“DIGITAL DESMET”

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Translating Early Applied Colors

Despite advances in the digitization of archival films, the translation of early applied colors into the digital domain has remained a critical issue for many reasons. Among the objectives of the Swiss project DIASTOR[1] was the development of new approaches for the digitization and restoration of film colors, employing scientific analysis in conjunction with film historical research and software development. The project's research areas pertained to early applied colors and their digitization, including the aesthetic and historiographic consequences of the technical processes involved. Based on an early film example from the 1910s, this article presents several areas of that particular focus, which resonate with contemporary archival debates.

The aim of this article is to contextualize the translation of historic aesthetic objects to the digital domain on several levels:

- to raise awareness of the film materials' origin and of the interrelated network of technological as well as institutional frameworks affecting the digitization process
- to point out the potentials, as well as the contingencies, when dealing with digital technologies within workflows[2]
- to highlight the potential role of research to mediate between disciplines, such as computer science, engineering, physical chemistry, film history and aesthetics, restoration ethics, and philological principles

An exhaustive documentation of all the factors at work in the historiographic process of transferring early films to the digital realm is impossible. Nonetheless, the awareness of certain specific factors that originate in digital technologies, as well as in the heterogeneous interdisciplinarity of the fields involved, can help to point out the importance of and the need for more open documentation and communication.

By highlighting the concrete setup of our approach, as well as by documenting the contingencies in experimenting with "Digital Desmet," we have combined philological requirements with a critical reflection on our workflow options and decisions. Our study does not focus on a deep exploration of the relationship of Digital Desmet to the history and evolution of the analog Desmet method for transferring early cinema to chromogenic[3] safety stock.[4] It rather discusses the translation of the ideas behind the analog method and the digital principles involved as a method. It also focuses on the attempts to remodel this method for digital workflows in analogy to a set of principal requirements for a universal "recipe." Issues of the technology of scanning, as evidenced by the scanner tests developed within the DIASTOR framework, and its epistemological underpinnings are brought to bear on a wider set of questions on how evolving technologies shape the aesthetics and interpretation of filmic source material. By describing the specific archival pragmatics active within the setup of testing Digital Desmet, the article documents and contextualizes the shift that digital technologies introduce into the archival practice when translating applied colors into the digital realm.

A critical attitude toward primary and secondary sources is fundamental to many academic disciplines—especially those with historical aspects. In film studies, and film history in particular, in which archival films can be used for film historical research and, consequently, film historiography, an understanding of the film archive as

a storage place for filmic sources is paramount. Source material and its use have thus been fundamental topics in film historiography.[5] Evolving technologies, including film scanning, shape the aesthetics and interpretation of filmic source material, and practices within archives and laboratories can be seen as co-constructive to that process. This article investigates the impact that digital technologies have on the interrelation of a multitude of players in the field—archives, post-houses, research in film history, and science. Their interactions will here be termed *archival pragmatics,* which we explore in more detail in the penultimate section of this article.

CONTINGENCIES IN SCANNING APPLIED COLORS

To understand the principles and problems of digitizing and restoring applied colors, it was necessary to investigate the basic elements that shape and influence the scanning process. Digitization is not an equivalent of the analog duplication process but rather a fundamentally different process whereby color values are extracted from an analog print and translated into a binary code. As elaborated elsewhere,[6] digitization is by its very nature a process of reduction whereby material properties of historical films are encoded into mathematical values by a specified protocol. Scanning as a technology and practice is connected to the context of the procedure, the physical and mechanical constraints of the scanner itself, the parameters set by an operator based on her experience, the interface of the scanner, and, last but not least, the quantification that assigns binary numbers to analog electrical signals. Scanning is thus highly dependent on all of these influencing factors. Many of these factors have to be regarded as "black box operations," because they are either unknown or unspecified entities.

As a consequence, one of the most crucial guiding principles for the investigation and application of scanning follows from its unstable and contingent nature: *every scan is a reading under certain conditions.* In other words, scanning is not a transparent practice but a transformation process that is crucial for the final results. It is therefore necessary to analyze the particular conditions, both on the level of the scanning apparatus and on the level of the practices in a given postproduction facility. During DIASTOR's scanner tests, it became clear that the human factor is crucial for the outcomes obtained. The educational background and practical experience of scanner operators have a significant influence on the settings they apply, and these settings are situated in a web of technical and economic constraints as well as in curatorial decisions and practical goals, such as the purpose of the digitization.[7] Likewise, scanner operators are required to comply with a facility's color management pipeline and its practices of color grading.

