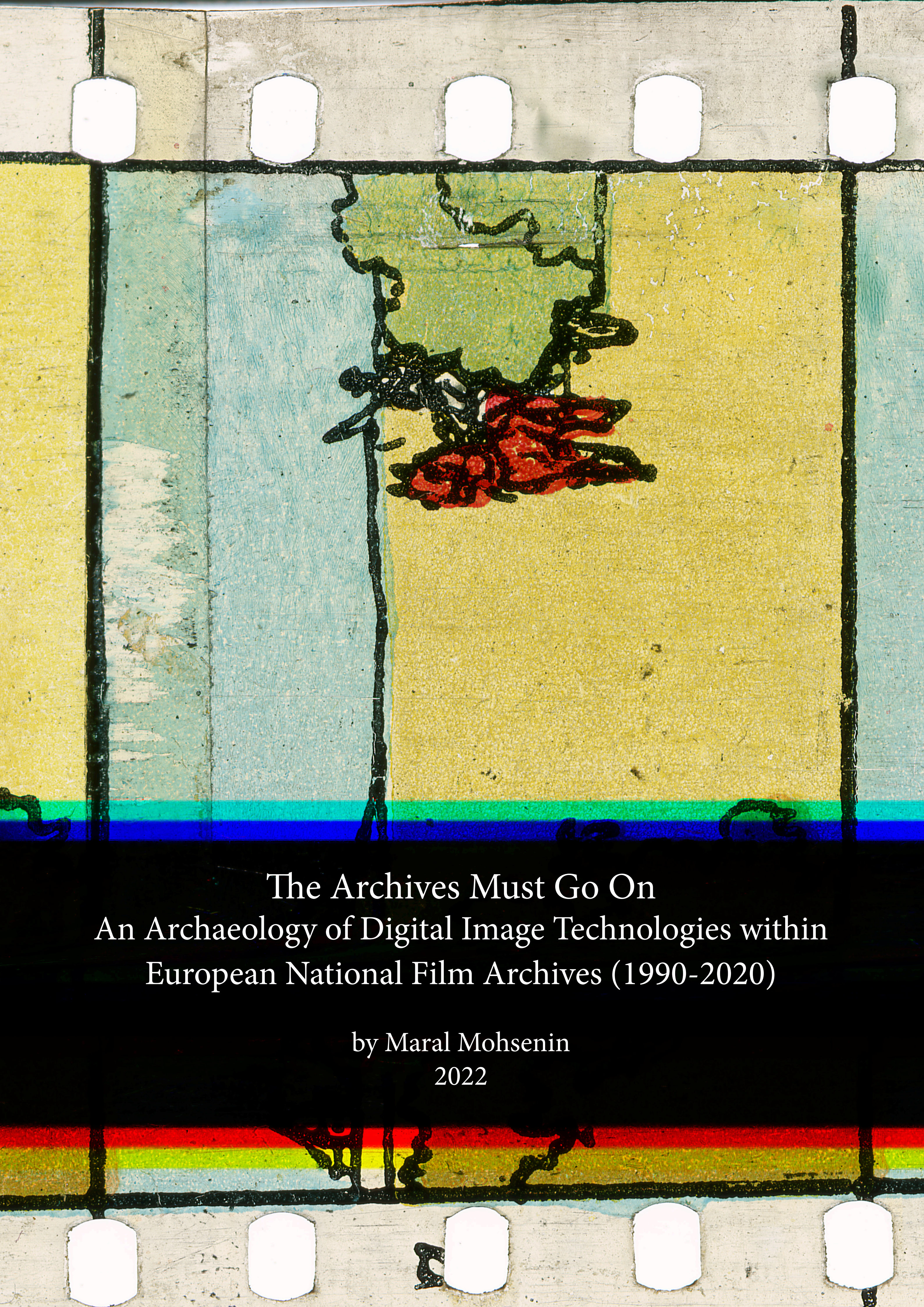
Year : 2022

The Archives Must Go On: An Archaeology of Digital Image Technologies within European National Film Archives (1990-2020)

Mohsenin Maral



The Archives Must Go On

An Archaeology of Digital Image Technologies within European National Film Archives (1990-2020)

by Maral Mohsenin

2022

UNIL | Université de Lausanne
Faculté des lettres

FACULTÉ DES LETTRES

SECTION D'HISTOIRE ET ESTHETIQUE DU CINEMA

The Archives Must Go On: An Archaeology of Digital Image Technologies within European National Film Archives (1990-2020)

THÈSE DE DOCTORAT

présentée à la

Faculté des lettres
de l'Université de Lausanne

pour l'obtention du grade de
Docteur ès lettres

par

Maral Mohsenin

Co-directeurs de thèse

Benoît Turquety (Université de Lausanne)
Giovanna Fossati (Université d'Amsterdam)

UNIL | Université de Lausanne
Faculté des lettres

IMPRIMATUR

Le Décanat de la Faculté des lettres, sur le rapport d'une commission composée de :

Directeurs de thèse :

Monsieur	Benoît Turquety	Professeur, Faculté des lettres, UNIL
Madame	Giovanna Fossati	Professeure, Universiteit van Amsterdam, Pays-Bas

Membres du jury :

Madame	Maria Tortajada	Professeure, Faculté des lettres, UNIL
Madame	Julia Noordegraaf	Professeure, Universiteit van Amsterdam, Pays-Bas
Madame	Sabine Süsstrunk	Professeure, École Polytechnique Fédérale de Lausanne
Madame	Annie van den Oever	Professeure, Rijksuniversiteit Groningen, Pays-Bas
Madame	Sonia Campanini	Dr., Goethe-Universität Frankfurt am Main, Allemagne
Monsieur	Trond Lundemo	Professeur, Stockholms universitet, Suède

autorise l'impression de la thèse de doctorat de

MADAME MARAL MOHSENIN

intitulée

The Archives Must Go On :
An Archaeology of Digital Image Technologies within European National Film Archives (1990-2020)

sans se prononcer sur les opinions du candidat / de la candidate.

La Faculté des lettres, conformément à son règlement, ne décerne aucune mention.

Lausanne, le 23.11.2022

Léonard Burnand
Doyen de la Faculté des lettres

The Archives Must Go On: An Archaeology of Digital Image Technologies within European National Film Archives (1990-2020)

ACADEMISCH PROEFSCHRIFT

ter verkrijging van de graad van doctor
aan de Universiteit van Amsterdam
op gezag van de Rector Magnificus
prof. dr. ir. P.P.C.C. Verbeek
ten overstaan van een door het College voor Promoties ingestelde commissie,
in het openbaar te verdedigen in de Agnietenkapel
op vrijdag 7 oktober 2022, te 16.00 uur

door Maral Mohsenin
geboren te Teheran

Promotiecommissie

Promotores:	prof. dr. G. Fossati	Universiteit van Amsterdam
	prof. dr. B. Turquety	Université de Lausanne
Overige leden:	prof. dr. J.J. Noordegraaf	Universiteit van Amsterdam
	prof. dr. M. Tortajada	Université de Lausanne
	prof. dr. S. Süsstrunk	École polytechnique fédérale de Lausanne
	prof. dr. A.M.A. van den Oever	Rijksuniversiteit Groningen
	dr. S. Campanini	Goethe Universität Frankfurt am Main
	dr. T. Lundemo	Stockholms Universitet

Faculteit der Geesteswetenschappen

This thesis was prepared within the partnership between the University of Amsterdam and University of Lausanne with the purpose of obtaining a joint doctorate degree. The thesis was prepared in the Faculty of Humanities at the University of Amsterdam and in the Faculty of Arts at the University of Lausanne.

Dit proefschrift is tot stand gekomen binnen een samenwerkingsverband tussen de Universiteit van Amsterdam en de Université de Lausanne met als doel het behalen van een gezamenlijk doctoraat. Het proefschrift is voorbereid in de Faculteit der Geesteswetenschappen van de Universiteit van Amsterdam en de Faculté des lettres van Université de Lausanne

The research for this doctoral thesis received financial assistance from Swissuniversities (*cotutelle de thèse* Scholarship) and the AIHR (Finishing PhD Fellowship) in University of Amsterdam.

Acknowledgements

My six-year PhD adventure comes to an end with this thesis; an achievement which would not have been realised if it were not for the help and support of so many people around me. Hoping not to forget anyone, hereby I express my gratitude to all of them.

First and foremost, my deepest gratitude to my two professors, Giovanna Fossati and Benoît Turquety, who have helped me develop and shape this thesis, influenced my academic and professional career, and supported me intellectually and personally throughout this journey. Thank you for always motivating me, for never pressuring me, and for believing in me even when I didn't believe in myself. I could never have wished for better supervisors; and consider myself so lucky to have been trained by the best.
My sincere thanks to the members of the Lausanne Jury: professors Laurent Le Forestier, Simone Venturini and Alessandro Rizzi. Your comments and recommendations helped me see my thesis under a new light and improve it at its very late stages. I am delighted to have had this great opportunity to discuss with you and learn from you.
Many thanks also to the members of the Amsterdam Jury for doing me the honour of reading my work: professors Maria Tortajada (merci pour tout, Maria!), Sabine Süsstrunk, Julia Noordegraaf, Annie van den Oever, Sonia Campanini, Trond Lundemo. Your work has been a great influence on mine, and your careers a source of inspiration and admiration for me.

Most heartfelt thanks to my friends, colleagues and fellow PhD candidates at the University of Lausanne: Valentine Robert, Stéphane Tralongo, Coralie Lamotte, Alexandra Schmidt, Adèle Morerod, Achilleas Papakonstantis and the others. Thank you for sharing the pains and joys of PhD with me, for the discussions, for proofreading parts of my thesis, for your support, and of course, for being amazing friends.
Special thanks to the great Carine Bernasconi, whose own thesis inspired the structure of mine. Your friendship and support since I first arrived in Lausanne have been crucial in my academic path but also in my personal life. Thank you for all the lively discussions, the joyous exchange, the laughs, and for sharing your passion for cinema, festivals and Iran with me.
Finally, all my gratitude goes to my two musketeers, Isabel Krek and Jeanne Rohner: I don't even know how I would have managed the day-to-day PhD life without you two. Thank you for listening to me, motivating me, giving me ideas, and for the "Projets & rêveries"!

It has been a very enriching experience to be part of the Moving Image Research Group at the University of Amsterdam, and I thank its members for the discussions, help and inspiration, especially Christian Olesen Gosvig, Eef Masson, Floris Paalman and Mark-Paul Meyer. My deep gratitude also to ASCA, most importantly for the PhD finishing grant.

All my thanks to Bronwyn Birdsall for carefully proofreading my thesis, and making my English proper!

My most sincere thanks to my friends and colleagues from the archival community: Gerdien Smit, Anne Gant, Camille Blot-Wellens, Jon Wengström, Jeanne Pommeau, Cassandre Marie Valfort, Alessandra Luciano, Christophe Dupin, Céline Ruivo, Walter Swagemakers, Ernst van Velzen, Per Legelius, Elena Tammaccaro, Caterina Palpacelli, Alessia Navantieri, Arianna Turci, Michal Bregant, Catherine Cormon, Thiago Ganhao, Sofia Pires, Julia Mettenleiter, Claudio Ricci, Heinz Schweizer, Jean-Baptiste Perrin, Nicole Tatjana Allemann, Andrea Haller, Martin Körber, Daniel Meiller, Stefan Drössler, Nikolaus Wostry, Anna Dobringer, Oliver Hanley, Ulrich Ruedel, and many others. Thank you very much for having accepted me as a part of the same community that I study in my thesis and for sharing your knowledge, experience and viewpoints with me.

Further thanks are due to Marie Frappat, Georg Thallinger, Rudolf Gschwind, Benoît Michel, Siegfried Foessel for giving me access to precious documents and for the generosity in sharing their experience. Special thanks to Renato Berta, Fredi M. Murer and Claude Champion for teaching me so much on cinema and film.

During the years that I spent preparing my PhD, the support from my colleagues at the Cinémathèque suisse has been instrumental. Thank you, notably, to Frédéric Maire, Carine Soleilhavoup, Aline Houriet, Caroline Neeser, Daniel Campoverde, Sophie Pujol, Marco Marchetti and Paolo Bernardini. All my thanks also to my ex-colleagues and friends : Tatiana Berseth, Nicolas Wittwer, Michel Dind, Maud Kissling (ma vie aurait été beaucoup moins drôle sans ta présence lumineuse), Anna Percival (heureusement que tu existes, Anna!), Richard Szotyori (une grande joie de partager ma cinephilie avec toi).
Finally, most heartfelt thanks to …
… Caroline Fournier for having taught me so much, protected me, supported me, believed in me, and given me a chance in the beginning of my career. I am proud to have learnt from you, and prouder to be friends with you.
… Nicolas Ricordel and Isabel Da Silva. Your arrival at the Cinémathèque changed the course of this thesis, and that of my life. Thank you for answering my naïve technical questions, finding me sources, for your genuine interest in my research, and for our friendship that I cherish so.
… Ariane Baudat for your generous help, your comments on my work, your cheerfulness, but also for being my swimming and partying buddy – I am so lucky to have known you.
… and Maryline Monnerat for being a friend, a sister and even at times a mother to me. You and Hervé are the closest I have to family in Switzerland. I can't imagine how my life would have been without your kindness, continuous caring and tender presence.

I would also like to thank deeply my friends and colleagues at the Geneva International Film Festival (GIFF), who have made Geneva my second home for the past 8 years, provided me with the opportunity to nourish my love for cinema and television without being concerned with archives for once, and helped me experience so many amazing moments. All my gratitude goes to Nathalie Gregoletto for her infallible trust, her continuous support and her precious friendship (qu'est-ce que j'aurais fait sans toi, Nath?), and to Emmanuel Cuénod for having made a programmer out of the young, motivated intern that I was. Shout out to Paola Gazzani Marinelli, Julia Schubiger, Mona Journo and Gaëlle Vidalie for all that we have lived through together. And finally, to Anaïs Emery: thank you for your trust and understanding, and for inspiring me by your brightness; it has been amazing to know you, work with you and spend time with you.

Cheers and love to my friends: Raffaele Storni (for always being by my side), Ali Bahmanpour and Raha Rajaei (for giving me the best of my faraway land that I missed so), Saharnaz Sarlak (for 20+ years of true friendship), Justine Duay (for being the strongest woman I know and always pushing me to be stronger), Isotta Regazzoni (for all the fun and the films), Claudine Follonier (for the beautiful moments spent together), Kaveh Azadeh (for the generous help).
I would never have made it to here without the unconditional love and support from my family: my grandmothers, aunts, uncles and cousins, who are my rays of sunshine in life. You have filled my life with happiness and light. Last but not least, all my thanks to…
… my uncle Kamyar (and Nastaran joon) for having initiated the love of cinema in me.
… my sister Hasti and my best friend Maryam Razeghian; for being my sources of joy and wellbeing, for loving me and supporting me despite everything, for laughing and crying with me, for walking beside me throughout the PhD and life. And Hasti joon, thank you for not having finished your PhD before your big sister!
… and above all, my parents Iman and Kambiz: words cannot describe how grateful and delighted I am to have you in my life. You are my everything. This thesis, like anything else that I do in life, is dedicated to you.

Summary

The Archives Must Go On.

An Archaeology of Digital Images Technologies within European National Film Archives (1990-2020)

By Maral Mohsenin

In 2012, film projection went digital, leading to widespread reactions to the claimed death of film and the beginning of a new era for cinema. However, that was not the first time that European national film archives came across digital image technologies. In this dissertation, I sweep through the thirty-year period between 1990 and 2020, in order to propose a comprehensive history of archival encounters with digital image technologies from an archaeological point of view. Through an intertwined coverage of archival discourses and technologies (as well as the sciences behind them), I analyse the patterns of technological development, adoption, adaptation or rejection during what can be theorised as a permanent socio-technical transition. I argue that these processes contributed to the shaping of imaginaries which in turn changed archival practices and discourses. On the one hand, they changed the way archives perceived and theorised digital image technologies, their potentials and their limits. On the other, they adapted the technologies to what corresponded more efficiently – albeit not thoroughly – to archival views and needs. Furthermore, I also claim that there is not one digital technology but many different ones, conceived through their own socio-technical culture, and refined towards specific goals.

I identify different periods, during which the archival community has been successively, and in different ways, concerned with digital image technologies. In the 1990s, digital image manipulation technologies were finding their way through the archival field, while the archival imaginary, confronted with these, developed theoretical discourses in close entanglement with the development of digital restoration machines and software (Chapter One). A polarised imaginary was formed from early on within archives, which simultaneously questioned the digital possibilities and threats. This dialectical discourse network was reinforced during the second period, between 2004 to 2011, where archives were faced with the perspective of an upcoming digital future although unable to predict how it would turn out (Chapter Two). The uncertainties prevailing during this time shook the very notions of film and film archives, leading to a dialectical categorisation and comparison of technologies in the form of grain vs.

pixel. When, in 2012, the digital future materialised amid the generalisation of digital projection, film archives, equipped with a considerable theoretical and technical body of knowledge, needed to face first the new projection technologies (Chapter Three), then the consequences of the new, hybrid, landscape of cinema, comprised of film, analogue and digital technologies (Chapter Four). Again, the archival imaginary would undergo modifications and adaptations; moving from a polarised state to a more hybrid one, where multiple technologies and discourses could co-exist. Instead of a film vs. digital approach, an ensemble of technologies, socio-culturally and historically constructed, conjugated to their specific context of use, has redrawn the archival landscape.

By crossing archival discourses with industrial and scientific ones, I integrate the technical details of (digital) image technologies within the study of film archives, a direction which has never been explored before. This novel research direction enables me to provide a comprehensive technological history of film archives.

Keywords: European national film archives, film preservation, image technologies, digital transition, digitisation, episteme and techne, discourse analysis, image science

Résumé

Les archives doivent continuer.

Une archéologie des technologies numériques de l'image au sein des archives nationales du film européennes (1990-2020)

Par Maral Mohsenin

En 2012, la projection cinématographique est devenue numérique, entraînant de nombreuses réactions sur la mort annoncée du film et le début d'une nouvelle ère pour le cinéma. Cependant, ce n'était pas la première fois que les archives cinématographiques nationales européennes se confrontaient aux technologies de l'image numérique. Dans ma recherche, je parcours la période entre 1990 et 2020, afin de proposer une histoire complète des rencontres des archives avec les technologies numériques de l'image, d'un point de vue archéologique. À travers une couverture entrecroisée des discours et des technologies archivistiques (ainsi que des sciences qui les sous-tendent), j'analyse les modèles de développement technologique, d'adoption, d'adaptation ou de rejet au cours de ce qui pourrait être théorisé comme une transition socio-technique permanente. J'argumente que ces processus ont contribué à façonner des imaginaires, qui ont à leur tour modifié les pratiques et les discours archivistiques. D'une part, ils ont changé la façon dont les archives ont perçu et théorisé les technologies numériques de l'image, leurs potentiels et leurs limites. D'autre part, ils ont adapté les technologies à ce qui correspondait plus efficacement - bien que pas entièrement - aux vues et aux besoins des archives. En outre, j'affirme également qu'il n'existe pas une seule technologie numérique, mais de nombreuses technologies différentes, conçues à travers leur propre culture socio-technique et affinées en fonction d'objectifs spécifiques.

J'identifie différentes périodes, au cours desquelles la communauté archivistique s'est successivement, mais de manières différenciées, préoccupée des technologies numériques de l'image. Dans les années 1990, les technologies numériques de manipulation des images ont fait leur chemin dans le domaine des archives, en même temps que l'imaginaire archivistique, confronté à ces technologies, a développé des discours théoriques en étroite relation avec le développement des machines et des logiciels de restauration numérique (chapitre 1). Un imaginaire polarisé s'est formé très tôt au sein des archives, qui interrogeait simultanément les possibilités et les menaces du numérique. Ce réseau de discours dialectique s'est renforcé au cours de la deuxième période, entre 2004 et 2011, lorsque les archives ont été confrontées à la perspective d’un avenir numérique, sans pour autant pouvoir en prédire la tournure (chapitre 2). Les incertitudes régnant à cette époque ont ébranlé les notions mêmes de film et d’archives de film, conduisant à une catégorisation dialectique des technologies sous la forme de grain contre pixel. Lorsque, en 2012, l’avenir numérique s’est matérialisé par la généralisation de la projection numérique, les archives cinématographiques, dotées d’un corpus considérable de connaissances théoriques et techniques, ont dû faire face d’abord aux nouvelles technologies de projection (chapitre 3), puis aux conséquences du nouveau paysage hybride du cinéma, composé de technologies filmiques, analogiques et numériques (chapitre 4). Au lieu d’une approche film vs numérique, un ensemble de technologies, socioculturellement et historiquement construites, conjuguées à leur contexte d’utilisation spécifique, a redessiné le paysage des archives.

En croisant les discours des archives avec les discours industriels et scientifiques, j’intègre les détails techniques des technologies (numériques) de l’image dans l’étude des archives cinématographiques – une direction qui n’a jamais été explorée auparavant. Cette nouvelle direction de recherche me permet de fournir une histoire technologique approfondie des archives cinématographiques.

Mots-clés : archives nationales européennes de film, préservation de films, technologies de l'image, transition numérique, numérisation, épistème et techne, analyse du discours, sciences de l'image.

Samenvatting

De Archieven moeten verder.

Een Archeologie van Digitale Beeldtechnologieën binnen Europese Nationale Filmarchieven (1990-2020)

door Maral Mohsenin

In 2012 werd overgestapt op digitale filmprojectie, hetgeen leidde tot wijdverspreide reacties ten aanzien van de zogenaamde dood van film en het begin van een nieuw tijdperk voor cinema. Dit was echter niet de eerste keer dat Europese nationale filmarchieven in aanraking kwamen met digitale beeldtechnologieën. In dit proefschrift behandel ik een periode van dertig jaar tussen 1990 en 2020, om vanuit een archeologisch standpunt een uitgebreide geschiedenis te schetsen van de archivale ontmoetingen met digitale beeldtechnologieën. Aan de hand van een verslag dat archiefdiscoursen verweeft met technologieën (alsook de wetenschappen die erachter schuilgaan), analyseer ik de patronen van technologische ontwikkeling, adoptie, aanpassing of verwerping gedurende deze permanente socio-technische transitie. Ik stel dat deze processen hebben bijgedragen aan de vorming van archiefveerbeeldingen die op hun beurt de archiefpraktijken en discoursen hebben veranderd. Aan de ene kant hebben ze de manier veranderd waarop archieven digitale beeldtechnologieën - en hun mogelijkheden en beperkingen - hebben waargenomen en getheoretiseerd. Anderzijds hebben ze de technologieën efficiënter afgestemd op de archivale opvattingen en behoeften, hoewel niet volledig. Verder beweer ik ook dat er niet één digitale technologie bestaat, maar vele verschillende, elk bedacht vanuit hun eigen socio-technische context, en verfijnd met het oog op specifieke doelen.

