like to thank the Deutsches Filminstitut - DIF, the Lichtspiel / Kinemathek Bern, the Bundesarchiv-Filmarchiv and the DEFA Foundation for providing the film material. Furthermore, a warm thank you to Joakim Reuteler, David Pfluger and all the members of the FilmColors team.

This project has received funding from the European Research Council (ERC) under the European Union's Horizon 2020 research and innovation programme, grant agreement No 670446 FilmColors.

### 5. REFERENCES

- [1] Flueckiger, B. (2018): *Timeline of Historical Film Colors*, Available from: <http://zauberklang.ch/filmcolors/> (20 October 2018).
- [2] Wallmüller, J.: Criteria for the Use of Digital Technology in Moving Image Restoration. *The Moving Image*, vol. 7, no. 1, pp. 78–91, 2007;

- [3] Fossati, G.: Obsolescence and Film Restoration. The Case of Colored Silent Films. In: Breuil, H. and Dazord, C. (eds), *Conserver l'art contemporain à l'ère de l'obsolescence technologique*, TECHNE Centre de recherche et de restauration des musées de France, Paris, pp. 102–106, 2013;
- [4] Flueckiger, B.; Op den Kamp, C.; Pfluger, D.: A Material-Based Approach to the Digitization of Early Film Colours. In: Fossati, G. et al. (eds), *The Colour Fantastic. Chromatic Worlds of Silent Cinema*. Amsterdam University Press, Amsterdam, pp. 237–259, 2018.
- [5] Read, P.: “Unnatural Colours”. An Introduction to Colouring Techniques in Silent Era Movies. *Film History*, vol. 21, no. 1, pp. 9–46, 2009.
- [6] Gregory, C. L.: Tinting and toning motion picture films. In: Gregory, C. L. (eds), *A Condensed Course in Motion Picture Photography*, New York Inst. of Photography, New York, pp. 177–198, 1920, p. 177.
- [7] Trumpy, G. and Flueckiger, B.: Chromatic Callier effect and its repercussions on the digitization of early film colors. *Journal of Imaging Science and Technology*, vol. 63, no. 1, 2019 (in press).
- [8] FIAF (2008): Code of Ethics, Available from: [https://www.fiafnet.org/imag-es/tinyUpload/Community/Vision/FIAF\\_Code-of-Ethics\\_2009.pdf](https://www.fiafnet.org/imag-es/tinyUpload/Community/Vision/FIAF_Code-of-Ethics_2009.pdf) (20 October 2018).
- [9] Weil, F.: The Optical-Photographic Principles of the Agfacolor Process. *Journal of the Society of Motion Picture Engineers*, vol. 20, no. 4, pp. 301–308, 1933.
- [10] Capstaff, J. G.; Miller, O. E. and Wilder, L. S.: The Projection of Lenticular Color-Films. *Journal of the Society of Motion Picture Engineers*, vol. 28, no. 2, pp. 123–135, 1937.
- [11] Reuteler, J. and Gschwind, R.: Die Farben des Riffelfilms. Digitale Farbrekonstruktion von Linsenrasterfilm. *Rundbrief Fotografie*, vol. 21, no. 1/2, pp. 37–41, 2014.
- [12] Diecke, J. (2018): Retracing the Film Material History of the German Democratic Republic, Available from: <https://filmcolors.org/2018/05/04/defa/> (20 October 2018).
- [13] Zeh, W.; Clever, A.; Watter, O.: Das Silbermasken-Einentwicklungsverfahren für den Agfacolor-Kinenegativfilm. In: Filmfabrik Agfa Wolfen (eds), *Veröffentlichungen der wissenschaftlichen Photo-Laboratorien Agfa. Band 8*. S. Hirzel Verlag, Leipzig, pp. 89–101, 1954.
- [14] Bay, H.; Ess, A.; Tuytelaars, T. and Gool, L. V.: Speeded-up robust features (SURF). *Comput. Vis. Image Underst.*, vol. 110, pp. 346–359, 2008.
- [15] Lagarias, J. C.; Reeds, J. A.; Wright, M. H. and Wright, P. E.: Convergence properties of the Nelder-Mead simplex method in low dimensions, *SIAM J. Optim.*, vol. 9, pp. 112–147, 1998.
- [16] Selan, J.: Using lookup tables to accelerate color transformations, in Chapter 24: GPU Gems 2: Programming Techniques for High-Performance Graphics and General-Purpose Computation, edited by M. Pharr (Pearson Education, Upper Saddle River, NJ, USA, 2005).