Technologies and applications are profoundly shaped by contemporary practices. As Giovanna Fossati observes,

> film restoration practice is intimately connected to that of filmmaking and post production as they resort to the same techniques and are often carried out by the same professionals. Most film restoration laboratories, for example, are traditionally the same ones where new films are produced and processed.[8]

While the technical details of individual scanners are omitted from this article generally, they were a central topic of DIASTOR's scanner tests.[9] A "test" implies an act of trial in which one tries to gather clarity about a practice within specific frameworks. Connected to a test are specific requirements for the results, in contrast to an experiment, in which the outcomes remain completely open.

Fundamental insights were gained from these tests that focused on the material–scanner interaction, including the human factor mentioned earlier. The testing comprised eight different film materials, among them a 35mm blue-tinted nitrate film. Several tested scanners had great difficulty with capturing the color; some were entirely "color-blind" and produced black-and-white representations of the blue-tinted images, underlining Paul Read's findings that "some dyes are outside the range of the recording system."[10] These effects are connected to the physical properties of film scanners that capture the three additive primaries red, green, and blue, often with narrow-band light sources or with white lights connected to narrow-band filters. Such an illumination setup was initially developed for the scanning of modern chromogenic negative stock in the digital intermediate (DI) process. Therefore nonstandard materials—for instance, any film material that has different properties from relatively recent chromogenic negatives[11]—may contain color information that lies outside of the range of the scanning device.[12]

Although the DI process was a commercially interesting area of application, the scanning of archival material is far from being an economically viable business model for scanner manufacturers to invest in specific further developments. Moreover, historical film colors were produced by highly diverse and heterogeneous types of technical approaches.[13] Paul Read has collected a great number of dyes and color compounds that were used in tinting and toning early film.[14] Each of these applied colors has its own spectral characteristics that may or may not match the scanner's physical setup.

Consequently, we should abandon altogether the notion of scanning as a reproduction of historical film colors. The general aim is not to reproduce the colors as they would appear on the screen in projection but to gather the color information present

in the film material. Most current digital systems of color representation characterize this information not only by a defined range of tones but also by limiting values for the black levels and the representation of white, sometimes including super-white.[15] All the information outside of this range—defined by the color space and called a system's *color gamut*—is by definition not available in the system and is lost in the process.

DIASTOR has thus established an *information-versus-appearance model* whereby scanning is understood as the gathering of as much color information as possible. This model complies with restoration ethics requirements for reversibility, because it delivers the most comprehensive digital representation possible of an analog film element. In the next section, we discuss different methods to capture comprehensive information in scanning.

In a second step, this information has to be transferred to the intended appearance by a transfer function. Several questions arise within this concept. In regard to the emulation of color appearance, the question of color reference and its possible transfer to a raw scan remains one of the most pressing topics. In a recent article in *The Moving Image,*[16] we presented the color analysis for the digital restoration of *Das Cabinet des Dr. Caligari* (Robert Wiene, 1920), which describes a calibrated method for documenting color appearance in a well-defined and standardized manner. Several aspects of this process remain open for discussion, such as the light sources applied, which greatly influence the look of the colors.[17] In contrast to the widespread practice of visual comparison of the historical film on a bench or on a light panel with the digital representation on the screen before or during color grading, this process produces much more stable results that are also compliant with restoration ethics requirements for documentation and transparency.

It should be noted that establishing a color reference is far from a solely technical process. There is seldom only one reference but rather a multitude. Sometimes there are several material versions of the same film in archives: different prints on varying film stocks or with individual color schemes. Therefore the variety of material and aesthetic objects requires the exploration of extrafilmic sources to understand their history. The necessary metadata are not always well documented. Especially in the case of early cinema, we rarely have access to the surviving material objects' provenance.

In accordance with the "archival pragmatics" that we'll explore, several sources and types of research are required from the "actors" involved, including archivists, film historians, lab technicians, and scientific researchers with knowledge in optics, chemistry, and digital image processing. Archivists have crucial knowledge about materials and all the available elements of the film. Their extended experience with historical films

Figure 1. Comparing the scanned image, *left,* to the reference photograph, *right,* in the color grading suite. Photograph by Barbara Flueckiger. Color image available in the electronic version of *The Moving Image,* accessible via JSTOR.

provides the foundation for their curatorial decisions in film restoration.