Ik identificeer verschillende perioden waarin de archiefgemeenschap zich achtereenvolgens en op verschillende manieren heeft beziggehouden met digitale beeldtechnologieën. In de jaren 1990 vonden digitale beeldmanipulatietechnologieën hun weg in het archiefveld, waardoor de archiefveerbeeldingen theoretische discoursen ontwikkelde in nauwe samenhang met de ontwikkeling van digitale restauratiemachines en software (Hoofdstuk Eén). Gepolariseerde archiefveerbeeldingen werd al vroeg gevormd binnen archieven, die tegelijk de digitale mogelijkheden en bedreigingen bevroegen. Dit dialectische discoursnetwerk werd versterkt tijdens de tweede periode, tussen 2004 en 2011, toen archieven geconfronteerd werden met het perspectief van een op handen zijnde digitale toekomst, maar niet konden voorspellen hoe die zou uitpakken (Hoofdstuk Twee). De onzekerheden die in deze periode heersten, deden de

noties van film en filmarchieven op hun grondvesten schudden, wat leidde tot een dialectische categorisering en vergelijking van technologieën in de vorm van korrel vs. pixel. Toen in 2012 de digitale toekomst gestalte kreeg door de veralgemening van digitale projectie, moesten filmarchieven, uitgerust met een aanzienlijk theoretisch en technisch corpus aan kennis, eerst de nieuwe projectietechnologieën het hoofd bieden (Hoofdstuk Drie) en vervolgens de gevolgen van het nieuwe, hybride filmlandschap, bestaande uit film, analoge en digitale technologieën (Hoofdstuk Vier). Wederom zou de archiefverbeeldingen wijzigingen en aanpassingen ondergaan; van een gepolariseerde staat zou zij overgaan in een meer hybride staat, waarin meerdere technologieën en discoursen naast elkaar kunnen bestaan. In plaats van een film versus digitale benadering, heeft een geheel van sociaal-culturele en historisch geconstrueerde technologieën, die gekoppeld zijn aan een specifieke gebruikscontext, het archieflandschap hervormd.

Door de archiefdiscoursen te kruisen met industriële en wetenschappelijke discoursen, integreer ik de technische details van (digitale) beeldtechnologieën binnen de studie van filmarchieven; een richting die nog nooit eerder is verkend. Deze nieuwe onderzoeksrichting stelt me in staat een uitgebreide technologische geschiedenis van filmarchieven te verschaffen.

Trefwoorden: Europese nationale filmarchieven, filmconservering, beeldtechnologieën, digitale transitie, digitalisering, episteme en techne, discoursanalyse, beeldwetenschap

Table of Contents

Introduction. Theorising a Permanent Socio-Technological Transition in Archives

"The work of an archive is alive, just like the cinema."[1]

Film archives have always functioned within the changing technological landscapes of cinema, where the adoption and generalisation of new technologies have impacted their practices such as restoration or conservation. As the places where cinema and its image technologies are conserved and re-presented, archives have had to adapt to the changes in moving image technologies throughout their history, sometimes participating actively in the technological conceptions, experimentations and adaptations, and sometimes following more passively in the dominant technological paths of the film industry. Resistance to new technologies has always been part of the picture (whether by the film industry or archives), as underlined by scholar Ian Christie:

> "Most of cinema's subsequent technological innovations have initially been deplored or resisted by those seeking to secure the medium's artistic status in the name of 'specificity', even if they have been later accepted and even celebrated as significant stylistic episodes."[2]

Indeed, the acceptance of various technologies has been achieved through numerous debates, trial-and-error, and going back and forth between discourses and practices. Some of the technological changes have received more discursive attention than the others, such as turnover from nitrate to safety film, or competition from television and video imaging, and, of course, the digital turn.

The integration of different digital technologies in archival practices started in the early 1990s and has been going on ever since. An expansive amount of discourses on technological mutations within film archives accompanied the actual adoption, adaptation or rejection of technologies, and described the era as that of digital transition. This dissertation aims to study how image technologies have been integrated into the already diverse landscape of archival

[1] Centre national du cinéma et de l'image animée (CNC), *1969 - 2009. Les Archives françaises du film. Histoire, collections, restauration* (Paris: CNC, 2009), 55.

[2] Ian Christie, 'Digital Frontiers: 2K to 4K and Beyond', in *Exposing the Film Apparatus: The Film Archive as a Research Laboratory*, ed. Giovanna Fossati and Annie van den Oever (Amsterdam: Amsterdam University Press, 2016), 263.

practices during the past thirty years. This period has witnessed film archives rethink their position with regards to technologies, re-defining their old practices, adopting or adapting to new ones, and rejecting others in the process of technological integration. Similar to many other so-called transition moments in archival history, the on-going process has brought archives into a new equilibrium point without ever achieving a definitive static state. Such "living" status of archives, as the first citation above implies, will be illustrated throughout this dissertation.

In the introduction, firstly, I will present the research questions which have motivated this study; secondly, I will situate it in the current landscape of cinema and archival scholarship; then, I will detail my theoretical framework and methodological tools; and finally, I will outline the structure of the thesis in order to provide a brief summary of the upcoming discussions.

1 Establishing the Research Questions: Apprehending a Socio-Technological Transition

During the period going from 1990 to 2020, film archives were faced with a multitude of (digital) image technologies. I describe the dynamic technological landscape within which archives function as permanently in transition, where socio-historical and cultural aspects merge with technical ones. Out of this encounter, emerge rich and polysemic discourses illustrating the interrelations between technologies and archives. In this dissertation, I address three interwoven questions focusing on the patterns of technological adoption, the multiplicity of technologies and the dynamic archival imaginary, as detailed below.

The first question to which I aim to respond is how new image technologies have historically been developed, adopted or adapted within film archives. This question implies a technical and discursive deconstruction of technologies based on their underlying scientific concepts, which set the stage for a better understanding of their function. How, indeed, do technologies, in their socio-cultural diversity, interact with their own scientific basis? How does one get from sciences to technologies? How do these scientific concepts (in different fields of chemistry, mechanics, optics or mathematics) contribute to the cultural adoption of their respective technologies and, vice versa, how are they influenced by the historically-charged cultural context of their adoption? As I will argue, by crossing the cultural and scientific histories of digital technologies in use in film archives, unexplored aspects of the film to digital transition are revealed which complexify the archival and scholarly debates beyond the technophobia and technophilia dialectic. There was no direct need or call from film archives for digital technologies; neither did digital technologies invade film archives, transforming archival practices one after another. Rather, non-linear and mutually-corresponding relationships were established between archives, technologies and sciences which favoured the adoption of certain technologies in lieu of others, responding to an efficiency balance between technical capacities and archival visions and needs.

In order to characterise the technological developments in the field of archives, a second question arises which reflects on how technologies can be categorised and distinguished one from another. Some archivists and scholars consider digital technology as a disruptive novelty whose arrival induced a paradigm change within film archives.[3] Archivist Paolo Cherchi Usai and scholar David N. Rodowick, for instance, have distinguished between film and digital technologies, and identified a technology-driven rupture in cinema and archives.[4] This standpoint would categorise cinema technologies into two main groups of film and digital, corresponding respectively to film or digital eras. Others, such as archivist and scholar Giovanna Fossati, argue for a more inclusive view of film history, which embraces all film or digital technologies as a continuous whole.[5] Attributing a disruptive power to digital technology is reminiscent of a sort of technological determinism which downplays, on the one hand, the constant modifications of film technologies, and on the other, the multiplicity and diversity of digital technologies – as well as their co-existence. Indeed, using the singular word technology for digital assumes that the one and same technology is applied everywhere, which is a partial view of the complexity of technological systems. Technologies carry along with them a rich history rooted in their diverse and culturally-charged scientific basis as much as in their polysemic socio-cultural context of development, adoption and application. Several technologies can be developed to achieve the same goal, through different means and tools. Where does one technology end and another start? I will claim in this dissertation that the image technologies in use in film archives are multiple and diverse; they may co-exist, influence each other, one could be remediated through another,[6] or they may replace each other. I will argue

[3] In the sense proposed by Thomas S. Kuhn, *The Structure of Scientific Revolutions*, 2nd Enlarged (Chicago and London: The University of Chicago Press, 1970). See also the concept of epistemological rupture coined by Gaston Bachelard, *La Formation de l'esprit Scientifique* (Digital Edition by Jean-Marie Tremblay, 2012), http://classiques.uqac.ca/classiques/bachelard_gaston/formation_esprit_scientifique/formation_esprit.pdf. Original text: Gaston Bachelard, *La Formation de l'esprit Scientifique*, 5th ed. (Paris: Librairie philosophique J. VRIN, 1967) [1934].

[4] Paolo Cherchi Usai, *The Death of Cinema. History, Cultural Memory and the Digital Dark Age* (London: British Film Institute, 2001); David N. Rodowick, *The Virtual Life of Film* (Cambridge, MA: Harvard University Press, 2007). See also: Edmond Couchot, *Images: de l'optique au numérique* (Paris: Hermès, 1988).

[5] Giovanna Fossati, *From Grain to Pixel: The Archival Life of Film in Transition*, 1st ed. (Amsterdam: Amsterdam University Press, 2009).

[6] The term remediation is borrowed from: Jay Bolter and Richard Grusin, *Remediation: Understanding New Media* (Cambridge, MA: MIT Press, 1999).

that the plural form of technologies needs to be used in order to englobe their multiplicity and diversity, whether film-based or digital-based (or any other form, for that matter).

Finally, how do film archives change socially and culturally with regards to these technologies? How do they adapt their practices in order to fit into new technological landscapes of cinema, and how do they redefine their own technological frameworks? Bearing the weight of a rich practical and conceptual history, the archival community produces a considerable amount of discourses on its own identity, practices and theories, which, in confrontation with new technologies, undergoes constant evolution, possibly in different directions. By crossing the history of film archives with the history of technologies, I intend to contextualise the debates on digital technologies in relation to the discourses and imaginaries of the archival community. Indeed, I will argue that the archival imaginary is not fixed, nor homogenous, but rather a dynamic, multifaceted entity that interacts with (new) technologies; shaping their adoption and adaptation, while refining its own status.

The Subject of the Research: Image Technologies

As the dissertation title indicates, in this research, I only focus on image technologies for cinema and archives, and I do not enter into discussions about sound or other aspects of cinema. Image, here, is understood in the technical and scientific terms, as an entity that visually represents and depicts an object, a scene, etc. This definition excludes mental or abstract understandings of an image. The cinematographic images come alive when moving, but in this study, in order to study their visual characteristics, I also take into account fixed images which are the source of moving images.[7] Hence, the image I will be talking about throughout my work, is in fact not one simple image, but it is multiple. It can be a material image recorded on a carrier, whether directly visible to the naked human eye (such as an image frame on the photochemical film) or in a primitive form in need of visualisation by a tool before being seen (such as a digital image which is decoded by a computer on a screen or a video image). Or it can be a projected image out of the source material image. While the material image on a photochemical carrier is permanently present, the images visualised on a screen or in projection are ephemeral. Of course, the projected image is also material in the sense that it is created by light and perceived by the human eye through the transfer of light. This perceived materiality is different compared to the materiality of an image on a carrier, as the second exists physically on an object via

[7] Again, images that are not directly related to cinematographic experience are excluded, such as photographs, paintings, etc.

material things (such as silver grains or colour dyes in a photochemical film). When talking about materiality, I refer to this second meaning, unless noted otherwise.

The dissertation will discuss both material and projected image technologies and the relationship between them, as they are both crucial in the archival context. Indeed, contrary to the spectators, who would only come in contact with the projected image, film archives, since their creation, conserved the material source of projection. Over the years, the material image, as an artefact, grew in importance. According to Martin Koerber (Deutsche Kinemathek), the research conducted by Harold Brown (BFI) from the 1960s on, which culminated in the publication of his ground-breaking book on film identification in 1990,[8] represented a "material turn" in film archives, where not only the "information written to the film" but also the material itself were to be taken seriously by archivists.[9] Similarly, Peter Bagrov (George Eastman Museum) has also mentioned that this attention to the material image was precisely what distinguished archivists from others.[10] What is certain is that images, whether as material objects or in projection, are both of interest to archives; while their degree of importance depends on archival tendencies and missions.

My main subject of study in this work is therefore the technologies that produce or reproduce the cinematographic images that film archives conserve or project. In order to study the images and their technologies, the dissertation lingers on image characteristics and concepts such as image quality. The latter, as I will investigate in the first two chapters, is a common term, but with multiple meanings with regards to different technologies. It is defined differently within theoretical (archival and cinematographic) discourses and technical or scientific discourses. In the first case, it does not have a unique definition within archives, nor strictly-defined aspects, but, as I will illustrate in the thesis, it is generally understood and used as a measure of comparison between different image technologies. In the scientific realm, some definitions of the term do exist, but they remain socio-historically variable. In short, image quality is an umbrella term which indicates the image characteristics such as sharpness and resolution (which I will thoroughly define in Chapter Two), and is perceived and understood differently from historical and cultural perspectives. In this dissertation, when I mention image quality, I

---

[8] Harold Brown, *Physical Characteristics of Early Films as Aids to Identification* (Brussels: FIAF, 1990).

[9] Camille Blot-Wellens et al., 'Physical Characteristics of Early Films as Aids to Identification. New, Expanded Edition of Brown's 1990 Book' (Il Cinema Ritrovato, Bologna, 23 July 2021), https://www.youtube.com/watch?v=lKgKhvTmhE8. Martin Koerber wrote the foreword to the book's expanded 2021 edition.

[10] Blot-Wellens et al. Of course, this statement is too general, as some film historians and even broader audiences are also interested in the film artefact. However, I'm citing it here in order to underline the importance of material image in the context of archives.

refer to the technical definition of the term (which is already quite diverse) and not as a measure for cultural or aesthetic judgment of artworks.

On a terminological note, in this dissertation I avoid using the word analogue for film and photochemical technologies, because it originally denoted devices functioning with continuous electrical current, and was notably used to distinguish two types of analogue and digital computers: "In the analog system, voltage or current is varied to represent different quantities in the complicated equations to be solved. In the digital system, all the information is converted into numbers rather than varying voltage or current".[11] The word could then describe video technologies, which indeed register electrical signals on magnetic tapes. It was only applied by extension to film technologies in opposition to digital technologies much later, in the 1990s. The first meaning of analogue, being analogous to something, could apply to any technology of image (re)production, whether film, video or digital. Its second meaning, representation via continuous transmission of information, could technically be applied to no image technology as these always include a sort of sampling (thus discontinuity). Its third and most common meaning, representation through continuous electrical signals, is best applied only to video technologies, as I will do exclusively throughout this thesis.

2 Literature Review: History of Archives Meets History of Technologies

The questions mentioned above call for a theoretical approach which is situated at the crossroads of the history of technologies and the history of film archives. In order to provide a technological history of film archives, this dissertation oscillates between two types of literature:

- Firstly, film archives, which have always been interested in the technological aspects of film, have produced an enormous amount of theoretical and technical studies on technologies in articulation with their pragmatics aspects. The archival output does not solely concern their own practices,[12] but it also contains texts on cinema technologies in general that are conserved by archives,[13] as well as archival histories.

[11] Joseph L. Blotner (RCA), 'This Electronic Memory Device Never Forgets', *Radio Age. Research, Manufacturing, Communications, Broadcasting, Television* 12, no. 4 (October 1953): 12.

[12] Examples: Eileen Bowser and John Kuiper, eds., *A Handbook for Film Archives* (London and New York: Garland Publishing, 1991); Paul Read and Mark-Paul Meyer, eds., *Restoration of Motion Picture Film* (Oxford: Butterworth-Heinemann, 2000).

[13] Such as: Roger Smither and Catherine A. Surowiec, eds., *This Film is Dangerous: A Celebration of Nitrate Film* (Brussels: FIAF, 2002).

- Secondly, the more theoretical axis of the history of technologies, a vast interdisciplinary field, has witnessed a rise in film studies in the past 25 years or so, in line with the development and integration of new technologies (and new media). It has produced relevant theoretical frameworks which prove essential in understanding what kind of relations cinema maintains with technologies.

While the first group of texts mostly constitute the primary sources for my dissertation, the second group has helped me define a theoretical framework which corresponds specifically to my subject of study. The history of technologies in film studies has undergone, as underlined by scholar Santiago Hidalgo, a variety of approaches in "two overlapping orientations": one which concentrates on the "materiality and operation of film technology", and the other which considers technology as a phenomenon creating conceptual and philosophical problems, disregarding the "primacy of machinery and devices".[14] These approaches, of course, are two extremes on a spectrum and may be developed and mixed in different circumstances to form viewpoints which defend or reject technological determinism. The latter, although a popular position during earlier studies of technological history,[15] has come to be refuted by newer studies,[16] while it occupies an important place within the film archiving field as well as in the more global digital culture.[17] This dissertation adheres to the vision that considers cinema's technological frameworks as "inherently transitional", as proposed by Giovanna Fossati.[18] This standpoint places the technologies within a continuous and dynamic historical framework.

As André Gaudreault and Martin Lefebvre have pointed out, a study of cinema technologies needs to "reinscribe the technological upheavals in their institutional context and to evaluate their impact on their contemporary discourses".[19] Benoît Turquety has also argued that an approach is needed which "[constructs] a possible mode for apprehending the [technologies]

[14] Santiago Hidalgo, 'Introduction', in *Technology and Film Scholarship. Experience, Study, Theory*, ed. Santiago Hidalgo (Amsterdam: Amsterdam University Press, 2017), 13–14.
[15] Barry Salt, *Film Style and Technology: History and Analysis* (London: Starwood, 1983).
[16] For example, see: Brian Winston, *Technologies of Seeing: Photography, Cinematography and Television* (London: British Film Institute, 1996); Frank Beau, Philippe Dubois, and Gérard Le Blanc, *Cinéma et dernières technologies* (Paris: De Boeck Supérieur, 1998). The same approach was widely embraced at the 2011 conference IMPACT in Montreal: Trond Lundemo, 'The Impact of Technological Innovations on the Historiography and Theory of Cinema, La Cinémathèque Québécoise, Montreal (1-6 November 2011)', NECSUS, 2012, https://necsus-ejms.org/the-impact-of-technological-innovations-on-the-historiography-and-theory-of-cinema-la-cinematheque-quebecoise-montreal-1-6-november-2011/.
[17] See for example: Nicholas Negroponte, *Being Digital* (New York: Vintage Books, 1995).
[18] Fossati, *From Grain to Pixel: The Archival Life of Film in Transition*, 2009, 13.
[19] André Gaudreault and Martin Lefebvre, 'Présentation', in *Techniques et technologies du cinéma. Modalités, usages et pratiques des dispositifs cinématographiques à travers l'histoire*, ed. André Gaudreault and Martin Lefebvre (Rennes: Presses universitaires de Rennes, 2015), 11. My translation.

that would make it possible to grasp all of their aspects without reducing their complexity […,] without falling into 'technological determinism'".[20] Such an approach, according to Turquety, would include not only the machines, but also the practices.[21] These scholarly studies challenge the understanding of cinema, as a technology itself or as dispositive,[22] and have driven to a point where cinema is considered as a complex entity in constant "negotiation" with technologies.[23] It is commonly agreed that an important part of cinema has indeed been historically technological, although the meaning of technology and its relation to cinema have not remained constant over time. The changing historical meanings of the term technology, with regards to cinema, should thus be understood in a more dynamic way, leading to new philosophical and theoretical implications.[24] Currently, several scholarly inter-university groups are involved in research in these directions, among which I can highlight TECHNES[25] and Configurations of Film[26].

The appearance of digital technologies in cinema has been central to the proliferation of these studies, as it not only reignites an old fascination with technologies in understanding cinema, but it also provides an analytical framework to study the so-called "digital revolution", where the impact of digital technologies can be placed "within a continuous history of transformation, experimentation, contest and struggle".[27] This phenomenon has been called as belonging to the

---

[20] Benoît Turquety, *Inventing Cinema. Machines, Gestures and Media History*, trans. Timothy Barnard (Amsterdam: Amsterdam University Press, 2019).[Benoît Turquety, *Inventer le cinéma. Épistémologie: problèmes, machines* (Lausanne: L'Âge d'Homme, 2014).]

[21] See other studies by Turquety, such as: Benoît Turquety, 'Forms of Machines, Forms of Movement', in *Cine-Dispositives: Essays in Epistemology Across Media*, ed. François Albera and Maria Tortajada, trans. Franck Le Gac, Film Culture in Transition (Amsterdam: Amsterdam University Press, 2015), 275–98.

[22] The notion of dispositive, introduced by Jean-Louis Baudry in the 1970s and extensively discussed in film studies by researchers such as Maria Tortajada and François Albera, Frank Kessler and André Gaudreault, imagines a three-way relation between film, technology (or machinery) and spectator, reigned by ideologies and discourses. Although a very interesting notion, I do not intend to use it in this thesis, as my focus is only on technologies and their context of development and adoption. For studies of dispositives, see: François Albera and Maria Tortajada, 'The 1900 Episteme', in *Cinema Beyond Film: Media Epistemology in the Modern Era*, ed. François Albera and Maria Tortajada (Amsterdam: Amsterdam University Press, 2010), 25–44.Frank Kessler, 'Notes on Dispositif', 2007, http://frankkessler.nl/wp-content/uploads/2010/05/Dispositif-Notes.pdf. François Albera and Maria Tortajada, 'The Dispositive Does Not Exist!', in *Cine-Dispositives: Essays in Epistemology Across Media*, ed. François Albera and Maria Tortajada (Amsterdam: Amsterdam University Press, 2015), 21–44.

[23] Gaudreault and Lefebvre, 'Présentation', 17.

[24] See: Annie van den Oever, ed., *Techné/Technology. Researching Cinema and Media Technologies – Their Development, Use, and Impact* (Amsterdam: Amsterdam University Press, 2014).

[25] http://www.technes.org/, accessed 7 February 2021.

[26] https://konfigurationen-des-films.de/en/about/, accessed 5 February 2021.

[27] Bruce Bennett, Marc Furstenau, and Adrian Mackenzie, eds., 'Introduction', in *Cinema and Technology: Cultures, Theories, Practices* (London: Palgrave Macmillan, 2008), 5.