In DIASTOR, we have established a three-pillar approach to connect information pertaining to color reference(s) based on these different sets of knowledge:

1. photographic documentation plus analysis of dyes or color compounds
2. research into stability and decay models of dyes and color compounds
3. film historical and aesthetic analyses, and study of written historical sources

To contextualize color appearance historically, we must understand each cinematic artwork as located at the intersection of two lines. One vector represents the synchronic[18] dimension: the period style at a certain time, for instance, the early 1910s. The other represents the diachronic dimension: the style of a production company, a

filmmaker, or a cinematographer.[19] In addition, the material aesthetics can be identified by the study of a group of films that were shot on a certain film stock or by a certain technical process of capturing, developing, and/or screening. By material aesthetics, we understand aesthetic effects that immediately can be connected to material properties of a capturing device, the developed film stock, or its actualization on a specific optical apparatus during screening.[20] Ideally, it should be possible to transfer this knowledge into a photographic representation of a filmic source material once research has confirmed that this element is indeed representative of the relevant historical aesthetics.

When both a raw scan containing a maximum of information and the color reference (the target image, containing the values for appearance) are present in the same digital medium, screened by the same digital projection with one defined light source and in one defined viewing condition, many unnecessary parameters are eliminated from the comparison. In split-screen projection, the final product of the color grading can be checked instantaneously against the color reference, both by visual inspection and by measuring RGB values. Therefore a final result is secured that complies with two requirements of restoration ethics, namely, transparency and documentation.

The information-versus-appearance model not only is a robust approach to transfer color values onto the information gathered in scanning but also provides an approach to combine different source materials into one final element, such as a black-and-white negative and several tinted positives. Based on film historical and scientific analyses, two DIASTOR partners—the Federal Institute of Technology in Zurich and Disney Research Zurich—have developed software for the semiautomatic transfer of color appearance onto a raw scan with a feature-based approach.[21]

TESTING "DIGITAL DESMET"

Based on the nitrate film *Aan de kust van Istrie* (On Istria's coast, circa 1910) with applied colors (tinting only) made available by EYE Filmmuseum, this section of the article addresses the question of the relationship of Digital Desmet to the analog Desmet method. The basic concepts behind the analog method were investigated to establish whether the digital method is merely a simulation of the analog method or whether other, additional opportunities have become available in attempting to remodel the analog method for a digital workflow.

Through their preservation and access strategies, film archives can be seen to actively co-shape a particular focus in film scholarship. As EYE senior curator Mark-Paul Meyer illustrates,[22] the reevaluation of color in early cinema through new restoration

Figure 2. Three different "stages" of *Aan de kust van Istrie* during its digitization process. Scanned images by Haghefilm Digitaal (NL). Color image available in the electronic version of *The Moving Image,* accessible via JSTOR.

techniques, for instance, can be seen as a classic example, because a renewed focus on color helped shape a new conception of early cinema. This was emphasized by filmmaker and former Nederlands Filmmuseum deputy director Peter Delpeut in his keynote presentation at the Colour Fantastic Conference in Amsterdam in March 2015.

Traditionally, two ways of reconstructing applied colors in the analog era can be discerned.[23] One method is duplication through color internegative film. The nitrate source material, a positive print with applied colors, is copied onto a color internegative, while attempting to capture as many details of that print as possible. The color internegative is then printed onto a color positive on modern stock. All the color fluctuations that exist in the source material, such as stains and unevenness caused by storage, fading, and projector lights, are in some form still visible in the end result after copying.

The alternative to this method is duplication through the Desmet method, named after Noël Desmet, who first devised the method at the Cinémathèque Royale de Belgique in Brussels. The nitrate positive is duplicated onto black-and-white negative film that is panchromatic—that is, sensitive to all colors—so that as much information as possible is captured. In contrast to the previous method, the colors are brought back in at a later stage when the negative is printed to a color positive on modern stock and when the particular color is flashed onto the film for tinting.

The analog Desmet method was devised for several reasons. First, it was cheaper than using color internegatives. Second, as a safety element, the black-and-white intermediate is chemically more stable. Third, and arguably most important, it was possible to eliminate some of the fluctuations, stains, and unevenness mentioned earlier. In the early to mid-1990s, the Desmet method became best practice for reproducing films with tinting and toning.