“material turn”, which is characterised as a reaction to digital turn.[28] When it comes to film archives, these discussions are relevant on two levels, depending on whether technologies are considered as archival objects or tools. Concerning the former, film archives, as a place where these (occasionally-obsolete) technologies are conserved, grow in importance. The 2016 book *Exposing the Film Apparatus*, edited by Fossati and van den Oever, theorised the film archive as a “research laboratory”: “a place that allows hands-on research on its objects and enables us to study the materiality of the medium, the specific formats used, its experiential impact, and its discursive context”.[29] This view, where an archival perspective enriches the technological history of cinema, is regularly echoed within archival discourses and I will also address it in my research. The second understanding, considering technologies as archival tools, is most importantly how my approach in this dissertation collides with the aforementioned theories, as they may also apply specifically to archival practices and technologies. I will explain later how this framework can be refined for the archival case.

In my work, as stated, I employ a mixed approach at the crossroads between pragmatic archival approaches and theoretical scholarly studies, which is indebted to Fossati’s seminal book, *From Grain to Pixel*. In a similar manner, Fossati had merged pragmatic archival views with philosophical and ontological studies in the field of cinema. She argued how the shift from photochemical to digital technologies did not represent a rupture within archival practices, as these had always been subject to technological mutations. To do so, she proposed a new way of perceiving technologies based on their social construction and theoretical understanding, which accounted for the historical continuity. Similarly, scholars from the University of Udine, which is equipped with a film laboratory specialised in amateur and small-gauge films called “La Camera Ottica”, have also bridged between pragmatic and theoretical aspects of archival technologies in their studies.[30] My approach in this thesis, while inspired by these works, differs from them as it is above all historical – rather than philosophical – and crosses the cultural histories of sciences and technologies to that of archives. The retrospective aspect becomes

[28] See: Giovanna Fossati, ‘Film Heritage Beyond the Digital Turn’, Inaugural Lecture, University of Amsterdam (Amsterdam: University of Amsterdam, 28 October 2016).

[29] Giovanna Fossati and Annie van den Oever, eds., ‘Introduction: Exposing the Film Apparatus’, in *Exposing the Film Apparatus: The Film Archives as a Research Laboratory* (Amsterdam: Amsterdam University Press, 2016), 24.

[30] See for example: Simone Venturini and Mirco Santi, ‘The History and Technological Characteristics of Cinematographic Production and Reception Device”’, in *Preserving and Exhibiting Media Art. Challenges and Perspectives*, ed. Julia Noordegraaf et al. (Amsterdam: University of Amsterdam Press, 2013); Lorenzo Della Rovere et al., ‘Behind an Experimental Film Heritage: Preservation and Restoration Protocols and Issues’, *Journal of Film Preservation*, no. 89 (November 2013): 115–23. For more information about La Camera Ottica, see: https://dium.uniud.it/it/dium/locali-e-strutture/laboratori/la-camera-ottica/, accessed 23 December 2021.

what distinguishes it from earlier studies, as the others were mostly done contemporarily to the events described.

Furthermore, this study builds upon several existing studies of archival histories, which outlined the archival landscape from its beginnings to now. Earlier general studies focused on the *raison d'être* of film archives, described to be tireless endeavours to save films.[31] More recent archival history-writing has been interested in the political and institutional frameworks which shape archival discourses and practices, and within which film archives function.[32] Of Particular interest is Caroline Frick's 2011 *Saving Cinema*, where she analysed the notion of film as cultural heritage within national and international frameworks. Her study recognised the differences in the modes of preservation and presentation of film. The existing archival histories, however, do not linger on technologies, while they do address the technical developments as events contributing to the change of course of actions in archival discourses or practices. Indeed, the specific study of technologies, their scientific basis and their cultural context of adoption or rejection, are hardly ever included in the historical study of archives, and as such, they represent a lack in current scholarly work, which I propose to fill in this dissertation. I aim to show, through this novel perspective, that the interrelations between film archives and the technologies to which they resort in their work shape their histories and practices. I will argue throughout my study that the mutual influences born in this collision go beyond the simple integration of a technology in archival practices; rather, they modify durably and constantly both archival and scientific imaginaries.

Finally, this thesis is prepared through my dual specialisation as a film archivist and scholar, as well as my experience as an electrical engineer. Indeed, my position as a film restorer (since 2016 at the Cinémathèque suisse) has provided me with an in-depth practical experience with film and digital technologies, and an inside look at archival practices, challenges and problems. My scholarly reflections have been considerably enriched thanks to the fact that they were developed from within the same film archival community that is the subject of my study. I have closely followed archival discourses in person since 2014 and have also been sometimes

[31] See for example: Penelope Houston, *The Keepers of the Frame. The Film Archives* (London: British Film Institute, 1994); Anthony Slide, *Nitrate Won't Wait: A History of Film Preservation in the United States* (Jefferson North Carolina/London: Mac Farland & Company, 2000); Raymond Borde, *Les Cinémathèques* (Lausanne: L'Âge d'Homme, 1983); Éric Le Roy, *Cinémathèques et archives du film* (Paris: Armand Colin, 2013).The latter, although published later, follows in the footsteps of earlier archival histories by offering a pragmatic summary of history and missions of film archives in the digital era.

[32] Karen F. Gracy, *Film Preservation: Competing Definitions of Value, Use, and Practice* (Chicago: The Society of American Archivists, 2007). Caroline Frick, *Saving Cinema: The Politics of Preservation* (New York: Oxford University Press, 2011).

involved in them, which again adds a touch of pragmatic knowledge to my scholarly work. Most technical examples, illustrations and film case studies have been drawn from my own experiences in archives. Further, the technical parts of the thesis have also benefited greatly from my background as an electrical engineer and computer scientist.[33] In writing this dissertation, I address my subject of study from a scholarly point of view and offer a historical and theoretical understanding of it, while drawing on my scientific and archival experiences.

3 Methodological Tools

In this dissertation, I propose to write a technological history of archives based upon different discourses. The study needs to be conducted via a methodology that can take diverse aspects into account: technical details and scientific basis, the diversity of discourses, as well as their socio-cultural context and politico-economic frameworks. Only through a comprehensive, linked study of all these aspects it is possible to understand the dynamics of technological adoption (or rejection) within film archives, its consequences on archival imaginaries and the relevance of the digital revolution hypothesis. What's more, considering the inherently-transitional character of cinema technologies, it is essential to consider different types of technologies in relation to each other. I will argue in this dissertation that the way film technologies were constructed, adopted, used and (occasionally) standardised has an influence on the coming (digital) technologies. A genealogical approach, applied regularly in film studies, could thus be a possibility, as it provides tools to analyse a technology in relation to other technologies of the same "family". This approach has been used by researchers such as Gaudreault and Marion,[34] as well as Sean Cubitt,[35] with regards to media and their "identity processes":[36] how newer media/technologies stand out in comparison to the older ones. However, in my study, it would be difficult to define a "family" out of the heterogeneous corpus of material and technologies to which I will refer, without falling into the delineations of film vs. digital. What seems more apt to me in order to discuss my subject, is to adopt an archaeological approach, inspired by the proposal of Michel Foucault in *Archaeology of Knowledge*:

---

[33] Bachelor's degree in "Electrical Engineering and Electrical Control" at the University of Tehran, 2011. Master's degree in "Mathematics and Computer Science Applied to Human Sciences" at the University of Lausanne, 2013.

[34] André Gaudreault and Philippe Marion, 'The Cinema as a Model for Genealogy of Media', trans. Timothy Barnard, *Convergence* 8, no. 4 (2002): 12–18.

[35] Sean Cubitt, *The Practice of Light: A Genealogy of Visual Technologies from Prints to Pixels* (Cambridge, MA: MIT Press, 2014).

[36] Gaudreault and Marion, 'The Cinema as a Model for Genealogy of Media', 12.

> "The never completed, never wholly achieved uncovering of the archive [in historical research] forms the general horizon to which the description of discursive formations, the analysis of positivities, the mapping of the enunciative field belong. […] [Archaeology] does not imply the search for a beginning; […] it designates the general theme of a description that questions the already-said at the level of its existence: of the enunciative function that operates within it, of the discursive formation, and the general archive system to which it belongs."[37]

The archaeological approach is most useful because of its focus on mobilising primary archival sources and documents as pieces of evidence which, in turn, provide the "discourses" without which it seems impossible to study technologies. Applied to my study, discourses, their formation and their function become tools which relate the existence and function of technologies (in their surroundings) among themselves, without exclaiming their dominance or insignificance. The archaeological approach avoids a linear reading of history and a search for "predecessors" or origins. Instead, it allows for an analysis of technologies (and their scientific basis) within their surrounding "episteme" in a dynamic way which accounts for their historical dependence. Based on Foucault's concept of archaeology, Maria Tortajada proposes to construct an "epistemic scheme", which highlights "the traces of a certain number of relations and imbrications which do not deny history but make it appear as a field of possibilities for a certain number of technical and symbolic achievements".[38]

Archaeology is commonly applied within media studies. The term "media archaeology" was coined by Siegfried Zielinski in the 1990s as "a pragmatic perspective means to dig out secret paths in history, which might help us to find our way into the future",[39] but its application had started already before. While several understandings and approaches of media archaeology have existed,[40] they converge all in the fact that they endeavour to deconstruct the media histories which "tell only selected parts of the story".[41] With a focus on "technological materialism",[42] they study the relationship between current and past media through their

[37] Michel Foucault, *Archaeology of Knowledge & the Discourse on Language*, trans. A. M. Sheridan Smith (New York: Pantheon Books, 1972), 131.
[38] Maria Tortajada, 'Archéologie du cinéma', *Cinémas* 14, no. 2–3 (2004): 45.
[39] Siegfried Zielinski, 'Media Archaeology', *CTheory* Special Issue: Global Algorithm (11 July 1996), https://journals.uvic.ca/index.php/ctheory/article/view/14321/5097, accessed 8 February 2021.
[40] For a summary, see: Erkki Huhtamo and Jussi Parikka, eds., *Media Archaeology. Approaches, Applications, and Implications* (Berkeley: University of California Press, 2011).
[41] Huhtamo and Parikka, 3.
[42] Wolfgang Ernst, 'Radical Media Archaeology (Its Epistemology, Aesthetics and Case Studies)', ed. Pau Alsina, Ana Rodríguez, and Vanina Y. Hofman, *Artnodes. "Media Archaeology"*, no. 21 (23 July 2018): 35–43.

functions and social representations, while rejecting their teleology. In this way, they create "alternate histories" where even failed and imaginary media find their place in the socio-cultural history.[43] In the contemporary context of a profusion of new technologies, this look to the past proves important and can be effectively put to use in order to follow the changes to the technological landscape of cinema, and by extension, that of archives. According to Thomas Elsaesser:

> "Since the beginning of the twenty-first century, our visual culture has undergone several kinds of change. And while on the surface it seems to be connected to, and even 'caused' by the digital turn, the closer look and a wider horizon, i.e. a media archaeological perspective, suggests that this 'turn' is also a 'return' to an earlier engagement with images, except that 'return' implies a linear sequence, which media-archaeology explicitly sets out to 'upturn' and to distribute spatially rather than chronologically."[44]

Avoiding the chronological linearity, the archaeological approach focuses instead on the conceptual relations between the possibilities of technologies and their use. Inspired by these scholarly studies, in this dissertation I aim to do an archaeology of digital image technologies within film archives: I will study digital image technologies in light of previous technologies, in a cross-analysis with archival discourses, and try to deconstruct categorisations based on the opposition of two groups of film or digital, despite the fact that archival discourses do suggest such a delineation more or less at every period, even now. To do so, I define a methodology which proposes an intertwined study of discourses and technologies throughout the past thirty years: respectively, episteme and techne. These two are linked and function within the socio-cultural context formed and nourished by them. Stemming originally from ancient Greek philosophy, the terms techne and episteme[45] have already been applied to (new) cinema technologies in other studies, most notably by Dominique Chateau in 1998.[46] Here, archaeology prepares the terrain at each temporal point for an epistemological study of technological

[43] Huhtamo and Parikka, *Media Archaeology. Approaches, Applications, and Implications*, Introduction.
[44] Thomas Elsaesser, 'Media Archaeology as Symptom', *New Review of Film and Television Studies* 14, no. 2 (2016): 205.
[45] They can be transcribed in different ways (technè, techné, épistémè, epistêmê, etc.), here I opt for the transcription without accents for the sake of simplicity. For a study of these concepts in Greek philosophy, see: Richard Parry, 'Episteme and Techne', Stanford Encyclopedia of Philosophy, 27 March 2020, https://plato.stanford.edu/entries/episteme-techne/?utm_campaign=elearningindustry.com&utm_source=%2Ftransfection-trans-infection-teaching-molecular-biology-common-elearning&utm_medium=link, accessed 9 February 2021.
[46] Dominique Chateau, 'Pensées lacunaires et nouvelles technologies', in *Cinéma et dernières technologies*, ed. Frank Beau, Philippe Dubois, and Gérard Le Blanc (Paris: De Boeck Supérieur, 1998), 67–84.

frameworks through the duality of their technical details (scientific basis) and their surrounding epistemes, similar to what Turquety has described:

> "The epistemology of machines attempts to understand, through the analysis of the objects and their genesis, the epistemological conditions of their conception and the 'implicit conceptual structures' that they put into play."[47]

Epistemology, here, would serve as a philosophical methodology to extract at each time the archival imaginaries around not only machines but also diverse forms of image technologies. It would help reveal the technological developments and their adoption, adaptation or rejection, explore their field of possibilities, underline the co-existence of several technologies, and relate the scientific concepts with discourses and practices. In order to make my methodological position clearer, I will explain hereafter what I mean by using the terms techne and episteme; how, concretely, they will be applied in my study; and how they are linked within their socio-cultural context.

3.1 EPISTEME: Discourse Network of Film Archives

A Greek word designating knowledge, episteme was an important constituting part of Foucault's archaeology. In *Archaeology of Knowledge*, he defined it as follows:

> "The analysis of discursive formations, of positivities, and knowledge in their relations with epistemological figures and with the sciences is what has been called, to distinguish it from other possible forms of the history of the sciences, the analysis of the *episteme*."[48]

Episteme represents, in the Foucauldian sense, patterns and modes of knowledge exposed by ways of enunciating and discursive practices. It can be thought of as the general scientific or philosophical state of collective knowledge about objects, technologies, sciences or else, which makes "theory, practice or opinion possible".[49] The episteme is thus naturally a dynamic state. Such a concept of the episteme has been applied to the historiography of the invention of cinema around 1900 by Maria Tortajada and François Albera. The episteme, according to them, includes the discourses and practices related not only to "*concrete* elements" but also to the "*concepts* that are linked to them".[50]

[47] Turquety, *Inventing Cinema. Machines, Gestures and Media History*, 22. Turquety makes use of this double archaeological-epistemological study in this book.
[48] Foucault, *Archaeology of Knowledge & the Discourse on Language*, 191. Emphasis in the original.
[49] Albera and Tortajada, 'The 1900 Episteme'. The concept of "1900 Episteme" was introduced by Tortajada and Albera in 2002 for the first time at the Domitor conference.
[50] Albera and Tortajada, 30. Emphasis in the original.

I would like to apply the concept of episteme to the historical study of film archives as the state of their collective knowledge, revealed through diverse discourses and practices. Within the episteme, these co-exist, meet or miss, change or influence one another. In order to analyse how these processes work, I characterise the patterns of discourses and practices in the episteme as a "network". The concept of a discourse network, borrowed from Friedrich Kittler, is particularly useful in this context. Inspired by Claude Shannon's ground-breaking information theory, Kittler's understanding of a discourse network includes not only the discourses (and practices) but also their producers and receivers, as well as the transmission channels through which they are enounced. By the latter, all domains of socio-cultural exchange are concerned.[51] This helps me to categorise the discourses (political, technical, etc.) within different circuits (which I will detail further down), at different levels (national, transnational, European, international), by different people (personal or institutional points of view, etc.) and under different circumstances. All of these are formed within a dynamic culture – which I will outline from 1990 to 2020 in order to depict the episteme of the digital transition era in the film archival community, as represented by its discourse networks.

By studying the discourses and practices of the film archival community, I aim to uncover the episteme in each period, mark the dominant trends within it and underline its dynamic nature shaped through socio-cultural interactions. I claim that the episteme leads to the development of archival imaginaries; a term that I will commonly employ in this dissertation in order to designate the common perceptions reigning within the community and influencing the discourses and practices. While episteme describes the general state of knowledge at a certain point, the archival imaginary refers to the beliefs and perceptions related to that state. The use of the term here is inspired by the concept of social imaginary, coined by Charles Taylor, which denotes how a large group of people "imagine" their social surroundings, leading to a "common understanding that makes possible common practices and a widely shared sense of legitimacy".[52] I claim that, considering the dynamic nature of episteme, the resulting archival imaginaries manifest dominant tendencies in each period under study; focusing on different practices and methodologies, as well as presenting different perceptions of digital technologies.

---

[51] See: David E. Wellberry, 'Foreword', in *Discourse Networks 1800-1900*, by Friedrich Kittler, trans. Michel Metteer and Chris Cullens (Stanford: Stanford University Press, 1990); John Armitage, 'From Discourse Networks to Cultural Mathematics. An Interview with Friedrich A. Kittler', *Theory, Culture & Society* 23, no. 7–8 (2006): 17–38.

[52] Charles Taylor, *Modern Social Imaginaries*, Public Planet Books (Durham and London: Duke University Press, 2004), 23.

However, this "common understanding", which is "both factual and normative",[53] "has no clear limits", and is "largely unstructured and inarticulate".[54] Hence, any attempt to depict an imaginary in this sense is but an account to sketch its various forms fragmentarily. The archival imaginary, understood in this way, is a heterogenous entity which I will try to capture (albeit in fragments) and formalise through my discourse analysis. While my goal is to make the dominant imaginary emerge at each point, it is important not to overlook the co-existence of several – sometimes contradictory – directions in it (most visible in Chapter Two). The discrepancies or similarities exist not only among different archives, but may also stem from the same archive or even the same archivist (depending on circumstances). Both homogeneity and heterogeneity in views, practices and discussions are important in the creation of a dominant archival imaginary.

I will argue that the archival episteme is regularly enriched when archives come into contact with discourses coming from other actors: institutions close to them (such as commercial laboratories, film catalogue owners, etc), the larger local or global film industries (production or distribution), the scientific community (technical universities and research centres) as well as technology providers and companies. Indeed, the archival episteme goes inevitably beyond the limits of archives and includes other entities, whose discourses collide with that of archives at certain points. While the construction of an episteme through archival discourses in this dissertation aims to reach exhaustivity, the other discourses are taken into account only when they collide, touch, or significantly miss the archival discourses. These connected discourses provide for a partial view of other imaginaries (such as scientific or industrial imaginary), in concepts where they relate to the film archival community.

Here, it is necessary to add nuances to the notion of the film archival community, the source providing the discourses used in this research and specify how they relate to the archival imaginary. When using the term "film archival community", I am referring to cinematographic film archives, mostly those in charge of national film heritage, which are politically mandated to collect and preserve film heritage in their country, and nationally financed to do so. This definition excludes a focus on regional or amateur film archives, as well as television and video archives, which are inherently different on two levels: firstly, they do not always conserve the same artefacts, and secondly, they differ in their missions and goals, as well as their institutional frameworks. Among these differences, I can evoke the fact that regional or amateur film

---

[53] Taylor, 24.

[54] Taylor, 25.

archives, while sharing many aspects with national film archives in terms of film artefact to conserve, are more specialised in smaller-gauge, alternative and non-professional practices, rather than industrial cinema filmmaking. Moreover, they rarely function within similar restrictive political and financial frameworks. The differences may also lie in the goals specified for archives and how the conserved audiovisual material are considered; whether primarily as historical documents to which access must be provided (for instance in television archives), or rather artworks (as defined by national film archives).[55] The digital transition did not impact different archives in the same way, neither do their challenges coincide necessarily with the timeline this dissertation presents. Of course, it is very difficult to draw definitive borders of this kind between archives; inevitably, they are sometimes blurred, when their discourses and practices merge or meet. As such, it is important to underline their connected discourses with national film archives, even though fragmentarily.

The second point in the definition of the film archival community is that I focus on European film archives here, which share some proximity, be it politically through their European connection and frameworks, historically, financially, or regarding their structural model as film archiving institutions. The European archives have been very active in discourse production within the global archival community. Again, the discussions within the archival community inevitably go beyond these geographical borders, but, in this study, I deliberately do not tackle the specific cases of film archiving either in North America or Australia (which have been extensively discussed by other researchers[56]), nor in non-European and non-American archives, especially those of the Global South (which remain mostly to be explored further in scholarly studies), as each of these deserves their own studies. When necessary, I do mention some interactions they have with European archives, as connected discourses.

In order to enable the most inclusive depiction of episteme, I have used a wide range of discourses in my research. Within the discourses stemming from the archival community, probably the most important and abundant ones are official FIAF sources. As the International Federation of Film Archives, FIAF was founded in 1938 by three European archives (Cinémathèque française, Germany's Reichsfilmarchiv and the British Film Institute) as well as the Museum of Modern Art (MoMa) Film Library in New York,[57] and quite rapidly archives

[55] I will mention certain interactions between television and film archives in the thesis.

[56] Frick, *Saving Cinema: The Politics of Preservation*; Gracy, *Film Preservation: Competing Definitions of Value, Use, and Practice*.

[57] For a detailed account of FIAF's birth, see: Christophe Dupin, 'First Tango in Paris: The Birth of FIAF, 1936-1938', *Journal of Film Preservation*, no. 88 (April 2013): 43–57.

from all over the world (especially Europe) joined in.[58] From its early days until now, FIAF has organised congresses,[59] conducted studies, and published several documents, books, journals, manuals, manifestos, etc. about film archiving. Despite being international, the FIAF sources are dominantly Euro-centric, and the European perspective is most present in it due to the high activity rate of European national archives within the organisation. In my research, I have studied these sources exhaustively in order to extract the European discourse, as well as the connected discourses with other archives and institutions close to archives.