The difference between the two methods can be seen as the difference between capturing a film element at the moment of reproduction and attempting to eliminate color fluctuations—in other words, between maintaining a film's current appearance and attempting to restore a hypothetical initial state. Whereas the first approach respects

an artwork's age value *(Alterswert)* as defined by Alois Riegl,[24] the second approach takes the risk of damaging a film's integrity by searching for its hypothetical authentic appearance.[25] Based on the three-pillar model presented in the previous section, these decisions must rely on a thorough investigation and be documented in a transparent way.

In the framework of DIASTOR, it was decided to test the difference between scanning the source material in color and scanning it in black and white, tracking the underlying difference between the analog methods mentioned previously.[26] Color film scanners assign the captured information to red/green/blue channels (RGB). With the guidance of a histogram as a statistical representation of the color distribution in these three channels, a color scan can be controlled to avoid any clipping. The color information can be kept and enhanced in grading based on the color reference(s), which can be seen as linked to the idea of reproducing the nitrate source material on a color internegative. This method will only be possible with certain applied dyes, as some tints will be outside the scanner's spectral sensitivity, as noted earlier.

Alternatively, a black-and-white image can be created in the postproduction stage from the color information obtained during scanning. The colors are brought back in at a later stage during color grading. This approach offers the benefit of a primary color correction on the black-and-white underlying "layer" only and a secondary color correction, which addresses the color "on top" separately. Accordingly, this method can be seen as an equivalent of the idea of capturing the information of the source material in a black-and-white "intermediate" and bringing the color back in at a later stage in color grading, just as the analog Desmet method was devised to do.

A surprising outcome of the initial research was that, irrespective of the starting information (within reason), the postproduction environment offers such vast possibilities that it is more or less possible to approximate the results in color grading. For a film archive, however, it is not only the ultimate visual representation that is important. The initial digital representation needs to be taken into account as well, alongside the steps from the digital to the visual representation, to respond to changing technologies in the future, including potential alternative methods of preservation.

Additionally, several ways of scanning the source material in black and white were explored. Theoretically, a black-and-white image can be obtained by using only one of the three available channels in a film scanner. However, the richer information obtained by scanning all three channels is almost always preferable in practice. Only digital means open up this option, which has no analog equivalent. For example, an analog Desmet-method black-and-white duplicate negative is traditionally never made with information from one color channel only.

In collaboration with Markus Mastaller from ARRI's facility in Munich, we explored a way to treat the three channels separately. Each channel was optimized and leveled individually, independently of the others, for a better acquisition of comprehensive information. The ARRISCAN is specifically able to tweak the separate color channels in the database that controls the capturing device. An immediate consequence of this method is that the "intermediate" element for long-term storage is in black and white, just as in the analog Desmet method. It is of vital importance to keep the color information's metadata for future reference—a need that exists when scanning in color as well. As this method is time consuming, it is usually not the preferred method in a practical postproduction environment. A quick calculation led to the conclusion that the scanning process takes between three and six times longer while working on the three channels separately as opposed to the three of them fused into one. Also, tampering with the settings on a deep level of the scanner does not come without risks, so working with experienced operating staff is of great importance.

There are several notable instances in which the digital environment and the idea of being able to operate in separate layers during scanning have significantly opened up intervention possibilities. One example is *clipping,* a situation in which the density of one of the channels is not within the tonal range of the selected color space and bit depth, so it would therefore make sense to go into the color channels separately. Another example would be local *discoloration* in certain image areas. It is possible to eliminate discoloration by addressing the color channels separately, as discoloration often shows up only in one of the channels. When the color channels are captured collectively, eliminating local fading or discoloration becomes more difficult and requires software intervention, often associated with the risk of producing unwanted artifacts.

In summary, two main strategies were devised for what could be developed into a "recipe" for a Digital Desmet method. The first was a color scan, made black and white in postproduction with the color information brought back later during color grading, irrespective of what the preferred choice of color reference was. The second, termed "Digital Desmet Plus" for current lack of a better term, would entail a black-and-white scan that is leveled out at the stage of scanning as opposed to postproduction and that, in testing within the framework of the DIASTOR project, has produced more flexible and versatile results. It is important to note that the intended visual representation is particularly culturally and historically contingent (as elaborated in the previous section in regard to the concept of appearance) and that the capturing of digital information needs to be performed at the highest quality possible to preserve future options. Therefore the sustainability of these results depends on many other issues, such as