Further oral or written sources that I have addressed in my research include journals, conferences, projects, festivals, internal archive documents, policy documents, training programs, etc. The Association of European Cinematheques (ACE) is another important organisation in the context of my study, which was founded as a local subdivision of FIAF, and whose activities, workshops, publications, projects and discussions have contributed to the shaping and modification of archival imaginary within Europe. There have also been several European publicly-funded projects (such as LIMELIGHT or EDCINE, which I will detail in the following chapters), driven by film archives, which provided them with the necessary theoretical and technical experience with regards to digital technologies. European national archives also regularly met at recurrent or one-time conferences, as well as several film festivals and training programmes, where the discourses were enriched and technical experiences shared. Furthermore, I have included several documents produced by archives on a national level (or by the political organisations in their countries) regarding their own practices, or documents derived from national projects which present a larger interest going beyond the strict national borders. Finally, a large number of sources from connected discourses (especially technical and scientific ones) have been mobilised in this research. Complete lists of the considered primary sources are provided in the appendixes and bibliography of the dissertation. These discourses may be political, theoretical or technical to different degrees. They are influenced by archives' status or missions, their relation to (and the use of) photochemical or digital technologies or the history of their practices.

I have faced some main shortcomings with regards to the mentioned sources. First of all, some oral sources (and even some of the written sources) were not recorded or archived; thus, the discourses had to be extrapolated through contemporary reviews or other pieces of evidence.

[58] See also the FIAF timeline: https://www.fiafnet.org/pages/History/FIAF-Timeline.html, accessed 23 December 2021.

[59] See: https://www.fiafnet.org/pages/History/Archival-Documents-about-FIAF-Congresses.html, accessed 23 December 2021.

Secondly, many of the discourses were published and exchanged online on websites which, at the time of my research (some 10 or 20 years later), were not available anymore. These were accessed, when possible, through archive.org's Wayback Machine. Despite these difficulties, through this heterogeneous corpus, I could reconstruct the archival episteme throughout the 30 years of digital transition covered here, and describe the evolutions of archival imaginaries.

3.2 TECHNE: Technologies and their Scientific Construction

The other side of the coin is techne, a philosophical concept translated as "craft, "skill", "know-how", denoting the knowledge practically applied – rather than the practice itself.[60] What I intend to cover under this term, is indeed not only image technologies themselves, but also, perhaps more importantly, the scientific knowledge that underlays them. Here, I will briefly review the meaning of "technology", and try to define exactly what I mean by it, and how it differs from the similar word, "technique". Indeed, the definition of technology and the terminological confusion of technology vs. technique have created a considerable amount of scholarly discussions.[61] To make the matter worse, the terms do not necessarily have the same meaning in different languages, and their meanings have also changed historically.[62] This confusion was evoked already back in 1984 by Rick Altman, who pleaded for a clear terminological distinction between technique and technology. Based on Altman's article, Benoît Turquety defined the terms as follows:

> "Technology seems, then, to delineate the realm of the hardware-related, the machines, and their components, whereas technique describes what concerns gestures, practices, and the conscious choices implied on the operators' side."[63]

This is indeed how I will apply the term "technique" in my research: how to work with objects, tools and machines. It is thus more related to practices, and to episteme, as explained above. On the other hand, the term "technology" seems a little more complicated. Concerning initially the "study" of technical objects, technology came later to designate generally "the mechanic

---

[60] See: Parry, 'Episteme and Techne'.

[61] Rick Altman, 'Toward a Theory of the History of Representational Technologies', *Iris* 2, no. 2 (1984): 111–25; Benoît Turquety, 'Towards an Archaeology of Cinema/Technology Relation: From Mechanization to "Digital Cinema"', in *Techné/Technology. Researching Cinema and Media Technologies – Their Development, Use, and Impact*, ed. Annie van den Oever (Amsterdam: Amsterdam University Press, 2014), 63–64; Fossati and van den Oever, 'Introduction: Exposing the Film Apparatus'.

[62] Turquety, 'Towards an Archaeology of Cinema/Technology Relation: From Mechanization to "Digital Cinema"', 53.

[63] Benoît Turquety, 'On Viewfinders, Video Assist Systems, and Tape Splicers: Questioning the History of Techniques and Technology in Cinema', in *Technology and Film Scholarship. Experience, Study, Theory*, ed. Santiago Hidalgo (Amsterdam: Amsterdam University Press, 2017), 242.

arts".[64] There is no doubt, as many scholars have noted, about the shift from the study of technical objects to the objects themselves, but what interests me more here, is what kind of objects were included in it and what relation they maintained with science. In 1855, in his inaugural lecture for the Chair of Technology at the University of Edinburgh, George Wilson defined technology as the "Science of Industrial Arts". The latter, also referred to as "Utilitarian or Use Arts" by Wilson, included not only mechanical, but also chemical and the then-new electrical arts (Wilson himself was a chemist). Interestingly, Wilson also included photography as a subject of study in his definition:

> "A Third division, of more limited value, but at present of great and increasing interest, will be the economic applications of light, as employed in the different modifications of Photogenic Art. This has hitherto been more an object of interest as a Fine Art, than as an Industrial one; but every day is adding to its value as furnishing an infallible, incorruptible, and most faithful copyist […]"[65]

Photography, beyond being a "Fine Art", was believed to also serve as a tool, thus justifying its inclusion in the category of industrial arts. This is of interest in the case of my research on cinema, whose technological aspect would regard not only its mechanical apparatus but also its photographic images. Moreover, Wilson also included "electricity" in industrial arts, as a coming basis for many future tools. However, this wide range was not necessarily a shared view in the changing historical understanding of technology. Leo Marx's study of the history of technology focuses on its understanding in relation to the mechanic arts and machinery, while David E. Nye's wider definition includes tools – of any kind – alongside machines.[66] Technology's most common meaning in the 20th century has been that of mechanical machines, as underlined by Benoît Turquety. According to Turquety, with digital technologies, a shift has occurred in the concept of technology in the "general culture", because digital "machineries and processes, apparatuses and workflows" are perceived to belong to "a different conceptual structure than mechanics".[67] This discussion provides me with the assumption that, considering the changing concept of technology, it could apply to different types of machineries, tools,

[64] Leo Marx, 'Technology: The Emergence of a Hazardous Concept', *Technology and Culture* 51, no. 3 (July 2010): 561–77.
[65] George Wilson, 'What Is Technology?' (Inaugural Lecture, University of Edinburgh, 1855).
[66] David E. Nye, *Technology Matters: Questions to Live With* (Cambridge, MA/London: The MIT Press, 2006).
[67] Turquety, 'Towards an Archaeology of Cinema/Technology Relation: From Mechanization to "Digital Cinema"', 63–64. This view is generally accepted (and mostly deplored) by technology historians such as Nye, *Technology Matters: Questions to Live With*, Chapter 1.

methods and processes. The technologies that I will discuss in this thesis can therefore be of various kinds: photochemical, mechanical, optical, electronic, digital, etc.

The next important point to clarify is how technologies interact with science. It is clear that the two are indeed closely related. But how? As Wilson understood technology, the branch was certainly to study the past Industrial Arts, just as it was also to discuss generally the application of science in view of coming new inventions. The relation of technology with science has indeed been a complicated one, in the sense that it somewhat reincarnates the paradox of chicken and egg. Applying this concept to audiovisual communication media, Brian Winston argued in 1998 that not all scientific discoveries and ideas lead (directly) to technologies, although sciences are indeed at the basis of technologies.[68] David E. Nye, on the other hand, underlined that many tools and machines (technologies) had preceded their scientific understanding.[69] I will investigate this non-linear, non-sequential relation between science and technology with regards to different image technologies throughout my research: I will show how the practical understanding of some technologies (for instance, grain technologies in Chapter Two) happened prior to their scientific explanation, while others were the result of specific scientific quests (such as digital projection, in Chapter Three).

When discussing the scientific concepts in this dissertation, I use only what is directly related to the technologies and technical concepts in use in film archives and sometimes the film industry, rather than the whole scientific context of the time. These encounters are at the heart of my work, and provide the most important elements necessary for my analysis of techne here. Moreover, it should be noted that different scientific methods used towards the same goal give (slightly) different results. Indeed, there is not one all-inclusive scientific method revealing objectively the ultimate truth behind any archival technology; rather different possible ways to get to a (scientifically subjective) solution. Scientific methods are all based on modelling, approximations and estimations, even prone to errors, which help solve a (technical) problem from a specific aspect. I will insist on this specificity of sciences throughout the whole dissertation; the scientific discussions here do not serve as the normative references of right or wrong, but provide insights into how an archival or industrial needs or desires were translated into the scientific language and modelled as such; how the proposed solutions could correspond to these initial triggers; or suggest new conceptions and technologies for use within the archival field.

[68] Winston, *Technologies of Seeing: Photography, Cinematography and Television*, Introduction.
[69] Nye, *Technology Matters: Questions to Live With*, 10.

To sum up, the use of the word techne in this dissertation is to allow the inclusion of technologies and their related scientific facts and processes. As a result, I will not only detail how image technologies are constructed and function, but also how they relate to their scientific understanding. This means the objects/tools themselves and the scientific knowledge that underlays or accompanies them, or emanates from them. In the case of archival technologies, this scientific construction often crosses paths with the archival episteme, as I will illustrate in my four chapters. The degree of interaction remains however different, leaving archives as actors, interlocutors or observers. It is therefore inevitable to include the scientific understanding, and consider its influential two-way relationship with the technologies. A look back at that helps me reconstruct essential parts of the imaginary surrounding image technologies: how did the science-technology connection correspond to archival practices? How did it come to be understood, used, and adopted? This exploration will uncover the details of digital technologies, leading to a clearer vision of what they can or cannot do. Most importantly, it will re-place them in the continuous technological history of archives.

3.3 The Socio-cultural Existence of Technologies

What binds the techne and episteme together is the socio-cultural context within which they both exist, change and meet; a process through which both are modified. Indeed, technology has inherently been considered in relation to humans, as socio-cultural beings, as stated by Nye:

> "Technologies are not foreign to 'human nature' but inseparable from it. […] Defining technology as inseparable from human evolution suggests that tools and machines are far more than objects whose meaning is revealed simply by their purposes."[70]

Early theorists and historians of technology had also considered it as such. The Industrial Arts, which were considered as objects of technology by Wilson in the mid-19th century, were what distinguished humans from "lower animals";[71] thus requiring the existence of a more complex socio-cultural context. Technology, notably at the beginning of the 20th century, was studied as a branch of sociology (and more specifically, ethnology),[72] as Emile Durkheim wrote in 1901:

---

[70] Nye, 2.
[71] Wilson, 'What Is Technology?'
[72] See Nathan Schlanger, 'Introduction. Technological Commitments: Marcel Mauss and the Study of Techniques in the French Social Sciences', in *Marcel Mauss. Techniques, Technology and Civilisation* (New York and Oxford: Durkheim Press, Berghahn Books, 2006), 1–29. In Film Studies, the social aspect of technology has been historically analysed by Benoît Turquety, as an effort to understand the cinema's mutations within an epistemological framework rather than an ontological one: Turquety, 'Towards an Archaeology of Cinema/Technology Relation: From Mechanization to "Digital Cinema"', 53–56.

> "The various instruments used by humans (tools, weapons, clothing, utensils of all sorts, etc.) are products of collective activities. They are always symptomatic of a determined state of civilisation, such that there are well-defined relations between them and the nature of the society that employs them. The determination of these relations constitutes therefore a sociological problem, and technology, considered in this aspect, is a branch of sociology."[73]

If technology is considered as being a part of sociology in this sense, it is imagined not only as a social product, but also bound by the cultural uniqueness of societies ("civilisations"). The question that is inevitably raised is how this socio-cultural context relates to technologies. This has been addressed in research by sociologists as well as technologists. While the former group has proposed conceptual frameworks to model the socio-technical relations, the latter has approached it on a quantitative/mathematical basis.[74] The field called STS (Science, Technology, Society) has produced many methodologies, such as Actor-Network Theory[75] (1980s), Social Construction of Technology[76] (SCOT, 1980s) and Social Shaping of Technology[77] (1999). As noted by Vinzenz Hediger, these approaches, in general, oscillate between "techno-determinism" and "social-constructivism", in search of a balance between "the social" and "the technical".[78] Scholarly work in Film Studies has extensively noted the importance of this discussion, by either applying one sociological methodology to their research (such as Giovanna Fossati's *From Grain to Pixel*), or by proposing their own methods. Annie van den Oever, for instance, developed a framework to explain how technologies go from a

[73] Emile Durkheim, 'Technology (1901)', in *Marcel Mauss. Techniques, Technology and Civilisation*, ed. and trans. Nathan Schlanger, 1st ed. (New York and Oxford: Durkheim Press and Berghahn Books, 2006), 31–32, [E. Durkheim, 1901, 'Technologie', Année sociologique, No. 4, pp. 593-594].

[74] For the second group, see: Frank W. Geels, 'From Sectoral Systems of Innovation to Socio-Technical Systems: Insights about Dynamics and Change from Sociology and Institutional Theory', *Research Policy* 33, no. 6 (1 September 2004): 897–920; K. H. Van Dam, 'Capturing Socio-Technical Systems with Agent-Based Modelling' (PhD Thesis, Delft, Technical University Delft, 2009), https://repository.tudelft.nl/islandora/object/uuid%3A1b36bc02-c7fe-4773-9ab2-3daa3b891754; Karolina Safarzyńska, Koen Frenken, and Jeroen C. J. M. Van den Bergh, 'Evolutionary Theorizing and Modeling of Sustainability Transitions', *Research Policy*, Special Section on Sustainability Transitions, 41, no. 6 (1 July 2012): 1011–24.

[75] Bruno Latour, 'On Actor-Network Theory: A Few Clarifications', *Soziale Welt* 47, no. 4 (1996): 369–81.

[76] Trevor J. Pinch and Wiebe E. Bijker, 'The Social Construction of Facts and Artefacts: Or How the Sociology of Science and the Sociology of Technology Might Benefit Each Other', *Social Studies of Science* 14, no. 3 (1984): 399–441.

[77] Robin Williams and David Edge, 'The Social Shaping of Technology', *Research Policy* 25, no. 6 (1 September 1996): 865–99.

[78] Vinzenz Hediger, 'Can We Have the Cave and Leave It Too? On the Meaning of Cinema as Technology', in *Technology and Film Scholarship. Experience, Study, Theory*, ed. Santiago Hidalgo (Amsterdam: Amsterdam University Press, 2017), 213–38.

"mere technology" to a "medium" (i.e., adopted) in four phases of "monstration", "celebration", "rejection" of the "alien quality", institutional "appropriation".[79] While considerably indebted to these reflections, this dissertation is not methodologically confined to one or another, but sweeps along the same lines in order to depict the formation of socio-technological structures in the case of film archives and explain concepts such as technological innovation, adoption and transition. Most importantly, it intends to include not only social but cultural practices in the study, in order to encompass the weight of history and culture of film archives and their surroundings, the habits of the people involved and their culturally-shaped preferences. The context in which techne and episteme of film archives exist and change includes also political frameworks and economic factors. These two aspects provide external forces which act as catalysts in some processes of technological development and adoption, while they may slow others down. As I will occasionally mention throughout the thesis, they are often not based on deep technical studies, but rather influenced by a global digital culture – which is more visible at their level.

Finally, the global understanding in contemporary culture distinguishes between technology and human by seeing technology as an external phenomenon, synonymous with digital. In this sense, new technologies are perceived as invasions; a reflection of which is visible in some archival discourses. Digital technologies stem from a computational thinking which has grown progressively since mechanisation. This concept follows in the footsteps of automation, which, as described by Lewis Mumford back in 1934, represented a technological turn going from earlier tools (used by humans) to machines (automating parts of human work).[80] But computational thinking goes further by modelling all processes and objects with the help of numbers and mathematics. Consequently, it "amplifies" the technological progress, as sociologist Dominique Boullier has suggested,[81] in terms of processes, speed, capacity, communication, diversity, etc. This brief digital genealogy, as I will illustrate throughout the dissertation, is important to understanding the socio-cultural context of technological adoption and transition and to deconstructing the misconceptions.

[79] Annie van den Oever, 'From Technology to Medium. The Apparatuses in the Archive as a Source for a New Film and Media History', in *The Archive/L'Archivio. Filmforum 2011. Atti Del 18° Convegno Internazionale Di Studi Sul Cinema.*, ed. Alessandro Bordina, Sonia Campanini, and Andrea Mariani (Udine: Forum Edizioni, 2012), 131–40.

[80] Lewis Mumford, *Technics and Civilization*, 7th ed. (London: Routledge and Kegan Paul, 1955), 9–12 [1934].

[81] Dominique Boullier, *Sociologie du numérique* (Paris: Armand Colin, 2019).

4 Periodisation and Structure of the Research

As this introduction promises, this dissertation will study the interplay between episteme and techne of film archives in their socio-cultural context during the past thirty years. In other words, it investigates the history of film archival practices and discourses on the one hand, and technologies and their accompanying sciences on the other hand; and most importantly, how these two interact. The idea is to articulate these two axes together in order to clarify the discussions and concepts by adding technical nuances to them. To do so, the four chapters each cover a period of the technological history of archives. The periodisation follows the logic of episteme through the identification of a dominant imaginary, which is then mapped, thanks to my technical studies, onto its corresponding technological landscape. This association of techne and episteme enables the study of non-linear processes of technological adoption, as well as their interaction with archival imaginary, and sheds light on the multiple (digital) image technologies co-existing within archival practices.

Each chapter takes as its starting point a significant event which best represents the coming change of archival imaginaries. Considering the high pace of these processes within episteme and techne and the nature of study based on discourses, the changeover year is approximative. The technologies and discourses considered in each period represent the dominant archival vision of that era, but they are not temporally confined to it; I will in fact strive to show also their evolution before and after the strict period within which they are studied. While the episteme is enriched throughout the past thirty years, the dominant archival imaginaries follow up one after another. Rather than a transformation, there seems to be a shift in the interest focus within the community, which, consequently, changes the archival perceptions of digital technologies. As mentioned above, many aspects are influential in the evolutions, most importantly the socio-cultural ones, as well as political and economic factors. The four chapters of this thesis do not intend to illustrate these all, but to extract a coherent narrative of the episteme-techne relations by assembling different aspects.

Chapter One, approximately covering the period between 1990 and 2004, is dedicated to the "Restored Image". Indeed, the first steps of archives faced with digital technologies was their application to image restoration. The knowledge accumulated through historical archival practices before this period served to shape their views on the upcoming technological needs, desires and possibilities, notably their quest for a "better image", as I will detail in this chapter. By the 1990s, films were primarily recorded and distributed on film, and digital technologies were meant to intervene as tools for manipulation of image details at an intermediate level between unrestored and restored film. The digital technologies, at this point, were perceived as invisible tools which could offer many image manipulation possibilities. From early on, however, the advantages were considered in conjunction with the possible dangers of the new tools, shaping thus the beginning of a dialectical imaginary, which was to deepen later. Through research and development of new technologies, in numerous projects such as LIMELIGHT and DIAMANT, the archival imaginary encountered the scientific imaginary: not only they were both modified in the processes as I will argue, but this encounter prepared the terrain for the adaptation, adoption and generalisation of some restoration tools (such as DIAMANT) while others (such as DUST) failed, or did not get realised.

The dialectical archival imaginary intensified through the following period, as covered in Chapter Two, which I have named “Hybrid Image”. The hybridity, here, references the co-existence of several technologies and the confrontation of archives with a period of larger socio-cultural and political infatuation with digital technologies, while at the same time most archives could not take concrete actions if not substantially helped through governmental or EU funding. During the time roughly between 2004 and 2011, archives had already become familiar with some digital technologies, and they expected the advent of a digital future, which would considerably change their work, role and identities. At this point, film, video and digital image technologies all co-existed and were subject to regular change. The dominant archival imaginary did not cease to compare them, although a thoroughly objective scientific comparison can be ruled out because of the difficulties in comparing different technologies through one single technological framework. The archival dilemmas and questioning of their own identity and role reinforced views such as museology within the community and produced reactions like the FIAF manifesto in attempts to save film. As I will explore in this chapter, the general establishment of a regime of constant comparison between photochemical and digital technologies perceived each group of technologies as apt for a specific application: photochemical technologies were considered superior and were assigned to preservation, while digital technologies were deemed as suitable only for access to films. However, the rare practical projects conceived during this time, such as Images for the Future, were to challenge this dialectical view.

Around 2011, the much-feared digital future materialised when cinema projection went digital (the so-called digital roll-out). As I will argue, this understandably represented an important technological change in archival views, to which a double reaction of rebellion and adaptation was formed. Chapter Three, entitled “Projected Image”, goes through the archival, industrial and scientific imaginaries on image projection through different technologies, and how the new technologies tried to remediate the older ones, approximately during the period of 2011 to 2014. I offer a technical study of projection technologies which links the archival discourses and practices of projection before and after the roll-out and sheds light on the socio-cultural and technical discrepancies of the time. As my technical study will show, the digitally projected image was scientifically and industrially crafted in a manner that would mimic film projection. These scientific and industrial imaginaries, while rarely colliding in a direct way with archival imaginaries, did modify the latter: neither film, nor film projection remained the same in the evolution of archival perceptions at the time. The museological tendencies within archives were reinforced and created a whole movement that fought against the disappearance of film and film culture. On the other hand, while militating for film through initiatives such as Save Film, archives also needed to adapt to digital projection technologies, despite the fact that these overlooked specific archival problems, such as the respect of original frame rates or aspect ratios.

Chapter Four, covering approximately the period between 2014 and 2020, recounts the consolidation of the thirty-year digital transition era. Called "Multiple Image", this chapter claims that by this time, enriched by considerable practical experience (that I will detail through case studies of France, Sweden and Germany), the archival imaginary finally seems to shift towards an acceptance of technological diversity and multiplicity, where different film and digital technologies co-exist; a direction evident not only in episteme, but also in the conception and construction of techne itself. Following the roll-out, archives needed to address the concrete consequences of the roll-out, as I will formalise in Chapter Four in two directions of digitisation and digital conservation[82], practices for which many European archives had finally secured economic funds through national channels. Digitisation and digital conservation were of course not new concepts by this time, but addressing their technical challenges was not common until this period. Regarding digitisation, my technical study of the multiple photochemical or digital workflows that an image goes through during its production, distribution and archival lifetime will underline the image multiplicity from material and visual points of view, and embed the practices of digitisation within the larger reproduction landscape. My examples of some recent restoration cases will illustrate these discussions, notably that on reproduction authenticity. In what concerns digital conservation, similarly, the material and conceptual aspects of digital

[82] In this dissertation, I will use the word conservation for the passive safekeeping of audiovisual material (on any support), while the word preservation will be reserved to a set of active practices, such as duplication, restoration or digitisation, which ensure the further conservation of films on newer material. This choice of terms comes from Nicola Mazzanti, 'Footnotes', in *Restauro, Conservazione et Distruzione dei Film*, ed. Luisa Comencini and Mattheo Pavesi, Fondazione Cineteca Italiana (Milan: Il Castoro S.r.l, 2001).

films will come under scrutiny in an attempt to follow the processes of the acceptance of digital conservation as an archival activity and the refinement of archival strategies in order to consider digital material and formats as archival.