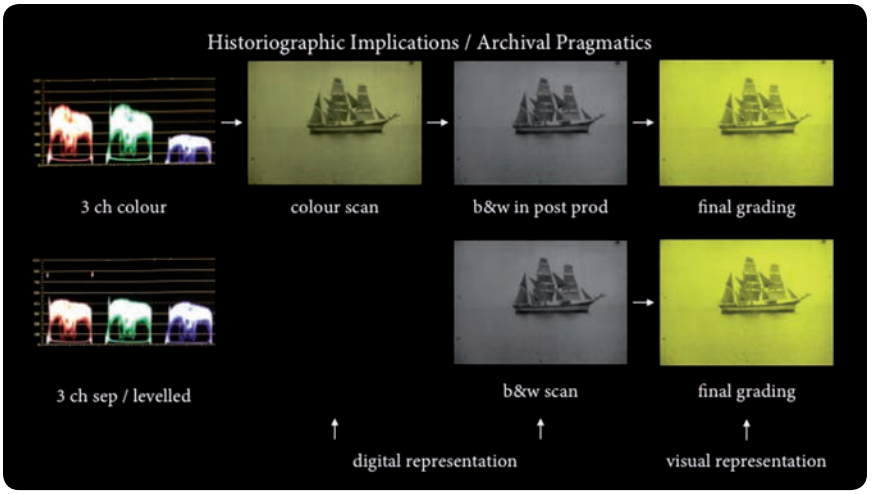

Figure 3. A visual impression of two main strategies for a potential Digital Desmet "recipe." Scanned images by Haghefilm Digitaal (NL) and Cinegrell postproduction (CH). Color image available in the electronic version of *The Moving Image,* accessible via JSTOR.

long-term preservation, metadata, and time and financial resources. All of these factors will play a role in choosing specific options within a given framework.

"ARCHIVAL PRAGMATICS" WITHIN DIASTOR

Paolo Cherchi Usai argues that in "many respects, the evolution of specialized research on early cinema is intertwined with the history of film preservation itself."[27] In this section, in view of our research interest in DIASTOR to study the impact of digital technologies on preservation and restoration workflows, especially when transferring early film colors into the digital realm, we conceptualize a framework that we call *archival pragmatics*. Throughout this article, *archival* has been understood as an interconnected network of different players active in the field of film preservation with diverse—sometimes opposing—interests and constraints framing operations and decisions. It is those internal and interrelated operations within this network that are termed "archival pragmatics," building on previous scholars' work.[28] We then connect the concept to the practices, interests, and constraints within a postproduction house, its technology, and its culture.

The original linguistic concept of pragmatics directs the focus of interest—in a general sense—to the functional context in which an (aesthetic) object develops meaning.[29] The object is defined by the modes of use and intentions of the producer and, at the same time, by the expectations and the interests of the recipient. The pragmatic perspective does not understand the meaning of an aesthetic object as given but

specifically includes the expectations and the intentions of its user. The meaning of an object originates in the function it fulfills with respect to the intentions of the producer. Simultaneously, it also develops meaning in regard to the expectations of the user through its use and effect in specific situations. The concept is useful to describe the different aspects involved when historical films as objects are translated into the digital realm. The approach includes the specific circumstances, technological frameworks, and interests of the digitization project in question.

The basic principles of pragmatics were adapted to film theory and analysis by Roger Odin[30] and to research in film history by Frank Kessler.[31] Kessler particularly has emphasized the importance of the pragmatic approach for the "effect" of digital images.[32] As digital images do not necessarily have an indexical relationship to the profilmic, Kessler highlights the heightened role of the viewer, who constructs the *enunciator* of the digital image, which in turn defines what the image shows. In terms of archival pragmatics, one could argue that the different expectations and intentions of the interconnected players in the field (plus the technology involved) and the defined digital "target images" (defined as being an image representing an "archival" image) shape the aesthetics of the digital reproduction of a historic film.

Our approach builds on Fossati's concept of understanding every restoration as connected to a new *dispositif*—that is, the technological and cultural environment of its reenactment and presentation—with specific frameworks that shape the decision-making processes and thus also the final digital representation. We are applying this expanded perspective, the historiographic dispositif, when we place the setup of scanner tests developed within the DIASTOR framework in their broader contexts. With this article, we thus seek to establish transparency and documentation, which are some of the most basic underpinnings in restoration ethics.[33] The work of labs in particular is often overlooked and not sufficiently documented for a broader public in terms of access to information about individual workflow steps. Various reasons may contribute to this nondisclosure; one of the trickiest is that we often deal with businesses for which know-how means commercial advantage. There are other reasons as well, especially when it comes to digital workflows in which the deeper algorithmic functioning, for example, of software tools, is not easily accessible to archivists or restorers.[34]

In our Digital Desmet scanner tests, we are identifying specific contingencies. It is crucial to understand the impact of the digital turn on the tools and workflows, as when Fossati cites Peter Parker's uncle in Sam Raimi's *Spider-Man* (2002): "With great power comes great responsibility."[35] When using digital software for film restoration, the restorer is charged with a greater responsibility than in the analog era, as new digital tools offer more choices with respect to the extent of intervention.

Cherchi Usai illustrates the impact of a film lab's work on the restoration process as well as its role for the reception of the material and pleads for more transparency:

> This is precisely the hidden face of film preservation: the name of the archive appears prominently . . . on the main credits of the restored film, while the organization technically responsible for it receives scant mention, if at all. To declare that a film available for viewing comes from a given archive is not enough; insofar as it wishes to make the preservation path fully transparent to the viewer, a collecting institution should acknowledge that film restoration is also a product of an expertise which expresses itself in the technical facility where the duplication work has been carried out.[36]

This enlarged role of the film lab should be addressed with more standardized processes of documentation and transparency. We seek to do so by describing the frameworks within specific labs. At the same time, we acknowledge the remaining impediment that it may not be in the interest of the lab to share all its choices and limiting constraints, because it acts in a competitive, commercial environment where a specific kind of expertise can be of economic value.

In practice, and as a consequence, the film historian needs to have awareness of the economic, technological, institutional, cultural, and aesthetic *filters* that affect the results from digitization. Building on established principles of restoration ethics, a historian should document all the aspects that lead to the specific appearance of the object of study, reflect on the contingencies in the analysis, or adapt the research questions of digitized source material.

CONCLUSION

The Digital Desmet research within the scope of DIASTOR has shown that so far the concept has been defined only vaguely as a digital emulation of an approach developed in the analog domain. However, every workflow is affected by a post-house's technical infrastructure and hardware and software limitations as well as by the scanner operator's and color grader's educational backgrounds and professional experience. Post-houses have their own color management pipeline that defines scanning approaches—exposure, resolution, geometry—and file formats, such as bit depth, tone mapping, and color space.

Digital technologies are also shifting and redefining the relationship and interaction of archives with labs and film scholars who work with the results of restoration. As outlined in our Digital Desmet tests, we must consider the information-versus-

appearance model to investigate and analyze digitally restored films. Ideally, there are several fields of interaction: the source material, including its analysis and documentation; the technical specs of the lab environment; the traditions and human interactions applied; the procedural properties of the workflow evolving in time; and the curatorial decisions made by the film restorer.

Basic and applied research as elaborated within the DIASTOR project, in which researchers from different disciplinary fields interacted to connect knowledge from film history, material analyses, and IT solutions in an autonomous academic space, is crucial for the development of model approaches, here termed "recipes." Specific case studies such as the scanner and Digital Desmet testing of early applied colors are not only located in the interconnected web of conditions and decision-making processes that we define as *archival pragmatics* but also illustrate real-world constraints to scientific investigation. Specific decisions in the digital workflow redefine and reframe the specific aesthetics of the historical source material.

In consequence, constant mutation and evolution call for a critical attitude of film historians, including a heightened awareness of the material properties of the object of study. Exposing the historicity of our studies is paramount when dealing with a fast-changing technological environment with a dearth of standards and documented workflows, which is perhaps especially true in regard to early film colors.

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David Pfluger has a doctorate in physical chemistry and was a senior researcher in the DIASTOR project. He brought to the team his background in physical chemistry and cinema postproduction and a particular knowledge of the Swiss archiving landscape. He works as a consultant for archives, and he has been a member of the Video and Film expert network of Memoriav since 2005.