I will close this introduction with an illustration by Swiss filmmaker Fredi M. Murer demonstrating the photochemical film "on the go"; a metaphor which thematises one of the main claims of this dissertation: cinema technologies move on, some die out on the way while others continue forcefully. And, so is the case with film archives and their practices.

Fredi M. Murer als Zeichner

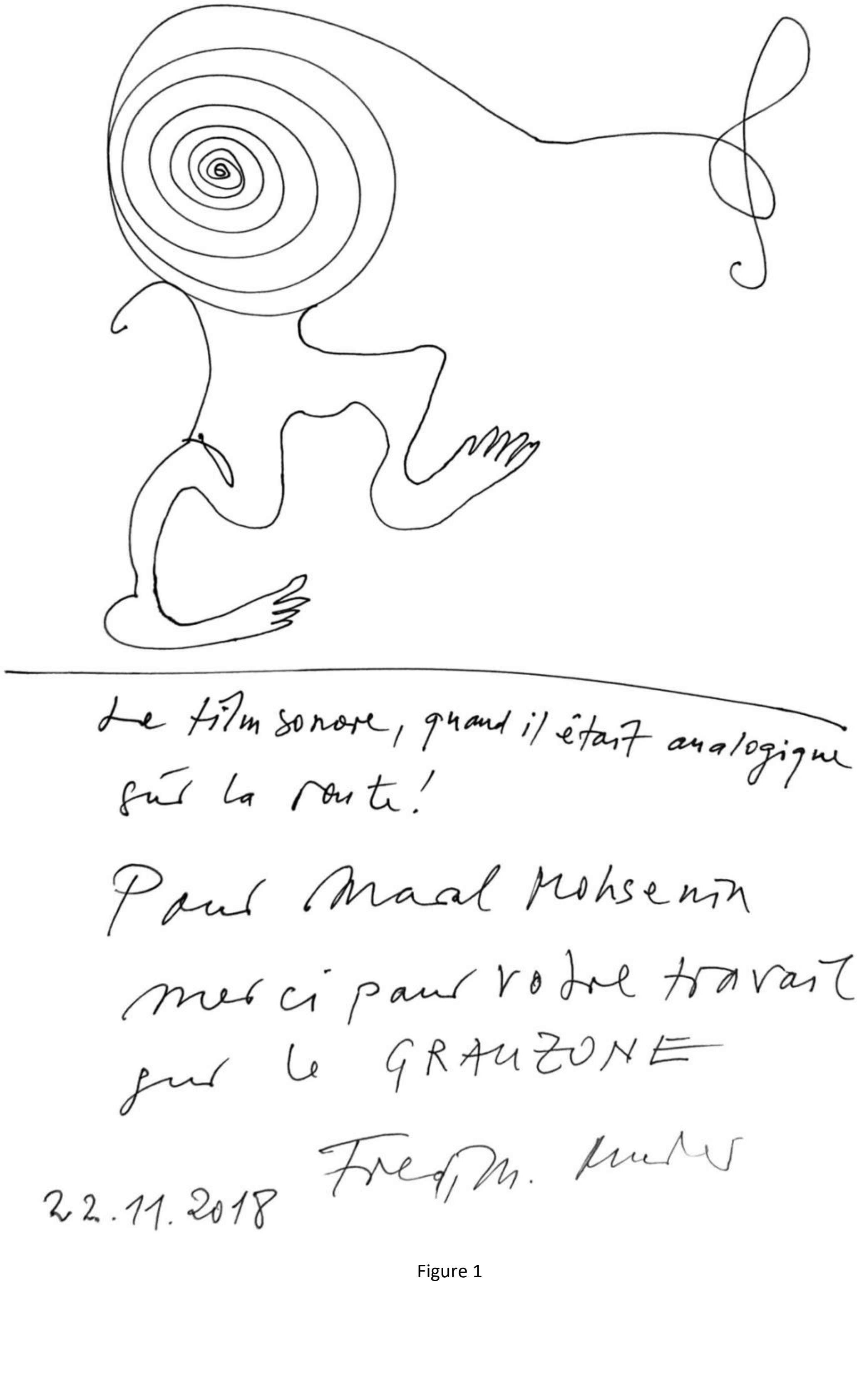


Figure 1

Chapter One. Restored Image: Digital as an Intermediate Step

Restoration was one of the first major film archival practices to integrate digital image technologies in its workflows. The first discourses evoking the possibility of using new technologies for film restoration started in the beginning of the 1990s and evolved exponentially towards a point where several film archives, as well as political institutions, universities and technologists became involved in international projects and discussions by 2004. This chapter retraces the archaeology of image manipulation technologies through discourses and practices of film restoration during this period of time, and argues that the adoption of these technologies did not follow a linear function. Some technologies were adopted and adapted from other fields (such as visual effects and post-production),[1] while others were developed precisely for film restoration, but not all of them remained in use in the long run. Embedded in the diverse technical and epistemic landscape of the film archival community, the adoption of technologies depended considerably on the existing historical and cultural practices. The goal of this chapter is to analyse how archival discourses and practices collided with scientific and technological developments.

Film restoration has been subject to a considerable amount of academic and professional literature from different perspectives. From the late 1980s, archivists and academics in Bologna[2] collaborated to develop a dual approach to film restoration, based on philology on the one hand and on ethical art preservation[3] on the other. Their landmark publication in 1994,

---

[1] This point has often been raised by archivists and scholars alike. See: Fossati, *From Grain to Pixel: The Archival Life of Film in Transition*, 2009. Read and Meyer, *Restoration of Motion Picture Film*. In a study by Commission Supérieure et Technique de l'Image et du Son (CST) of digital restoration this was also underlined: "The two other fields, special effects and restoration, present strong similarities, whether technically or from the point of view of materials or procedures." (Bruno Despas and François Helt, eds., *La restauration numérique des films cinématographiques* (Paris: CST, CNC, 1997). My translation).

[2] Michele Canosa (University of Bologna), Leonardo Quaresima (University of Bologna and University of Udine), Gianluca Farinelli and Nicola Mazzanti (Cineteca di Bologna). For the "Bolognese School", see: Marie Frappat, '"L'école bolonaise" de restauration des films', in *L'avenir de la mémoire: Patrimoine, restauration et réemploi cinématographiques*, ed. André Habib and Michel Marie (Villeneuve-d'Ascq: Presses Universitaires du Septentrion, 2013), 39–45. Céline Ruivo, 'Le Technicolor trichrome : Histoire d'un procédé et enjeux de sa restauration' (PhD Thesis, Université Sorbonne Nouvelle–Paris 3, 2016), 77–78.

[3] Deriving, notably, on the works done by Cesare Brandi and Aloïs Riegl. See: Cesare Brandi, *Teoria del restauro* (Rome: Edizioni di Storia e Letteratura, 1963). Alois Riegl, *Der moderne Denkmalkultus: sein Wesen und seine Entstehung* (Braumüller, 1903), https://diglib.tugraz.at/der-moderne-denkmalkultus-1903, accessed May 30, 2020. Among publications during this time, see for example: Luisa Comencini and Mattheo Pavesi, eds., *Restauro, Conservazione et Distruzione dei Film*, Fondazione Cineteca Italiana (Milan: Il Castoro S.r.l, 2001); Simone Venturini, ed., *Il Restauro Cinematografico: principi, teorie, metodi* (Pasian di Prato: Campanotto Editore, 2006).

Teoria e metodologia del restauro cinematografico,[4] included articles from archives' point of view, as well as more theoretical articles from academics. The approach imagined an ethical framework for a restoration which considered film not only as content, but also as a carrier. Pushing this framework further, Paolo Cherchi Usai (co-founder of *Le Giornate del cinema muto* Festival in Pordenone in 1982, archivist and curator), inspired by art conservation, insisted that all prints were unique and should be treated as such. He thus qualified a restoration only as a simulation.[5] These theoretical bases interacted since early on with the concept of digital, notably in determining if a disruption had occurred or not, as they were developed almost simultaneously with digital technologies and discourses.

During the 2000s, while digital technologies were gaining more ground in film restoration, the need for a clearer theoretical framework for restoration ethics was evoked in several publications.[6] The works published on the digital transition treated the arrival of digital technologies either as a disruption, or as a continuous pattern in film technology. The first point of view, as defended by Cherchi Usai,[7] adhered to a more general school of thought on digital image and digital manipulation in cinema and photography, where these were considered to have changed nature; digital cinema was not cinema anymore.[8] The second view was promoted most notably by Giovanna Fossati, Leo Enticknap and Rossella Catanese. Fossati's seminal work, *From Grain to Pixel*,[9] offered a dynamic theorisation of film restoration and its ethics, in view of its transition into digital. She identified several frameworks corresponding to different contexts and included the technological aspect of film restoration in the discussions. Being herself an archivist as well as an academic, Fossati's approach was pragmatic and theoretical at the same time, and it paved the way for all subsequent research in the field. Leo Enticknap (University of Leeds), who also had practical experience in archives, tried to fill the gap between archives and academia, and most notably, by emphasising the technological "roots" of

---

[4] Gian Luca Farinelli and Nicola Mazzanti, *Il Cinema Ritrovato, Teoria e Metodologia del Restauro cinematografico* (Bologna: Grafis Edizioni, 1994).
[5] Paolo Cherchi Usai, *Burning Passions: Introduction to the Study of Silent Cinema*, 1st ed. (London: British Film Institute, 1994); Paolo Cherchi Usai, *Silent Cinema: An Introduction*, 1st ed. (London: British Film Institute, 2000); Paolo Cherchi Usai, 'Film as an Art Object', in *Preserve Then Show*, ed. Dan Niseen et al. (Copenhagen: Danish Film Institute, 2002), 22–38.
[6] See: Mazzanti, 'Footnotes'; Sabine Lenk, 'Pour une théorie de la restauration de films', Mediologie, 2008, https://sites.google.com/view/mediologie/m%C3%A9moire-et-m%C3%A9dias/sabine-lenk, accessed 30 May 2020.
[7] Paolo Cherchi Usai, 'The Demise of Digital (Print #1)', *Film Quarterly* 59, no. 3 (2006): 3.
[8] See for example: William J. Mitchell, *The Reconfigured Eye* (Cambridge, MA: MIT Press, 1992).Rodowick, *The Virtual Life of Film*.
[9] Fossati, *From Grain to Pixel: The Archival Life of Film in Transition*, 2009.

films and trying to make these roots more visible in film studies.[10] He also underlined the multiplicity of film and restoration practices, which had subsisted from photochemical to digital cinema. Rossella Catanese also joined in this point of view, by considering the continuity between photochemical and digital image as an analogy between their outputs, characterised by social practices.[11] The search for a theoretical basis for restoration was also the main focus of Marco Pescetelli's 2010 PhD dissertation,[12] which went in a more philosophical direction, regarding film restoration as an interpretative discipline.

From a historical point of view, Marie Frappat's 2015 PhD thesis, *L'invention de la restauration des films*, retraces the histories of different restoration practices since the early days of cinema.[13] Scholar Simone Venturini (University of Udine) has also underlined the importance of a historical/archaeological study of restoration as restored "editions" of films are a product of their immediate cultural milieu.[14] From a technical point of view, the major work is Mark-Paul Meyer and Paul Read's book published in 2000, *Restoration of Motion Picture Film*,[15] which resulted from a collaboration between archives, laboratories and technologists within the Gamma Group (to which I will come back further in this chapter). It provides a valuable source for information on photochemical techniques – with an eye on ethical issues.

In this chapter, I will address what remains unexplored in this literature: the link between concepts of film restoration and the adoption of related digital image technologies. In other words, restoration is studied here at the crossroads of history of technology and history of film archives. While inspired by the works mentioned above, my analysis here will go beyond the

---

[10] Leo Enticknap, *Film Restoration. The Culture and Science of Audiovisual Heritage* (New York: Palgrave Macmillan, 2013). See also: Leo Enticknap, *Moving Image Technology: From Zoetrope to Digital* (London and New York: Wallflower, 2005).

[11] Rossella Catanese, *Lacune binarie. Il restauro dei film e le tecnologie digitali* (Rome: Bulzoni, 2013); Rossella Catanese, 'The Digital Restoration of Film', *BiD: Textos Universitaris de Biblioteconomia i Documentació*, no. 33 (December 2014), http://bid.ub.edu/en/33/catanese3.htm, accessed 30 May 2022.

[12] Marco Pescetelli, 'The Art of Not Forgetting: Towards a Practical Hermeneutics of Film Restoration' (PhD Thesis, London, University College London, 2010).

[13] Marie Frappat, 'L'invention de la restauration des films' (PhD Thesis, Paris, Université Sorbonne Nouvelle Paris III, 2015).

[14] Simone Venturini, 'Introduzione', in *Il Restauro Cinematografico: principi, teorie, metodi*, ed. Simone Venturini (Pasian di Prato: Campanotto Editore, 2006). The position of researchers from University of Udine is particular thanks to its specialised lab (La Camera ottica), and to the fact that film restoration is studied under two research axes of "Film and Heritage" as well as "Media Archeology". See for example: Simone Venturini, 'Tecnologie, tecniche, testi. Problematiche teoriche e metodologiche di restauro del film sonoro italiano dei primi anni Trenta', in *Svolte tecnologiche nel cinema italiano*, ed. Sandro Bernardi (Rome: Carocci editore, 2006), 49–66; Simone Venturini, 'La Restauration de films : une Histoire (post-)moderne', *Techné*, no. 37 (2013): 97–101; Della Rovere et al., 'Behind an Experimental Film Heritage: Preservation and Restoration Protocols and Issues'.

[15] Read and Meyer, *Restoration of Motion Picture Film*. This book was edited by Meyer and Read on behalf of Gamma Group, whose activity I will extensively discuss later in this chapter.

disruption/continuity dilemma, and focus on the socio-cultural patterns of technological adoption by adopting an archaeological approach (also enabled by my historical distance to the subject), rather than a theoretical or philosophical one. In methodology, I draw inspiration both from Fossati's social study of technologies and Frappat's approach based on historical cultural practices, while I insist more specifically on a study of attempted and adopted sciences and technologies (digital or photochemical) behind film restoration practices and how that changed the concepts of film restoration.

Throughout this chapter, I will demonstrate how the process of technological adoption in archival imaginaries went from being a quest towards "better" images, to a more hybrid approach of theoretically- and culturally-framed adoption of some technological developments over others. My analysis will illustrate how, during this first period of the integration of digital image technologies in archival practices, digital was considered as an invisible, intermediate step, entailing specific theoretical assumptions; which would then undergo modifications. It will also reveal how the changing scientific and archival discourse networks met and mutually influenced each other in this process. While archival discourses inspired certain tendencies in the development of technologies, the scientific and technological discourses also had an impact on the archival concepts and practices. To explore that, I will go into the details of the scientific basis of the image technologies, as well as their technological implementations (software and hardware), providing a comprehensive view of the dynamics of a discourse network. Through that, I will insist on how different scientific and technological directions were tested before some were adopted and some rejected, and how the dominance of some scientific views influenced the archival views.

In sum, my aim in this chapter is to show how interactions and continuous dialogue between film archives, technology providers and scientific research played a crucial role in digital film restoration's eventual adoption; how the adoption, itself, was a constantly-changing process with many steps of adaptation; and how both archival and scientific imaginaries changed in the process.

1 Archives, Restoration, and the Way They Were

Digital image technologies have been used in film archives since the 1990s. But before that, film archives had a rich historical existence, through which they had constantly mutated. Based on this history, their discourses and practices had been shaped in a dynamic way which interacted with their socio-cultural context. In this subchapter, I summarise firstly the evolution of restoration practices up to the 1990s. Then, I evoke the archival reactions to new technologies before digital; namely videotapes. Finally, I offer an overview of the professionalisation of film archives during the 1980s which was changing the overall archival landscape. This serves as an introduction to illustrate the archival imaginary before the 1990s, and understand thereafter how already-existing discourse networks were enriched and altered by further archival publications, research groups, presentations, projects, etc.

1.1 For a History of Film Restoration Practices: In Quest of a "Better" Image?

As several scholarly studies have suggested,[16] film restoration has had a complex history and has included several practices, sometimes without bearing the name restoration. It has been defined in a broad way by Meyer and Read:

> "When we speak […] about restoration we mean the whole spectrum of film duplication, from the most simple duplication with a minimum of interventions up to the most complex ones with a maximum of manipulations."[17]

Such a definition englobes practices going from a simple duplication to complex reconstructions, each corresponding to different socio-technical constraints as well as cultural purposes: to reissue a film, prepare it for projection in different technical and contextual circumstances, adapt it to new audiences,[18] safeguard it, exchange it with other archives, etc. Films could indeed be re-presented in several different technological forms and in various spaces, such as commercial theatres, ciné-clubs, cinémathèques, schools, community centres, temporary or itinerant cinemas, even at home. While it was possible to re-run old prints in some cases, in many others, it was necessary (or desired) to obtain new prints by duplicating films. The duplication could either produce new 35mm prints, or opt for 16mm, 9.5mm or 8mm reductions, according to the equipment available in different exhibition spaces as well as the goal of film's re-presentation. Many studies have illustrated examples of these diverse practices.[19] These practices share the goal to present films again, be it for commercial reasons or as an attempt to promote or expand the understanding of film history.

---

[16] Fossati, *From Grain to Pixel: The Archival Life of Film in Transition*, 2009; Frappat, 'L'invention de la restauration des films'; Enticknap, *Film Restoration. The Culture and Science of Audiovisual Heritage*.
[17] Read and Meyer, *Restoration of Motion Picture Film*, 1.
[18] See: Eileen Bowser, 'Some Principles of Film Restoration', *Griffithiana* 13, no. 38–39 (October 1990): 170–73.
[19] For use of film in classrooms, see: Eef Masson, *Watch and Learn: Rhetoric Devices in Classroom Films after 1940* (Amsterdam: Amsterdam University Press, 2012). For different uses of 16mm film in distribution, see Jan Christopher Horak, 'Archiving, Preserving, Screening 16mm', *Cinema Journal* 45, no. 3 (2006): 112–18. For more examples of non-theatrical film exhibition, see: Maria Vélez-Serna, *Ephemeral Cinema Spaces. Stories of Reinvention, Resistance and Community*, Film Culture in Transition Series (Amsterdam: Amsterdam University Press, 2020).

The film industry itself followed different strategies to re-commercialise old films for further theatrical exhibition. Re-releasing was one of these strategies which would recreate prints of old films. Some films would have modifications in colour, sound, or editing, and some would remain generally similar to their old prints. Many classic films were regularly re-released, such as *Snow White and the Seven Dwarfs* (produced by the Walt Disney Company, 1937), which had eight US re-releases in 1944, 1952, 1958, 1967, 1975, 1983, 1987 and 1993;[20] the latter being a specific case which I will explore later in this chapter. The films could undergo technical modifications upon their re-release. Alfred Hitchcock's *Dial M for Murder* (1954), which had been produced in 3D but shown only on few occasions as such in 1954, was re-released in 1980 in 3D again. However, it was reproduced not in its original 3D system (two prints – one for each eye – with polarised glasses), but as a single-strip side-by-side StereoVision print, a 3D system from the late 1960s.[21] From the 1950s, television (and later video) market would also require reproduction of old films in order to re-present them on television or transfer them to video. This, too, might bring about changes to the editing or technical aspects of the film (colour, aspect ratio, etc).[22] Duplication could make use of different sources: original negative(s), internegatives, prints, etc., influencing the image quality and look.[23]

The various practices mentioned above were conducted not only by film industry or other organisations, but also very frequently by film archives. Exchanges between archives in many cases required a duplication.[24] It was commonplace too to duplicate from unusual formats (such as 28mm or 90mm) to a more common format (35mm), in view of their projection on modern equipment,[25] or simply for preservation. Other practices included, for instance, the replacement

[20] https://www.imdb.com/title/tt0029583/releaseinfo, accessed 2 June 2020. The film was also re-released in other countries regularly, and not necessarily in the same years as in the US. A more detailed list of *Snow White*'s rereleases in different countries can be found at: https://filmic-light.blogspot.com/p/release-dates.html, accessed 2 June 2020.

[21] For more information on this film (and on 3D in general), see: http://www.3dfilmarchive.com/dial-m-blu-ray-review, accessed 2 June 2020. The film was also digitally restored in 3D in 2011.

[22] Scholars such as Enticknap have noted the television reformatting of films: Enticknap, *Film Restoration. The Culture and Science of Audiovisual Heritage*, 12–13.. This can also be attested by the existence of television prints at film archives. For an early technical presentation of the challenges of showing films on television, see: John H. Battiston, *Movies for TV* (New York: The MacMillan Company, 1950).

[23] These two notions will be thoroughly discussed in Chapter Two. At this point, I am using them in a non-scientific manner, indicating their first apparent meaning.

[24] For more information about film exchange programs inside FIAF, see Bregt Lameris, *Film Museum Practice and Film Historiography. The Case of the Nederlands Filmmuseum (1946-2000* (Amsterdam: Amsterdam University Press, 2017), 47–49.

[25] See for example: Ross Lipman, 'Problems of Independent Film Preservation', *Journal of Film Preservation*, no. 53 (November 1996): 49–58; 'Joint Preservation Project: Rochester-Bologna', *Bulletin FIAF*, no. 45 (October 1992): 22. A historical study of the format change (in the 1940s and 1950s) in the US and in France is given by Frappat, 'L'invention de la restauration des films', 111–56. A specific case of this is the reproduction of paper

of a damaged print, the creation of step-printed versions of silent films (to match the 24fps framerate of contemporary projectors) and the duplication from nitrate to safety material for preservation. These practices were routine, and their systematic execution gained more momentum from the 1980s in many European film archives. According to Frappat, the term restoration became commonplace in film archives from this time onwards to define a methodical intervention on films,[26] and, accompanying a flourishing interest for presenting old films, it led to a so-called restoration boom during those years. Many highly publicised (and sometimes controversial) restorations were conducted during this time. An early, mixed technical and theoretical framework for unifying different restoration practices was defined, which re-evaluated the relationship between the restored film and its original:

> "Restoration is the more stringent procedure, and it includes aspects of preservation, that is transferring the visual or sound content of the material on to a format in order to preserve it or restore it to something like its original quality."[27]

The content, or as Fossati has proposed, the conceptual artefact[28] could be detached from its materiality in order to continue existing on a new carrier, while the image (whether projected or on the film) needed to look similar to what it had been. According to how the original was defined, the detachment between material and conceptual film could introduce irreversible changes to it. The concept of original, though not uniquely defined, was a keyword in restoration during the 1980s, as explained by Vincent Pinel (Cinémathèque française, 1983-1991):

> "To restore a film is to re-establish it in the nearest formal state to its original presentation."[29]

Pinel did challenge the concept of original by asserting that uncertainties might persist regarding it: whether the film should be restored as the audience saw it or as the director intended it?[30] The answer to this question could yield diverse visions of restoration,

---

prints on 35mm, see: Carl Louis Gregory, 'Resurrection of Early Motion Pictures', *Journal of the Society of Motion Picture Engineers* 42, no. 3 (March 1944): 159–69.