NOTES

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1. DIASTOR (2013–15) was supported by a grant from the Swiss Commission for Technology and Innovation (CTI) and carried out applied research in collaboration with academic institutions and private companies. See the DIASTOR Research Project at http://www.diastor.ch/.
2. For the interaction of technology and social structure, see Giovanna Fossati, *From Grain to Pixel: The Archival Life of Film in Transition* (Amsterdam: Amsterdam University Press, 2009), applying the sociological SCOT (Social Construction of Technology) theory to film restoration.
3. In chromogenic film, the color-forming substances are either present in several layers in the emulsion or added during film developing later. The basic principle was discovered in 1911 by Rudolf Fischer. Unfortunately, the dyes used in these processes proved to be unstable, thus leading to color fading of the films. See "Timeline of Historical Film Colors," http://zauberklang.ch/filmcolors/cat/chromogenic-monopack/.
4. Paolo Cherchi Usai, "The Color of Nitrate: Some Factual Observations on Tinting and Toning Manuals for Silent Films," in *Silent Film,* ed. Richard Abel, 21–30 (New Brunswick, N.J.: Rutgers University Press, 1996); Paul Read and Mark-Paul Meyer, eds., *Restoration of Motion Picture Film* (Oxford: Butterworth-Heinemann, 2000); Annike Kross, "Die Simulation von Filmfärbungen und -tonungen nach dem sogenannten Desmet Verfahren. Beschreibung und Analyse des Verfahrens und seine Anwendung an Beispielen aus der Sammlung des Nederlands Filmmuseums" (MA thesis, Fachhochschule für Technik und Wirtschaft Berlin, 2006); Ulrich Ruedel, "Dye Tinting in Film Restoration: *Das Rätsel von Bangalor,*" *The Reel Thing,* 28th ed. (AMIA Conference, Austin, Tex., 2011); Ulrich Ruedel and Kieron Webb, "Silent Colour Film Restoration: From Dyes and Grains to Digital," in *Proceedings, AIC Congress* (Newcastle-upon-Tyne, U.K., 2013).
5. Robert Allen and Douglas Gomery, *Film History: Theory and Practice* (New York: Newbery Award Records/Albert A. Knopf, 1985); Frank Kessler, "Filmgeschichte und Filmkopien," *Kinoschriften 5,* 199–209 (Vienna: Verband der Wissenschaftlichen Gesellschaften Österreichs, 2002).
6. Barbara Flueckiger, *Visual Effects. Filmbilder aus dem Computer* (Marburg: Schüren, 2008); Barbara Flueckiger, "Material Properties of Historical Film in the Digital Age," *Necsus* 1, no. 2 (2012), http://www.necsus-ejms.org/material-properties-of-historical-film-in-the-digital-age/.
7. See also Martin Koerber, "Who Are These New Archivists?," in *Works in Progress: Digital Film Restoration within Archives,* ed. Kerstin Parth, Oliver Hanley, and Thomas Ballhausen, 43–50 (Vienna: SYNEMA, 2013).
8. Giovanna Fossati, "Obsolescence and Film Restoration: The Case of Colored Silent Films," in *Conserver l'art contemporain à l'ère de l'obsolescence technologique,* ed. Cécile Dazord and Marie-Hélène Breuil (Paris: TECHNE Centre de recherche et de restauration des musées de France, 2013), 103.
9. The DIASTOR scanner tests were performed using eight samples of film stock: blue-tinted BW nitrate (35mm), Technicolor (35mm), Dufay Colour (35mm), Kodachrome (16mm), Ektachrome (16mm), a (Kodak) faded print (16mm), BW reversal (16mm), and a CRI negative (16mm). Tests were conducted on eight scanners, most of them in the high-end segment: Altra mk3

by Sondor, Switzerland; ARRISCAN by ARRI, Germany; D-Archiver by CIR, Italy; Director by Lasergraphics, United States; Golden Eye by Digital Vision, Sweden; Kinetta by Kinetta, United States; Northlight by Filmlight, United Kingdom; and Scanity by DTF, Germany.

10. Paul Read, "'Unnatural Colors,' An Introduction to Colouring Techniques in Silent Era Movies," *Film History* 21, no. 1 (2009): 27.

11. In DIASTOR's study of early Agfacolor for the restoration of *Opfergang* and *Immensee* by the Friedrich Wilhelm Murnau Stiftung, similar problems for these chromogenic stocks were identified.

12. See also Giorgio Trumpy and Barbara Flueckiger, "Light Source Criteria for Digitizing Color Films," in *Proceedings of the Colour and Visual Computing Symposium* (Gjøvik, Norway: IEEE, 2015).

13. See http://zauberklang.ch/filmcolors/.

14. Read, "Unnatural Colors."

15. Wide-gamut and super-wide-gamut systems such as ACES (Academy Color Encoding System) and high-dynamic-range imaging have been developed in recent years and will require new methodologies for capturing and screening devices such as scanners and displays. See https://www.smpte.org/sites/default/files/ACES%20-%20G.%20Joblove%20-%20SMPTE%20Montreal,%20NFB%20-%202013-05-28%20-%20prot.pdf. At present, these do not solve the basic problems outlined here.