[26] Marie Frappat, 'Pour une histoire de la restauration des films : des premières reconstructions aux interventions en numérique' (Festival Toute la mémoire du monde, Cinémathèque française, Paris, 2015).

[27] Helen P. Harrison, 'Preface', in *Joint Technical Symposium 1987: Archiving the Audiovisual Heritage*, ed. Eva Orbanz, Proceedings of the 2nd JTS in Berlin on May 20-22, 1987 (Berlin-West: Stiftung Deutsche Kinemathek, 1988), 8.

[28] Giovanna Fossati, 'Obsolescence and Film Restoration: The Case of Colored Silent Films', *Techné*, no. 37 (2013): 103–6.

[29] Vincent Pinel, 'Pour une déontologie de la restauration des films', *Positif* 421 (1993): 90. My translation.

[30] Vincent Pinel, 'The Responsibility in Daily Work', in *Joint Technical Symposium 1987: Archiving the Audiovisual Heritage*, ed. Eva Orbanz, Proceedings of the 2nd JTS in Berlin on May 20-22, 1987 (Berlin-West: Stiftung Deutsche Kinemathek, 1988), 144–46.

corresponding also to different functions. But by then, the focus on original was mostly understood with regards to the conceptual film, and it did not aim a recreation of original image technologies in their material existence on film or in projection. Given the multiplicity of technological solutions during the 1980s, restoration practices always altered the original material film: the same film stock or film technologies were rarely available anymore, because newer technologies commonly replaced older ones when they were introduced. In what follows, I argue that the discourses and practices of film duplication and restoration were often nurturing a rhetoric of better image, a concept which later became polemical with the use of digital image technologies in archival restorations.

Towards a "Better Image" in Restoration Practices

In 1984, *Becky Sharp* (Rouben Mamoulian, 1935) was restored under the supervision of Robert Gitt (UCLA Film archives):

> "Thanks to today's superior film stock, we succeeded to a greater extent than did Technicolor in 1935; indeed our dupes, cut into Becky Sharp, match the surrounding footage quite well, whereas the dupes made by Technicolor for effects are rather harsh and very grainy."[31]

According to Gitt, the new film stock used for this restoration, which was Eastman 5384, was "superior" in quality to the film's original film stock. By that, he referred to the sharper and less grainier images that could be obtained by Eastman 5384 (a later generation of Eastman 5381 from 1972). Introduced in 1982, this product was promoted as "the culmination of many years of research and development efforts in the areas of dye stability, film lab productivity, ecology practices and image quality".[32] Technically, it is certain that the new stock created different-looking images. Because of its increased sharpness and finer grain, it was promoted as better by the manufacturer, Kodak, and also judged as superior by many archivists (such as Gitt). With the characteristics of Eastman 5384, and departing from three-strip nitrate negatives for most of the film, the restoration of *Becky Sharp* "ensured minimum loss of quality, in terms of grain, sharpness and good highlight and shadow detail, through elimination – wherever possible – of additional print generation".[33] This way, an image was obtained which, according to Gitt, looked "better" than the original prints. The problem with the word "better" is that it

[31] Robert Gitt and Richard Dayton, 'Restoring Becky Sharp', *American Cinematographer* 65, no. 10 (November 1984): 103.
[32] John Waner, 'Report on the New Eastman Color Print Film', *American Cinematographer* 63, no. 4 (April 1982): 391.
[33] Gitt and Dayton, 'Restoring Becky Sharp', 106.

needs to be positioned in a fixed, neutral, referential framework, which was missing in the case of archival preservation work conducted between different technological systems. It was however quite a common expression. The same goes with another restoration by Gitt, that of *The Night of the Hunter* (Charles Laughton, 1955):

> "The restored prints contain no new scenes, but they can truly be called 'new and improved'. As Gitt explained, 'printing technology has improved so much in the last fifty years that the new prints are actually slightly better than the 1955 prints made off the same negative'. The sharpness and depth of the image restore the range of grays in, for instance, a picnic sequence of dappling sun that reveals Laughton's Impressionistic sense of light. Also more sharply defined now are scenes of high contrast, studies in the art of chiaroscuro: houses lit up against the night or the preacher riding a horse on the horizon, singing a hymn to the dawn."[34]

The same criteria of sharpness, as well as a focus on more details were mentioned in order to qualify the restoration, obtained through newer technologies of film stock and printing, as superior to the original prints. It seemed that the particular look of the original print, defined partly by technical possibilities of the time, did not need to be reproduced but "improved". It was visibly considered inferior according to the new dominant vision in the 1980s, which promoted finer grain and sharper images. The look created by the new film stock and printing technologies was appreciated by Michael Friend (Academy Film Archives) at the dawn of digital technologies:

> "Improvements in all parts of the chain of duplication technology (printers and processes such as step contact and wet gate priming, better film stocks, better lenses for optical copying, and now, various digital tools) have made it possible to extract ever more information from the original negative, and hence to make improvements in the presentation of older films in their original format as well as in ancillary media."[35]

This statement illustrates how the closeness to the original print look was not a concern in the technologically-changing landscape of cinema. It was rather believed that the more details that could be extracted from the old negatives, the better would be the new presentation. Historically, thus, it was commonplace to use new technologies in order to create finer-grain, sharper and more detailed images (compared with original prints) out of the same negative or intermediate elements. Such an image was regularly qualified by archivists and industry actors

[34] Jeffrey Couchman, 'The Night of "The Night of the Hunter"', *Journal of Film Preservation*, no. 64 (April 2002): 7.

[35] Michael Friend, 'Film/Digital/Film', *Journal of Film Preservation*, no. 50 (March 1995): 38.

as better or superior.[36] According to Fossati, when an archival film is restored "as closely as possible" to the original print, but with "different technologies" of film stock and equipment, it is to be considered a "simulation",[37] which implies that the images cannot be identically reproduced. Of course, different film stock technologies result always in different images (in terms of granularity, sharpness, colour stability, contrast, etc.); but does this difference indicate necessarily an improvement? How does that relate to the concept of original? These questions will resonate throughout this thesis. The so-called better image, which did not aim to reproduce the original print, was generally used as an obvious statement by archivists; but it should be re-contextualised within a history of film stock manufacture and mainstream cinema vision where finer grain, sharpness or more details were associated to technical superiority of an image over another (beyond aesthetic considerations).

The FIAF Preservation Commission[38] was actively involved in the search for new film stock technologies during the late 1980s and the early 1990s, notably by elaborating a catalogue of film stocks. In 1990, a Commission member, Peter Williamson (Museum of Modern Art – MoMa) met with Agfa Gevaert film manufacturers "regarding the company's interest in the general needs of film archives, particularly in the area of possible changes in film stock characteristics". According to the commission report, "there were extensive discussions of the duplication of black-and-white films. The general need for improved grain structure, sharpness, flare characteristics, shape of the characteristics curve, and exposure latitude were noted by Agfa".[39] The technical details in this description illustrate what the archives were looking for, which, in their eyes, would bring improvement to the quality of their reproductions. In this, their vision was aligned with that of the film stock manufacturers where a sharper, cleaner image was considered superior.

The so-called improvement in image quality of restored films because of new film stock or printing technologies did not remain unchallenged and generated some (rare) critical reactions. In 1989, the *Sight & Sound* magazine called this practice "hyper-restoration":

---

[36] This phenomenon has been mentioned before by scholars: Sabrina Negri, 'Simulating the Past. Digital Preservation of Moving Images and the "End of Cinema."', *Cinéma & Cie: International Film Studies Journal* 16, no. 26–27 (2016): 45–53; Enticknap, *Film Restoration. The Culture and Science of Audiovisual Heritage*; Frappat, 'L'invention de la restauration des films'; François Albera, 'Restaurez, restaurez, il en restera toujours quelque chose', *1895*, no. 40 (2003): 89–101.

[37] Fossati, *From Grain to Pixel: The Archival Life of Film in Transition*, 2009, 142.

[38] The Preservation Committee of FIAF, formed in the early 1960s, changed its name to FIAF Technical Commission (TC) in 1993.

[39] Henning Schou, 'Report from the Preservation Commission', *Bulletin FIAF*, no. 41–42 (January 1991): 17–18.

> "For the London Film Festival in 1985, however, the [BFI] Archive produced a new print of [*Gone to Earth* (Michael Powell and Emeric Pressburger, 1950)] which Michael Powell declared to be closer to his initial intention in terms of color printing, than he had been able to obtain in 1950. There's hyper-restoration for you."[40]

Indeed, as explained by Enticknap, the restoration of Powell and Pressburger's Technicolor films in the 1980s gave a "better contrast and resolution" than the 1940s' Technicolor prints, for which the quality control "was notoriously unreliable".[41] In a memorial lecture organised by the British Kinematograph, Sound and Television Society (BKSTS) in October 1999, Clyde Jeavons (former curator of BFI archives and an active member of FIAF) recalled the *Gone to Earth* restoration as the realisation of "what the director wanted", and therefore ethically-justified.[42] Verifying if indeed Michael Powell was unsatisfied with the original prints at the time goes beyond the scope of this work, but apparently some thirty years later, he, alongside BFI archivists, had a preference for the new look created by the technologies of the 1980s. Despite some shy resistance such as *Sight & Sound*'s "hyper-restoration" concept, it seems that the status of original prints as reference did not apply to the look of the images and their characteristics such as sharpness or graininess. In fact, the look of the images was hardly discussed from an ethical point of view. The archival community did question the concept of original,[43] but always from the point of view of the film's content and form, for instance regarding additions such as colourisation.[44] At the Joint Technical Symposium (JTS) in Berlin

[40] Alan Stanbrook, 'As It Was in the Beginning', *Sight & Sound* 59, no. 1 (1989): 32. See also: Andrew Pollack, 'Digital Film Restoration Raises Questions About Fixing Flaws', *New York Times*, 1998.

[41] Leo Enticknap, 'Electronic Enlightenment or the Digital Dark Age? Anticipating Film in an Age Without Film', *Quarterly Review of Film and Video* 26, no. 5 (October 2009): 415–24.

[42] Clyde Jeavons, 'Film Preservation – Why Bother? Part Three', *Image Technology* 82, no. 4 (May 2000): 17.

[43] For example, the FIAF Symposium in Canberra in 1986 was dedicated partly to "Technical and Ethical Problems of Film Restoration".

[44] This is a rhetoric stand that was notably visible in trends such as the colourisation of black-and-white films during the 1980s, most notoriously by Ted Turner (Turner Entertainment) but also by other American studios (Sony Entertainment, 20th Century Fox, etc). The practice was not limited to American companies nor to the 1980s, and it did find some uses much later in other countries, for example in India for the 2004 restoration of *Mughal-e-Azam* (K. Asif, 1960); or in Azerbaijan for *The Cloth Peddler* (Rza Tahmasib, 1945, colourisation done in Hollywood in 2013 with a funding from the Heydar Aliyev Foundation). Colourisation has always been a very controversial practice, and it was almost banished by the end of 1990s. The practice remains still in use notably for found footage films, recent examples being *Apocalypse, la Seconde Guerre mondiale* (France 2 Documentary, Isabelle Clarke and Daniel Costelle, 2009) and *They Shall Not Grow Old* (Peter Jackson, 2018), and it regularly creates controversies. For a history and analysis of colourisation from the point of view of film archives, see: Slide, *Nitrate Won't Wait: A History of Film Preservation in the United States*; Frick, *Saving Cinema: The Politics of Preservation*. For a discussion of colourisation from the historians' point of view, see: Laurent Véray, *Les Images d'archives face à l'Histoire. De la conservation à la création* (Paris: SCEREN-CNDP-CRDP, 2011).

in 1987, a panel was organised on "Ethics of Film Restoration" which aimed to provide answers to some questions of this type:

> "How far should an archivist go in 'enhancing' archival material to make it more acceptable, playable or viewable to today's and the future public. Have the techniques of 'colorization' and other 'improvements' any place in the work of an archivist, and if they haven't, what should the archivist be doing about it: should he ignore it, protest or ensure that he at least is saving material which is as close as possible to the original intention of the people who created it?"[45]

What was called "improvement" and "enhancement" seemed to go against the concept of original (as the conceptual film) and was thus highly doubted by archivists. However, it did not question the actual image technologies regarding film stock or equipment and the kind of image modification that it would produce. The specific image "improvements" (such as increased sharpness), as claimed by Michael Friend and Roberto Gitt, were not included in the ethical discussions on original. This was to change later, when faced with digital technologies, as I will show further in this chapter.[46]

1.2 Archives and New Technologies: The Case of Video

By the 1990s, archives were already exposed to some new image technologies other than film, in the form of video. Questions had been raised if video material needed to be collected by film archives, whether video technologies could contribute to archival practices, etc. In 1978, the FIAF symposium in Brighton, organised by David Francis (National Film Archives), presented a half-day reflection on "Film to tape, tape to film: The Present and the Future". This part of the symposium was largely overshadowed by its parallel programme on early silent cinema, "Cinema 1900-1906", in the following years. Nevertheless, at the time, it presented a new look on the technological basis of cinema, and contributed to the proliferation of such discourses in the archival imaginary. This symposium was said to serve two functions:

> "Firstly to show how non-broadcast standard videotape can be used for access and research purposes in the Archive and how such tapes can be easily and cheaply produced utilising a Steenbeck or a projector: secondly to keep delegates up-to-date with

[45] Harrison, 'Preface', 7.

[46] This point is noted by Enticknap, *Film Restoration. The Culture and Science of Audiovisual Heritage*, 157. According to him, the photochemical duplication of nitrate film on safety material didn't cause a row at the time because "nitrate stock was not available anymore". This, of course, remains a valid point regarding the general technological framework of film restoration.

> developments in the tape industry which might have a future bearing on the safeguarding of film and television images."[47]

The idea of openness to (hypothetic) new technologies was already present in archival discourses by 1978. At this time, the new technology was videotape; and it was changing constantly. So, the symposium organisers wondered, there could be a future possibility where videotapes (or, in general, electronic imaging) would replace film as archival material; which would, by the way, rid archives of the numerous problems of film conservation. More importantly, the symposium also presented a comparative demonstration of films, with and without use of video as an intermediate step. This possibility of using (new) technologies other than film, in a film-video-film workflow, had therefore been evoked in archival discourses at least since 1978.

During the 1980s and 1990s, video was in fact considered principally as a dissemination media (by both generalist film archives and mainstream film industry). A niche (experimental) film production on video did exist but that did not seem to challenge much traditional film's existence nor its claimed superiority as an image recording medium. Despite that, the topic of videotapes was regularly subject to discussion within the archival community. Members of the FIAF Preservation Committee would visit video companies and film archivists would engage in discussions with video and television archives. For example, at the 1990 Joint Technical Symposium, in which many film archives participated, there was a presentation on electronic correction of films for television with the aid of computers by Don Kershaw (BBC's post-production unit).[48] In 1992, there was an open forum in *FIAF Bulletin* on "Video in Film Archives?", where one positive answer and one negative answer were published. While Steven Ricci (UCLA Archives) applauded the possibilities video would offer in terms of access and research, and acknowledged the existence of certain documents only on video formats, Mary Lea Bandy (Film Preservationist at MoMa) was more sceptical:

> "So far I have heard no sufficiently forceful or convincing arguments to persuade us to alter what has been our focus since 1935: to collect, preserve, and exhibit film as it was originally produced and shown. Preservation and public access should continue to follow established archival practices."[49]

---

[47] 'Programme of the Symposium: "Cinema 1900-1906" and of the Symposium: "From Film to Videotape and from Videotape to Film"', FIAF 1978 Brighton Congress Report (Brussels: FIAF, 1978), Appendix 14.

[48] Don Kershaw, 'Electronic Correction of Archive Film', in *Archiving the Audiovisual Heritage. Third Joint Technical Symposium*, Proceedings of the 3rd JTS in Ottawa on May 3-5, 1990 (Rushden: Stanley L Hunt (Printers), 1992), 161–63.

[49] Mary Lea Bandy and Steven Ricci, 'Video in Film Archives?', *Bulletin FIAF*, no. 45 (October 1992): 35.

This idea, expressed here towards video material, would remain one of the main arguments countering the integration of digital technologies in film archives. It shows that even before the availability of digital technologies for archives, archivists were confronted with new technologies and held strong diverse (sometimes opposed) positions concerning their adoption or rejection as part of archival practices.

1.3 Professionalisation of Archives: Construction of an Epistemic Discourse Network

In October 1980, UNESCO published its recommendation for safeguarding and preservation of moving images, on which FIAF had been working for a few years.[50] This helped to accelerate the political recognition as well as professionalisation of film archives at national and international levels. Several film archives underwent structural and identity mutations in the years leading up to the 1990s. Geo-political developments in many areas of the world[51] contributed to the changing landscape of film archives. More regional or thematic film archives were created.[52] The ever-more presence of newer audiovisual technologies, such as video, cast doubt on the missions of archives and presented the need to extend their scope. These changes inspired many discussions during the FIAF congresses and in *Journal of Film Preservation* in the beginnings of the 1990s, culminating in a questioning of FIAF's identity and future.[53]

The professionalisation of archives was praised by Ray Edmondson in the editorial of *FIAF Information Bulletin* in 1991:

> "One important evidence of this growth and maturing is that there is now a literature of film and television archiving (and audio archiving, too, if we look into a closely related field). Around the world, there are the written policies, standards and procedures of individual archives. There are FIAF's own publications, guidelines and statutes. There is the UNESCO 'instruments', there are training courses and 'how to' manuals. Policy and ethical issues are aired regularly in film, television and other journals. All this amounts to a considerable body of knowledge, and suggests that worldwide there are

---

[50] UNESCO, 'Recommendation for the Safeguarding and Preservation of Moving Images', adopted by the General Conference at its twenty first session (Belgrade: UNESCO, 27 October 1980). See also: Wolfgang Klaue, 'Wolfgang Klaue on the UNESCO Recommendation for the Safeguarding and Preservation of Moving Images', *Journal of Film Preservation*, no. 100 (April 2019): 41–42.

[51] In Europe, many countries gained independence following the fall of the Soviet Union. Others underwent radical political mutations. The German unification, for instance, brought about the fusion of State Film Archive of the GDR and Bundesarchiv (West Germany).

[52] For example, the Cinémathèque de Bretagne was founded in 1986.

[53] Wolfgang Klaue et al., 'The Future of FIAF', *Journal of Film Preservation*, no. 51 (November 1995): 2–28.

now many hundreds of people who would regard themselves as professional film or TV archivists."[54]

These publications and projects did not start in the 1980s, but much earlier, at least since the 1960s, when the FIAF Preservation Committee was created and started researching film archiving subjects. However, the progress accelerated in the 1980s, and there were particularly more possibilities for knowledge exchange among archivists.[55] By the late 1980s, as put by Edmondson, a significant "body of knowledge" had been formed, and collaborations with universities contributed to enrich the technical knowledge of film archiving.[56] Then, the beginning of the 1990s witnessed the creation of some new training programmes on film archives. In 1990, a training programme in Bologna prepared a group of young people with the goal of creating a film laboratory[57] specialised in restoration at Cineteca di Bologna. L'Immagine Ritrovata was born out of this training initiative in 1991. In 1990, the first university programme in film archiving in University of East Anglia was created, and in 1993, the film conservation and restoration curriculum of HTW Berlin (University of Applied Sciences) was founded.[58] In 1995, Ray Edmondson, who was already writing a text on the Philosophy of Audiovisual Archiving several years prior,[59] considered that with all the recent developments, film archiving was on the right track to become a profession, that the "essential qualities" were already there, but some links were still missing, asserting that "[archives] need a more formal and obvious framework than [they've] had in the past to enable [the] field to grow properly".[60] The progress in the film archiving field was then in full swing, many unexplored areas were to be delved into, and theoretical, philosophical and ethical discussions were to attain a higher place. These changes in the archival landscape were accompanied also

[54] Ray Edmondson, 'Guest Editorial: Towards a Philosophy of Film Archiving', *Bulletin FIAF*, no. 41–42 (January 1991): 6–7.

[55] Notably conferences such as Joint Technical Symposium (1983) and festivals such as Giornate del Cinema Muto (1982) and Il Cinema Ritrovato (1987).

[56] Manchester Polytechnic, for instance, started a research on degradation of cellulose triacetate film (Vinegar syndrome) in the late 1980s. This work continued for some years, and the main researcher Michele Edge also took part later in the FIAF Technical Commission and in many film archival conferences. See for example: Michele Edge and Joan Whitehead, 'The Decay of Polymers in Information Storage Carriers', in *Technology and Our Audiovisual Heritage. Technology's Role in Preserving the Memory of the World. Fourth Joint Technical Symposium*, ed. George Boston, Proceedings of the 4th JTS in London on January 27-29, 1995 (Downbarn: Stantonbury Parish Print, 1999), 19–30.

[57] The lab was in the beginning working also on photography, but it ceased this activity quickly.

[58] For more information, see: Philipp Dominik Keidl and Christian Gosvig Olesen, eds., 'Institutionalizing Moving Image Archival Training: Analyses, Histories, Theories', *Synoptique* 6, no. 1 (2018).

[59] Its first edition, as a UNESCO text, was finally published in 1998 and has since been updated several times. Ray Edmondson, *Audiovisual Archiving: Philosophy and Principles*, 3rd ed. (Bangkok, Thailand: UNESCO, 2016), https://unesdoc.unesco.org/ark:/48223/pf0000243973.

[60] Ray Edmondson, 'Is Film Archiving a Profession?', *Film History* 7, no. 3 (1995): 245–55.

by a relative augmentation of public funding for archives, particularly in Europe; which, in turn, accelerated the professionalisation.

On the European front, the beginning of the 1990s was a particularly fruitful period. As a regional subgroup of FIAF, Union des cinémathèques européennes (UCE) had been formed in 1987 but remained in an embryonic state. During a meeting in San Sebastian on September 20-22, 1990, its name was changed to Association des cinémathèques de la communauté européenne (ACCE)[61] and it was decided that the association should take a more official turn by exploiting its European affiliation in order to seek financial and legislative support from the European Commission. During the 1990 meeting, an ACCE Working group was also created and Cineteca di Bologna took responsibility as its secretariat.[62] At that time, the Working group was composed of representatives from Nederlands Filmmuseum,[63] Cinémathèque royale de Belgique, Service des Archives du Film du CNC,[64] Cinemateca Portuguesa, National Film Archive,[65] Cinémathèque de Toulouse, Filmoteca Valenciana and Cineteca di Bologna.

The first major project that ACCE launched was the Lumière project. Funded by the MEDIA I Programme of the EU (1991-1995), the project supported European archives in their quest for lost films and film restorations, particularly in cases where they could collaborate together. Although financially it represented a minority funding, the project did produce (and encourage) many restorations and incited archives to work more on their collections.[66] At the same time, some archives had also undertaken national plans for their films. For instance, the film archives service of CNC in France, which had already once embarked on an ambitious nitrate safeguarding project in 1982, implemented again in 1990 a new national plan to transfer all its nitrate films onto a more stable support, polyester. The plan was devised by the French Ministry of Culture and Information, which was to finance this operation for 15 years. In 1991, inside ACCE, a European research group of film archives and laboratories was also designated, to be known as the Gamma group in its later years.

---

[61] The name was again changed to ACE (Association des Cinémathèques européennes) in 1996.
[62] 'Regional Meetings: Europe', *Bulletin FIAF*, no. 41–42 (January 1991): 20–23.
[63] Renamed Eye Filmmuseum in 2011.
[64] Centre national du cinéma et de l'image animée (CNC) is the coordinating national organisation for cinema in France. Financed by the French government (Ministry of Culture), it is responsible for the production, promotion and archiving of cinema in France. Its *Archives françaises du film* (AFF) are one of the main film archives in France, in charge of legal deposit, and an active member of FIAF and ACE.
[65] Renamed BFI National Archive in 2006.
[66] A short report of some Lumière restorations was provided by Gianluca Farinelli: Gian Luca Farinelli, 'Restauration sur le vieux continent', *Journal of Film Preservation*, no. 52 (1996): 49–51. See also: Catherine A. Surowiec, *The Lumiere Project: The European Film Archives at the Crossroads* (Lisbon: Guide - Artes Graphica, 1996).

> "The committee comprised senior film archivists and technicians in charge of film conservation departments or working film laboratories within national film archives, together with technicians from commercial laboratories which specialise in archival film conservation and who do not work for national and local archives. The final group consisted of many of the most experienced individuals in their fields."[67]

The research group would seek funding through different EU schemes to run study projects related to film archives. The first project the group undertook, called FILM, focused on film archival education and was financed through the European programme FORCE (which financed projects on continuing education). Several other subjects were studied such as colour (publication in 1998),[68] vinegar syndrome (publication in 2000),[69] film restoration,[70] and of course, new technologies.[71] Gamma Group continued its research until 2002, when it was dissolved because of internal and external conflicts.[72] The main virtue of the group's activities was that it initiated a systematic research collaboration, as well as a practical dialogue, between archivists and film lab technicians, few years before digital technologies found their way into film archives. If FIAF Technical Commission had been collaborating with universities, Gamma group added the third component of the formula: technicians and technologists. In other words, an association of sciences, technologies and archives (as the user group) would be required if new technologies were to be developed, implemented and put to use.

In conclusion, many large-scale projects were in progress by the early 1990s in Europe. Facing the shortcomings and problems unmasked by these operations, European archives seemed to be on the lookout for potential solutions.

---

[67] The description of Read and Meyer's *Restoration of Motion Picture Film,* https://www.elsevier.com/books/restoration-of-motion-picture-film/read/978-0-08-051619-6, accessed 1 January 2022.

[68] Gamma Group, *Tutti I Colori Del Mondo/All the Colors in the World* (Bologna: Diabasis, 2000).

[69] Gamma Group, *Vinegar Syndrome. A Handbook* (Bologna: Gamma, 1998).

[70] This research paved the way for the publication of Read and Meyer, *Restoration of Motion Picture Film*.

[71] Gamma Group, *The Use of New Technologies Applied to Film Restoration: Technical and Ethical Problems*, Caleidoscopo (Bologna: Gamma, 1996). I will come back to this later in this chapter.

[72] In one of the last meetings of Gamma group, a possible overlapping with FIAF Technical commission was mentioned. The existence of upcoming projects – such as FIRST (2002-2004) – was also raised in the discussions, which would explore similar concepts as Gamma Group. As a result, some members of the group could not see the necessity of keeping up anymore; and the proposed initiatives of others did not save the group. This information is extracted from: Nicolas Ricordel, 'Rencontre de Gamma Group dans le cadre du Festival Il Cinema ritrovato', Unpublished Report (Paris: CNC, 4 July 2002).

2 Restoration Goes Digital

By the early 1990s, archives had already established a mixed epistemic and technical framework within which they functioned. This dynamic framework, which shaped the archival understanding of practices such as restoration, was not technologically limited and could potentially integrate newer technologies within its cultural boundaries. The perspective of new digital technologies applied in film restoration not only incited some technical archival experiments, but it also generated a considerable theoretical debate which included the philosophical reflections on the changing image, as well as the necessity of developing an ethical framework englobing the technologies. These early technical and theoretical steps paved the way for an adaptation of new technologies to archival imaginaries, while simultaneously modifying also the latter. In what follows, I will first cover the technical discourses and aspects, before detailing the theoretical reactions of film archives. This will help me present how the technological progress was imagined, and how it was hoped to comply with certain archival requirements; before I can illustrate, in subchapter three, how these early visions corresponded or not to what was going to be implemented.

2.1 Technical Infrastructure: Adopting What Was There?

Throughout film history, many tools and methods have been utilised for special effects and post-production that could manipulate image details.[73] These could, for instance, remove or insert objects in the image, composite images, etc. While technically they could have been of interest in film restoration to remove, for instance, dust and dirt, and provide cleaner, sharper images, the non-digital tools were hardly ever applied in film restoration. Of course, they were mostly tailor-made to specific purposes, but this could not be the only reason why archives did not manipulate their images to get rid of the unwanted damages. In fact, the necessity of image manipulation was rarely mentioned in archival discourses when restorations were carried out with photochemical tools. Dust and scratches could be removed thanks to manual or mechanical cleaning of films before duplication, or through the use of a wet-gate (which could also yield cleaner images as the liquid in the gate would fill in the scratches, preventing their reproduction on the new element). But not much was done to intervene on the details of the images to remove damages, despite the fact that such interventions were potentially possible from a technical point of view.

[73] For descriptions of some special effects methods, see: Raymond Fielding, *The Technique of Special Effects Cinematography*, 4th ed. (Focal Press, 1985); Richard Rickitt, *Special Effects. The History and the Technique* (Billboard Books, 2000).

From the 1980s, image manipulation gained more ground within the television industry when old films were prepared for broadcast, and in higher definitions. Such tools were also modified and adapted to industrial use in special effects by this time; and many machines were created to this end. By the early 1990s, film archives were aware of the possibility of "electronic correction",[74] and followed the technological progress in this domain curiously. As Henning Schou (head of FIAF Preservation Commission) mentioned in the Commission's report in 1991, these technologies were believed by archives to be potentially applicable to film restoration:

> "[…] the original camera footage can be edited on high definition video using digital processing. Special effects and titles can be created through the typical television effects generators. […] This system may be used for restoration of moving images."[75]

Archives' technological curiosity motivated them to join the film industry to discover the possibilities offered by new machines and technologies, developed for special effects, industrial post-production or television. In the following parts, I will first illustrate how early technological systems for special effects were developed and perceived within the larger film industry, and how archives interacted with these machines through a series of scattered experiments. The technologies might have been shared in the beginning, but, as I will argue, the conceptual tensions finally drove archives to conceive their own vision of how a digital restoration machine should be: I will detail how an ideal restoration machine was imagined within the archival community; before moving, in the next subchapter, to the theoretical standpoints of film archives.

2.1.1 Crossing Paths with the Film Industry: Same Machines, Different Goals

From the late 1980s, visual effects were digitised: machines and tools were created which could digitise the image, manipulate it on a digital computer, and finally record the image back on film. The market of digital visual effects saw new players engage in different activities to provide technological solutions. Firstly, there were companies already specialised in digital technologies, such as Quantel. Secondly, main film service providers and labs extended their activities to include a digital intermediate step in film post-production, the most important example being the foundation of Kodak's Cinesite in 1992. I will explain how these companies, despite their different profiles and specialities, held similar discourses on their machines, which, according to them could be put to different uses (special effects or restoration).

[74] The term comes from: Kershaw, 'Electronic Correction of Archive Film'.
[75] Schou, 'Report from the Preservation Commission', January 1991.

Quantel (short for Quantised Television) was founded in 1973 specifically to produce digital equipment for television, such as Analog-to-Digital and Digital-to-Analog converters of video signals. In 1981, they released Paintbox, a computer graphics workstation as a video-in and video-out machine. As it offered the possibility of working on video images, it was widely used in television post-production. In 1993, Quantel presented a new machine, Domino, whose input and output were film, designed specifically for film visual effects and post-production. Domino was presented to film archives at the Joint Technical Symposium in 1995 for its potential use in film restoration. On this occasion, David Scammell, Quantel's Marketing Manager, drew on the company's twenty years of experience in digital technologies in order to promote their machine. He underlined the similarities between visual effects and film restoration, "since many of the techniques that produce stunning visual effects can be used to provide equally stunning repairs to film material that might otherwise be considered past saving".[76]

Domino was a machine with three main components: film scanner, workstation, and film recorder. Photochemically-filmed images could be transferred into the digital domain, manipulated at the intermediate step and finally recorded back to film. Similar to television systems before such as Paintbox, the whole machine was conceived together and it was expected to perform together. Domino was used notably in *The River Wild* (Curtis Hanson, 1994), which needed specific interventions on some scenes:

> "When Meryl Streep tackles white water rapids, her boat is actually safely suspended by wires from a helicopter hovering overhead. The film editor used Domino to get rid of the wires with an electronic airbrush. The river was also a lot less wild than it looks. The editor lifted patches of white water from one part of the picture and duplicated them elsewhere to build a raging torrent."[77]

The same principle of a three-component machine also served as the basis of another machine from the same era, the Kodak Cineon Digital Film System. Cineon was presented in 1993 by Cinesite, Kodak's new laboratory for digital visual effects, founded in 1992. Cineon's development was announced by Kodak already back in 1989 and a prototype was introduced

[76] David Scammell, 'Digital Techniques in Film Image Restoration - The Human Touch', in *Technology and Our Audiovisual Heritage. Technology's Role in Preserving the Memory of the World. Fourth Joint Technical Symposium*, Proceedings of the 4th JTS in London on January 27-29, 1995 (Downbarn: Stantonbury Parish Print, 1999), 145.

[77] Barry Fox, 'Domino effect conquers the big screen', *New Scientist Magazine*, no. 1957 (24 December 1994), https://www.newscientist.com/article/mg14419573-500-domino-effect-conquers-the-big-screen/, accessed 26 April 2020. The elimination of wires could be performed via traditional post-production methods as well. Regularly, they would almost disappear after some duplication steps with the help of specific lights, even though they may have remained visible on the camera negative.

in the autumn of 1991. A film scanner called Genesis, a digital image manipulation workstation (made up of several computers and networks and their corresponding software Cineon), and a film recorder called Lightning constituted the final machine. Like Domino, Cineon's whole architecture was conceived together, and it performed corresponding to a film-digital-film workflow. Cineon and Domino were not supposed to create digital images and leave them in the digital domain. The beginning and end of the workflow were film. The digital technologies were merely there to manipulate the images.

Domino and Cineon came from companies offering two different sets of technological competencies: during the same Joint Technical Symposium in 1995, Kodak's Marketing Manager, Paul Watkins, stressed Kodak's "unrivalled fund in imaging science knowledge",[78] instead of twenty years of experience in digital technologies (which Kodak did not have in 1993). Stemming from diverse scientific sources, the machines were however thought to serve in similar manners. Watkins reiterated the discourse of his Quantel homologue regarding film restoration: "although the initial thrust for digital film techniques came from the features post production and special effects communities, the application of the technology to restoration was a natural extension".[79] The "natural" application to film restoration was of course a debatable statement from both companies, especially considering their potential financial profit in marketing their product this way. What seems more certain to me, is that through digital technologies, the film industry assimilated visual effects and film restoration in a way that they had never done through optical and photochemical technologies. A dive into the technical details of these digital images helps me analyse this statement better.

What supposedly made Cineon and Domino more acceptable for cinema film use, rather than former television imaging systems, was the fact that they scanned, processed and output film images frame by frame and in "high definition", as Schou had mentioned in 1991. The term was not mathematically defined at the time. In this context, definition referred to the quality of an analogue video in terms of the number of horizontally-scanned lines in a video image: SD (Standard Definition), for instance, could indicate either 576 lines or 480 lines per image height. High definition, therefore, could include any new higher definition compared to existing ones. When Cineon was designed, the so-called definition of cinematographic film was calculated by Kodak researchers with regards to a camera negative with an Academy aperture. According to

[78] Paul Watkins, 'Digital Restoration of Film: The Kodak Cineon Digital Film System', in *Technology and Our Audiovisual Heritage. Technology's Role in Preserving the Memory of the World. Fourth Joint Technical Symposium*, Proceedings of the 4th JTS in London on January 27-29, 1995 (Downbarn: Stantonbury Parish Print, 1999), 136–43.

[79] Watkins, 138.

Glenn Kennel (Kodak researcher and technologist), 4000 samples/width were necessary to describe the image details on the negative (also considering a camera's optical characteristics). Beyond the 4000 (=4K) samples per width, the "improvement [was] negligible".[80] There was thus already an intention, on the part of manufacturers, to create digital images which reproduced all the details of a photochemical image inscribed on a 35mm camera negative. Of course, the technical study of Kodak did not aim a total precision, and it did not make a distinction between different negative film stock, but the approximate equivalence between negative image and 4K uncompressed digital image remained prevalent, and was subsequently cited also by archivists in their studies. The development process of such high-definition machines seemed to nurture further the supposition that cinema images are superior to television images. This discourse distinguished the new machines from existing television systems, which could supposedly overcome the challenges of the latter,[81] and thus correspond more to archival practices.

The uncompressed digitised image by the Cineon scanner was called "the Digital Negative", and defined as "a digital representation of the typical negative film".[82] At first called Cineon (.cin), the image format became DPX (Digital Picture Exchange) in 1992. It was developed as a means for "the exchange of digital image data between film, television, and computer systems [which] requires the conversion of the basic image data representations".[83] The digitised image remained in this format throughout the whole operations in Cineon. Destined to act as an intermediate between film and digital imaging systems, the format was designed in a way to maintain "all characteristics of the input camera negative", based on a data metric defined by the "spectral sensitivity of print film (5384), the spectral radiance of a printer […], and a nominal negative film base density (5248)"; or the "printing density", which "is the density on a negative that a print film would 'see' while in a standard printer balanced to a minimum film density".[84] The colour was presented in a logarithmic manner[85] to correspond to the printing density response, and the bit depth and pixel count were also defined in a way to correspond to

---

[80] Glen Kennel, 'Digital Film Scanning and Recording: The Technology and Practice', *Journal of the SMPTE* 103, no. 3 (March 1994): 176.
[81] See for example: Cinesite Digital Film Center, 'Grayscale Transformations of Cineon Digital Film Data for Display, Conversion, and Film Recording', Version 1.1, 12 April 1993.
[82] Cinesite Digital Film Center, 9.
[83] Cinesite Digital Film Center, 3.
[84] David Snider et al., 'Digital Moving-Picture Exchange: File Format and Calibration', *SMPTE Journal* 102, no. 8 (August 1993): 713.
[85] Instead of increasing linearly, the logarithmic colour representation is more sensitive to darker colours, meaning that more shades of black are represented than shades of white. This corresponds approximately to the performance of the human eye, as well as photochemical film.

the "resolutions needed to accurately scan Kodak's newest fine-grain EXR films".[86] These descriptions show how, in the development of DPX, the links with the source photochemical image and photochemical practices were strong. The DPX image format was very rapidly standardised by the SMPTE, and it was also adopted by other similar systems, such as Discreet Logic's Inferno (1995).

The digital image in the film-digital-film workflow of these machines was thus designed as close as possible to the source film image, and it was supposed to remain exclusively at an intermediate step, before being recorded back on film. But its temporary existence enabled digital manipulations, which were designed specifically with special effects in mind. Indeed, the film stock used as a reference for the determination of DPX characteristics were newly-manufactured Kodak stock. So, the format was most suited for the special effects or post production of new films, rather than restoration of old films with their different (mostly discontinued) film stock. However, as noted before, these technologies were also "naturally" marketed for archival use.[87] Archive expert Paul Read also underlined the "natural" extension of Digital Intermediate (DI) to film restoration with the same technical means.[88] Contrary to traditional methods of special effects, which were rarely shared and applied by archives, digital methods were indeed envisaged for archival use as well. Traditional methods were mostly developed in correspondence to specific tasks, while digital methods provided possibilities of manipulating pixels of digitised images by an operator on a workstation, in a manual or automatic way, which could potentially suit different tasks. But the fact remains that the machines were not conceived for archival films, and this could complicate their archival application, as I will demonstrate in the following parts.

2.1.2 Early Archival Experiments: DI for Restoration

By the early 1990s, film archives had already accumulated a considerable discursive and technical background on film restoration. Equipped with a flourishing body of knowledge on the activities they led, they were regularly reinventing and refining them. They were engaged in many preservation projects and had acquired an expertise in photochemical technologies, which also made them aware of their shortcomings. Their initiation to digital technologies at this time, at crossroads with film industry, was crystallised in a series of early archival

[86] Snider et al., 'Digital Moving-Picture Exchange: File Format and Calibration', 712.
[87] Watkins, 'Digital Restoration of Film: The Kodak Cineon Digital Film System', 138.
[88] Paul Read, 'The Digital Intermediate Post-Production Process in Europe', *Journal of Film Preservation*, no. 62 (April 2001): 62.

experiments around 1993 which were conducted almost simultaneously, but in different countries and fulfilling different goals. In what follows, I will detail these experiments in order to show how the early confrontation with industrial machines led archives to identify and formulate their specific needs with regards to film restoration.

Kodak, *Snow White*, and the "Future of Film Restoration"[89]

> "Digital restoration makes a grand entrance as the queen of animated features is re-awakened with a kiss from Cinesite."[90]

At the beginning of 1993, Disney studios, which had been in the midst of a large preservation project of their whole film library since 1987, partnered with Cinesite to perform a restoration of *Snow White and the Seven Dwarfs* in a 4K digital intermediate workflow in view of the film's reissue in July 1993. Having been in contact with Kodak which was developing Cineon, Disney decided to order a digitally-restored one-minute test on the prototype Cineon machine.[91] The test results were considered successful, and Disney greenlit the restoration of the whole film via DI on Cineon. This already hit as a surprise, as the system was designed for fragments not for an entire film, according to Bill Peck (Manager of Advanced Technology Products at Kodak):

> "We felt the initial applications would involve scene salvage and visual effects, including electronic paint or retouching and compositing, mainly for very short sequences […] That was where the greatest need for this technology existed. We initially thought of restoration as a longer-term developmental project because so much computer processing power and memory is required to work at full film resolution."[92]

This view shows how the machines were thought of primarily for effects such as compositing on fragments, rather than a full film restoration. Despite this, the restoration went ahead in Cinesite, and the film was back on domestic screens on 2 July 1993. It was promoted as being the first digitally restored film by a major American studio; presumably the first of the many to come. The success of the restoration, at least discursively, seemed to create a collective illusion that everything could now be achieved with digital technologies:

[89] Alan Brakoniecki, Press Release of the Restoration of Snow White and the Seven Dwarfs (Burbank, California: Eastman Kodak Company, 24 June 1993).
[90] Bob Fisher, 'Off to Work We Go: The Digital Restoration of Snow White', *American Cinematographer* 74, no. 9 (September 1993): 48.
[91] Fisher, 52.
[92] Bill Peck as quoted in Fisher, 50.

> "Cinesite is able to digitize old film and enhance images in such a way that dirt, dust, tears and scratches can be cleaned off the negative, with grain structure adjusted accordingly."[93]

Such vision, which was later criticised by Michael Friend as "technological romanticism",[94] promoted a sort of omnipotence enabled by new technologies:

> "Without compromising a single frame, Cineon technology allowed a complete restoration, including the removal of dust, dirt, and scratches that have accumulated over the years. The result is the most faithful and richly detailed restoration that has been accomplished to date."[95]

As Kodak advertised, "Cineon technology" was thus supposed to remove all unwanted damages. For that, there were two categories of operators/workstations at Cinesite:

- Dust-busters who would remove dust from the digitised images, frame by frame.
- Painters who were responsible for correcting colours, repairing scratches, scuffs, misalignments and certain light flares, and similar tasks, with a digital image enhancement and retouching software.[96]

Dust-busting probably used an interpolation method to reconstruct the missing image information, while the painting workstation was a more open, less specific, function. The second could digitally paint over the image problems, and it could thus be used in a diverse set of activities, ranging from repairing line scratches to colour correction. This gave a wide range of possibilities (while remaining manual, to be done by the operator), which could go beyond the simple elimination of wear and tear signs. With such tools, much could be done technically, but it depended upon the operator and the decisions taken by him, as well as the final goal of the digital restoration.

> "The main goal […] was to dig beneath the surface of the original film and correct imperfections which have been there for 56years […] including 'cel dust', light flares and color fringing. […] Most of these flaws probably weren't noticed by earlier generations of moviegoers, because print films and projection systems weren't as good, and audiences probably weren't as discerning. But some of these imperfections would be glaring today. We felt they would distract the audience."[97]

---

[93] Chris Pizzello, 'Forecasting the Digital Future', *American Cinematographer* 75, no. 3 (March 1994): 22.
[94] Friend, 'Film/Digital/Film', 41.
[95] The Press Release of the film, *PRNewswire*, June 24, 1993.
[96] Fisher, 'Off to Work We Go: The Digital Restoration of Snow White', 53.
[97] Harrison Ellenshaw as quoted in Fisher, 52.