16. Barbara Flueckiger, "Color Analysis for the Digital Restoration of *Das Cabinet des Dr. Caligari*," *The Moving Image* 15, no. 1 (2015): 22–43.

17. Ibid.

18. The term *synchronic* denotes a cross-section of a group of films during a defined, narrow period, whereas *diachronic* encompasses a longitudinal development in time.

19. As proposed by David Bordwell, "Historical Poetics of Cinema," *Georgia State Literary Studies* 3 (1989): 369–98.

20. The systematic exploration of the material–aesthetics relationship for large groups of films captured on a wide range of film stocks will be the topic of the research project "ERC Advanced Grant Film Colors." See abstract in the research database of the University of Zurich at http://www.research-projects.uzh.ch/p21207.htm.

21. Simone Croci, Tunç Aydın, Nikolce Stefanoski, Markus Gross, and Aljosha Smolic, *Advanced Tools and Framework for Digital Film Restoration* (unpublished report, 2015).

22. Mark-Paul Meyer, "Authenticiteit en fotografische materialiteit," in *Zorgen voor onzichtbare assets. Over het behoud van digitale AV-collecties,* ed. Annemieke de Jong, 95–108 (Hilversum: Beeld en Geluid, 2011).

23. Paul Read and Mark-Paul Meyer, eds., *Restoration of Motion Picture Film* (Oxford: Butterworth-Heinemann, 2000), 287–90, 295–97; Kross, "Die Simulation von Filmfärbungen."

24. Alois Riegl, *Der moderne Denkmalkultus. Sein Wesen und seine Entstehung* (Vienna: W. Braumüller, 1903).

25. Anna Bohn, *Denkmal Film. Band I. Der Film als Kulturerbe. Band II: Kulturlexikon Filmerbe,* vol. 2 (Vienna: Böhlau, 2013), 251.

26. All research in this case study pertains to the ARRISCAN, used with the same film material at two different facilities: Haghefilm Digitaal in Amsterdam, Netherlands, and Cinegrell postproduction in Zurich, Switzerland.
27. Paolo Cherchi Usai, "Early Films in the Age of Content; or, 'Cinema of Attractions' Pursued by Digital Means," in *A Companion to Early Cinema,* ed. André Gaudreault, Nicolas Dulac, and Santiago Hidalgo, 1024–68, 1636 (Chichester, U.K.: Wiley-Blackwell, 2012).
28. Fossati, *From Grain to Pixel*; Cherchi Usai, "Early Films in the Age of Content"; Rossella Catanese, *Lacune binarie. Il restauro dei film e le tecnologie digitali* (Rome: Bulzoni, 2013); Bohn, *Denkmal Film.*
29. Ludwig Wittgenstein, *Philosophische Untersuchungen* [Philosophical investigations] (Oxford: Blackwell, 1953); John L. Austin, *How to Do Things with Words* (Oxford: Oxford University Press, 1962); John Searle, *Speech Acts* (Cambridge: Cambridge University Press, 1970); Jacques Aumont and Michel Marie, eds., *Dictionnaire théorique et critique du cinéma,* 2nd rev. ed. (Paris: Armand Colin, 2008), 198; Winfried Noeth, *Handbuch der Semiotik,* 2nd rev. ed. (Weimar, Germany: J. B. Metzler, 2000), 155–58.
30. Roger Odin, "Dokumentarischer Film-dokumentarisierende Lektüre," in *Sprung im Spiegel,* ed. Christa Blümlinger, 125–46 (Vienna: Sonderzahl, 1990).
31. Frank Kessler, "Filmgeschichte und Filmkopien" and "Historische Pragmatik," *Montage/AV,* November 2, 2002, 104–12.
32. Frank Kessler, "What You Get Is What You See: Digital Images and the Claim on the Real," in *Digital Material,* ed. Marianne Boomen (Amsterdam: Amsterdam University Press, 2009), 192.
33. Bohn, *Denkmal Film.*
34. Julia Wallmüller, *Kriterien für die digitale Laufbildbearbeitung in der Restaurierung* (Saarbrücken, Germany: Dr. Müller, 2008).
35. Fossati, *From Grain to Pixel,* 92.
36. Cherchi Usai, "Early Films in the Age of Content."