Cel dust was photographed in the negative elements at the time of the film's making, and had obviously been present on all previous versions of the film during its first release and the reissues. Looking back at the older technologies, Disney judged them inferior compared to the new ones, claiming that what was not disturbing at the time, would be for new audiences. The viewing habits of spectators, in terms of how an image should look like, had indeed probably changed during the 56 years between the film's first release and its new DI restored version, although that cannot indicate that cel dust was suddenly to become a visual distraction to spectators. Disney, however, aimed to use digital technologies to supposedly overcome such perceived shortcomings of the film's original technologies and prepare them for new audiences (as it imagined them). The restoration did not aim to recreate any original, but create a new version. Here, the restoration goals seemed to have changed compared to the film's previous photochemical restorations (as recent as 1987), despite the fact that the latter was also released several years later after the film's first release, and thus addressed to new audiences. In terms of following a closeness with an original reference (a contemporary print for instance), this restoration did not correspond to the archival vision, although it was recognised as a possibility by the community.[98] Rather, it followed the quest for the so-called "better" images: sharper, and cleaner.

France: Studies, Experiments and Search for New Technological Solutions

In France, in 1993, the restoration project of Lumière films led by Michèle Aubert (CNC) also experimented with digital technologies. As Jean Louis Cot, the restorer in charge of the project, wrote in October 1993, some of the films could be restored via partial or complete DI methods. Indeed, CNC was presented with an example of "retouched digital transfer" on an Australian Lumière film, by a French computer graphic designer[99], Philippe Poulet (Médiaform Création). According to Cot, this was done on a digital restoration software that Poulet had developed, and he envisioned naming Lumière. CNC seemed to be concerned exclusively with the cleaning of the image:

> "[The film] is retouched to eliminate dust and marks. When it is cracked or torn, the undamaged parts, similar to those missing, are taken from other frames and pasted to establish the integral image."[100]

[98] Bowser, 'Some Principles of Film Restoration'.
[99] In French: infographiste. The term specifies a person who works on images with the use of computers.
[100] Michèle Aubert, 'News from the Affiliates. Archives Du Film Du Centre National de La Cinématographie', *Journal of Film Preservation*, no. 47 (October 1993): 35–38. My translation.

The damages that CNC intended to remove were those accumulated throughout the lifetime of film elements. This was a fundamentally different approach compared to Disney's, which was trying to get rid of the original technical characteristics embedded in the image. In CNC's vision, the question of new audiences was not addressed, but a historical original was imagined in the form of the contemporary print with no degradation marks. The two practices of restoration had different goals, but made use of the same techniques to achieve them: dust-busting and compositing. Some Lumiere films were eventually restored at the Société ANCOR (represented by Jean-Paul Musso) which "had implemented between 1992 and 1994 a unique system of restoration for 35mm old and damaged films via a scanner".[101]

The Lumière restoration was not the first confrontation of CNC with digital image technologies. In 1992, CNC was the consultant on the drafting of a European project, LIMELIGHT, which aimed to create "a New Generation of Fast and High Resolution Digital System to Scan, Process and Print Cinema Quality Images".[102] The project had many French partners, notably Bertin & Cie., Debrie-CTM and Laboratoires Neyrac Film; and their participation was supervised and followed by CNC. Bertin was a tech company spanning different domains, Debrie-CTM was specialised in making film equipment such as viewing tables for laboratories, and Laboratoires Neyrac Film was a post-production and restoration lab working closely with the French film archives of CNC. The project, which focused on the two markets of digital restoration and digital post-production, debuted officially in 1994. I will extensively discuss the LIMELIGHT project in subchapter 3.2. These experiments in France led to the creation of a film restoration workgroup inside CST in 1995, which collaborated not only with CNC but also with private companies such as ANCOR and Centrimage, both active in the digital restoration field during the mid-1990s.

Other Experiments and the Search for Restoration Problems

Some digital restoration experiments were also conducted in Sweden and in Germany. Swedish Film Institute worked on the DI restoration of a ballet film shot on Gevacolor, *Eldfågeln* (Hasse Ekman, 1952), whose negative was badly faded.[103] In Germany, around 1994, Optronik GmbH Potsdam also installed and experimented with a system for DI restoration; which was in fact a patchwork of products from other companies assembled together by Optronik. Their three-component machine (comprised of scanning, processing and printing modules) made use of a

[101] Despas and Helt, *La restauration numérique des films cinématographiques*, 13. My translation.
[102] The official name of the LIMELIGHT Project.
[103] Jon Wengström's mail to author, 4 May 2020.

scanner and an electron-beam recorder from the Oxberry Company;[104] as well as a Silicon Graphics workstation with 2D software from Parallax.[105] Optronik worked with a 3K scanner and a 4K recorder,[106] which represented a lower scanning pixel count compared to Cineon and Domino. In this workflow, the 3K digitised image would go through DI at 3K, then it was resampled towards 4K for recording. The higher recording pixel count was thought necessary to avoid errors such as aliasing, which occurs when zones with compact image details are reproduced at a sampling rate lower than sufficient.[107] In a somehow contradictory way, Optronik judged 3K good enough to transfer photochemical image details into a digital image, but the resulting 3K image needed to undergo a digital enhancement before shooting back on film. When Optronik partnered with Bundesarchiv to restore Max Skladanowsky's Bioscop-films, the digital intermediate step was to "correct" damages accumulated on film elements:

> "All the pictures have been retouched manually with the computer […] With motion tracking we tried to correct image position defects, which were introduced by later copying processes, to get better steadiness of images. The titles have been painted following originals of Skladanowski, photographed, scanned and corrected with the computer."[108]

While the Swedish experiment focused on colour retrieval, the German experiment aimed to clean and reconstruct the images. Both restoration experiments tried to reconstruct an original print before degradation; but with technically different approaches. The Swedish experiment intervened at a macro level on images (as a whole) to reconstruct faded colours, while the German focused on individual image technologies to eliminate historical damages and it recreated (mixing photochemical and digital technologies) what had disappeared: the titles.

---

[104] Oxberry division of Richmark Camera Co. produced film scanners for special effects.

[105] Parallax's software, Matador, was developed in 1989 and it was already used in many post-production and visual effects labs (such as George Lucas' Industrial Light and Magic) until 1995 when the company was acquired by Avid Technology. The software's name was changed to Avid Matador at that time, and it remained common in post-production. Matador was a paint application; it offered the possibility to paint over an image on a computer. For more information, see Parallax's showcase: https://www.youtube.com/watch?v=_koaelNZpTs, accessed 23 June 2020. The film *A Car Ride in the Pyrenees* (Pathé, 1910), was partially restored on Avid Matador by Nederlands Filmmuseum in 2000 in collaboration with Laboratoires Neyrac Film.

[106] Jürgen Ristow, 'Digital Film Restoration: First Experiences and Results', in *Technology and Our Audiovisual Heritage. Technology's Role in Preserving the Memory of the World. Fourth Joint Technical Symposium*, ed. George Boston, Proceedings of the 4th JTS in London on January 27-29, 1995 (Downbarn: Stantonbury Parish Print, 1999), 132.

[107] For more information on aliasing, see: Roger R. A. Morton, Christopher L. DuMont, and Michelle A. Maurer, 'Relationships between Pixel Count, Aliasing, and Limiting Resolution in Digital Motion Picture Systems', *SMPTE Motion Imaging Journal* 112, no. 7–8 (July 2003): 217–24.

[108] Ristow, 'Digital Film Restoration: First Experiences and Results', 134.

When Jürgen Ristow (director of Optronik, who had worked before at DEFA film studios) presented the German restoration experiment during the Joint Technical Symposium of 1995, he noted that tools for scratch retouching already existed, but there was a need for special software to correct the colours of highly "bleached movies",[109] repair bacterial attacks and remove subtitles. In 1994, existing software packages (which were designed for visual effects) did not provide specific solutions for these problems. Ristow's position was that of a technology provider close to film archives, who noticed what was still missing from the technologies in use at the time. Moreover, what was technologically available, did not always function as desired; for instance, the Swedish experiment on colour retrieval had apparently produced results that were not considered satisfying by the archive.[110]

While the existing technological possibilities could achieve a lot, even too much, archives preferred to focus their attention on what was missing, by identifying their own needs. The digital technologies needed to be adapted, and solutions needed to be developed in order for restorations to be conducted closer to archival vision. The need for the plurality and adaptability of technologies, each one suited for a specific use, meant that machines conceived for industrial visual effects would not necessarily suffice for restoration.

2.1.3 The Ideal Digital-Intermediate Machine for Restoration

The early experiments with industrial machines, as well as archives' rich episteme by the mid-1990s, helped them formulate more clearly their needs and wishes with regards to a DI restoration system, as well as their vision of the required technological solutions. The assembly of these technologies would create a machine or a system,[111] responding to what archives expected: a machine which would get damaged film as input, restore it digitally, and then record it back on film. But which characteristics did this digital "magic box"[112] need to reunite in order to correspond to the archival imaginary?

In 1996, Brian Jenkins (BFI) conducted a study on digital restoration on behalf of the FIAF Technical Commission:

> "Systems transferring film images to the digital domain for manipulation and then returned to film are major tools in the feature film industry. Current television systems

[109] Term used by Ristow to designate films with faded colors.

[110] According to Jon Wengström in the same mail to author, 4 May 2020.

[111] Both terms were used in the discourses of the time, with no distinctions, as the whole system could be considered as a complex modular machine achieving a unique goal.

[112] The term, used in an ironic way, comes from Mark-Paul Meyer, 'Film Restoration Using Digital Technologies', *Journal of Film Preservation*, no. 57 (December 1998): 33.

> are able to correct many of the problems associated with archive film in real time. If the advantages of film-to-digital-to-film transfer and real-time restoration could be combined, it would make a powerful and effective film restoration tool."[113]

In this study,[114] Jenkins brought together the advantages of two technological fields: correction systems for television on the one hand, and scanning and recording between film and digital on the other. The television systems could manipulate analogue or digital video signals in different ways and towards different goals. Sometimes they had a digital workstation with a small screen where an operator could apply the manipulations (for example for motion graphic design in Quantel Paintbox), and sometimes the machine would automatically process the video signal in real-time (i.e., when the video was running at full speed). In the second case, the video did not need to be visualised, a series of operations were designed which automatically detected the possible errors and corrected the signals. This understanding seems to be what was aimed ideally for film restoration by the FIAF report, if the input and output to such systems were film instead of video signals: "the ideal system would be a 24-fps one working in real time providing truly transparent quality".[115] As Jenkins noticed, this was not possible with available machines:

> "High resolution systems, like Cineon, transfer one frame at a time into the digital domain. This has become possible by the development of high resolution digital frame stores. […] With current technology it is not possible to scan the film at this high resolution and digitally correct the film image in real time. This is due to the very high data rate and the time it would take to process the data in order to maintain the image quality and provide the necessary transparency."[116]

From these statements, it becomes clear that some characteristics were hoped for to adapt these technologies to archival needs. Firstly, the system needed to function in real-time, which required an automation of operations, similar to television systems. The second would be the image "transparency" of the film-digital-film transfer, which indicated that the image quality should remain constant throughout the whole system. In what follows, I will deconstruct the notions of automation and transparency through an overview of archival discourses, and I offer an analysis of how discourses and technologies mutually communicated.

---

[113] Brian Jenkins, 'The Restoration of Archive Film Using Digital Techniques', *Journal of Film Preservation*, no. 54 (April 1997): 39.

[114] The report of the study was presented at the 1996 and 1997 FIAF Congresses before being published in the *Journal of Film Preservation*.

[115] Jenkins, 'The Restoration of Archive Film Using Digital Techniques', 38.

[116] Jenkins, 36.

The Tension between Automatic and Manual

Archivists hoped that, for a number of processes, technological solutions could be developed and integrated in a restoration machine to automatically correct the damages, as Jürgen Ristow had noticed at the JTS 1995. For instance, according to him, “bacterial attacks”, scratches and unsteadiness needed to be automatically corrected.[117] But archives were conscious that not every type of damage could be automatically corrected, and even for those which could be automated, the results would have to be verified by an operator. During the restoration of *Snow White*, the tension between automatic and manual processes was already visible, as operators in Cinesite were working on partly-automated software packages developed by Kodak:

> “While it was a highly automated process, its execution required both subjective judgement and skill. [The operators] had to make certain that we weren’t creating new artifacts and that image information wasn’t misread as cel dust. Cel dust was a lot more apparent; for example, if it was on Snow White’s face, than it was on a background element of the image.”

Quantel’s presentation in JTS 1995 focused on automation as well, presenting Domino as a “digital restoration system with a human touch”, where the system was built with the human interaction in mind.[118] The system was supposed to do a considerable part of the job, while the human would supervise. If every little task was to require human intervention, the cost of digital manipulation would be too high;[119] but a full-automation did not seem to be an objective by Quantel and Kodak, which both acknowledged the need to find an equilibrium between the two early on. However, at the same JTS, Milan Krsljanin (Sony) emphasised a full automation of restoration processes:

> “For the restoration and preservation of films and videos: a range of work stations with software components for the digitalization and treatment of films are available. [Researchers] at the Sony High Definition Picture Centre in Culver City are working to develop more sophisticated tools that will repair images and restore the original film quality. The aim is to be able to automatically repair image degradation.”[120]

[117] Ristow, ‘Digital Film Restoration: First Experiences and Results’, 132.
[118] Scammell, ‘Digital Techniques in Film Image Restoration - The Human Touch’.
[119] For the restoration of *Snow White*, 60 people worked on digital image cleaning for two months.
[120] Milan Krsljanin, ‘HDVS as a Digital Motion Picture Archival Medium’, in *Technology and Our Audiovisual Heritage. Technology’s Role in Preserving the Memory of the World. Fourth Joint Technical Symposium*, ed. George Boston, Proceedings of the 4th JTS in London on January 27-29, 1995 (Downbarn: Stantonbury Parish Print, 1999), 152.

Sony's system envisaged a transfer of film material on a new digital tape called High Definition Video System (HDVS); no shoot back to film was planned. In this way, it was entirely different from what film archives had in mind. The automation of image restoration was not considered as an intermediate step in a film-digital-film workflow, but as a necessity in a (mass) migration, a situation more common in television and video archives. Such automation was embraced and sought after within television archives through several projects. The European project AURORA (1995-1998), led by l'Institut national de l'audiovisuel (INA),[121] was supposed to produce and make available a system for "AUtomated Restoration of ORiginal film and video Archives".[122] But even in this case, the possibility of manual intervention was reserved for the user, as described by the objectives of the project: "restoration in real time with control of level of correction by the user" and "interactive restoration tools for high quality restoration or for badly damaged materials".[123] However, the subsequent European projects led by television archives, such as BRAVA (2000-2002) would focus more on automation and drop the desire to manually intervene in the restoration processes.[124]

The term "automation", very common during the 1990s with the exponential presence of computers, had gained momentum since the late 1940s.[125] John Diebold (Harvard Business School), among the first researchers to theorise automation, distinguished two types of automation in 1955: firstly, an advanced mechanisation to a very high degree (i.e. extensive use of complex machines), and secondly a "whole new system of automatic feedback control".[126] A feedback controller calculates, in continuous iterations, the difference between the desired value and the observed value, and applies corrections. An automatic system, in this sense, is thus a machine that can make logical decisions based on observations as well as a set of ideal responses. Automation for film restoration processes implied using computer software to automatically detect and then remove certain damages. The software would observe images to find and classify the damages, and decide to apply the corrections. This process would already

[121] French Public Broadcasting Television and Radio Archives.

[122] 'AUtomated Restoration of ORiginal Film and Video Archives | AURORA Project | FP4', CORDIS | European Commission, accessed 2 April 2019, https://cordis.europa.eu/project/id/AC072.

[123] 'AUtomated Restoration of ORiginal Film and Video Archives | AURORA Project | FP4'.

[124] 'Broadcast Restoration of Archives through Video Analysis | BRAVA Project | FP5', CORDIS | European Commission, accessed 2 January 2022, https://cordis.europa.eu/project/id/IST-1999-11628/fr.

[125] My study here is concerned with automation as a characteristic of machines (of any type). For studies on automation and moving images, see the papers presented at Film Forum Gorizia, Italy, on March 21-23, 2019. The conference, entitled "Moving Pictures, Living Machines", approached the question of automation from a media archeological point of view. See: Greta Plaitano, Simone Venturini, and Paolo Villa, eds., *Moving Pictures, Living Machines: Automation, Animation and the Imitation of Life in Cinema and Media. Conference Proceedings Series* (Udine/Gorizia: Mimesis Edizioni, 2020).

[126] John Diebold, 'Automation', *Textile Research Journal* 25, no. 7 (July 1955): 635.

Proposition de typologie pour le traitement numérique des défauts

	Détection interactive Nécessité d'intervention d'un opérateur.	**Détection automatique**
Correction interactive Nécessité d'intervention d'un opérateur	**Type 1** Défauts pouvant se confondre avec un élément d'image et dont la correction ne peut se faire sans l'aide d'une information contextuelle. En général tout défaut ne pouvant être classé dans les autres typologies.	**Type 2** Défauts d'émulsion ou taches de toute nature non permanentes et ayant une surface importante (ex. champignons, voiles fugitifs). Instabilités sévères (ex. filage).
Correction automatique	**Type 3** Défauts fixes et surface limitée (ex. cheveux, taches fixes). Irrégularités stables (points chauds). Différences de contraste, de couleur, de netteté, entre séquences.	**Type 4** Défauts dont le modèle mathématique ne se confond pas avec des éléments d'image : poussières, rayures, instabilités modérées de position ou d'exposition.

		Detection	
		Interactive	Automatic
Correction	Interactive	Defects that might be identified as an element of the image and correction of which could not be done without contextual information.	Emulsion tearing off or spots of any kind, nonstationary and wide (mushrooms, irregular shades)
	Automatic	Static defects of small areas (hairs, static spots), stable irregularities, "hot spots," contrast, color or sharpness differences in the sequence.	Defects whose mathematical model cannot be confused with an image element (dusts, scratches, small instabilities in the position or the exposition)

Table 5.2. Proposal of a classification for defects [135].

Figure 2 Top picture: CST's table on classification of damages. Bottom picture: the same table translated and reprinted in an image processing textbook.[127]

[127] Despas and Helt, *La restauration numérique des films cinématographiques*, 30; Gilles Aubert and Pierre Kornprobst, *Mathematical Problems in Image Processing*, 2nd ed. (New York: Springer, 2006), 272.

entail possible errors based on the methods of observation, as explained above. Then, in order to realise the "advanced mechanization of the whole process", the developed algorithms needed to be applied to all possible film damages. What complicated enormously this task, was the fact that film damages appeared under a countless number of forms. In 1993, the CNC article on digital transfer of a Lumière film, already ruled out this automation possibility:

> "Each Lumière film having its own specificities (for exposure, development and even optics), an automation of processing them in large numbers is excluded."[128]

In a CST report on digital restoration, an equilibrium was proposed between automatic and manual detection and correction schemes by categories of damages (Figure 2). It identified types of damages that could or could not be automated. The table prepared as a result of this study was not only taken as an industrial reference among companies providing film restoration services in France, but it was also consulted by image processing scientists.[129]

Similarly, according to Michael Friend, some tasks needed to refer to human "subjectivity", such as "where a specialist manually 'repaints' or otherwise manipulates images directly", while others, such as restoration of faded colours, could benefit from the computer "objectivity", for instance through using one of the scientific methods of "extrapolation".[130] This objectivity does not mean that computer methods are free from estimation, prediction and supposition. Extrapolation, for example, is a statistical method which estimates a value based on an empirical trend of previous observations (Figure 3, Figure 4). It gives the most probable answer – which is not the only possible answer – as a prediction. Digital technologies may avoid human subjectivity, but they do introduce a mathematical/computational subjectivity.

Therefore, there was definitely room for software development in order to automate more processes and provide better technological solutions, but film archival discourses seemed to be unanimous that a degree of human control must be preserved.

Transparency: Countering Generation Loss?

> "The system is 'transparent', meaning that no resolution will be lost in the process."[131]

In 1993, a report of the FIAF Preservation Committee described Kodak's Cineon system as "transparent". The 1996 FIAF study also underlined this assumption:

[128] Aubert, 'News from the Affiliates. Archives Du Film Du Centre National de La Cinématographie'.
[129] Aubert and Kornprobst, *Mathematical Problems in Image Processing*, 272.
[130] Friend, 'Film/Digital/Film'.
[131] Henning Schou, 'Report from the Preservation Commission', FIAF 1993 Mo I Rana Congress Report (Brussels: FIAF, May 1993).

"Transfer systems like Cineon, Domino and others have shown that film-to-film copies can be made via the electronic digital domain effectively without distortion or loss; that is, in a *transparent* manner. These systems were introduced to enable the feature film industry to take advantage of digital picture manipulation and processing without any apparent degradation of the elusive film quality."[132]

According to Jenkins, the "transparency" feature of duplication via DI ensured that no "apparent" loss nor distortion occurred. This seemed to be a common perception within the archival community, but it should be questioned cautiously. Firstly, in what way digital intermediate was thought to be transparent? Secondly, what was the requirement for the digital image so that the whole process could be considered transparent?

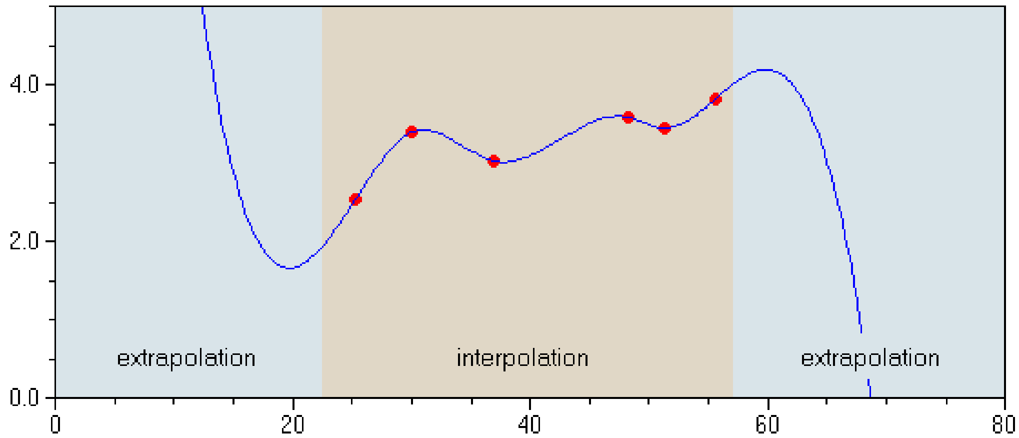


Figure 3 Visualisation of extrapolation and Interpolation as statistical methods. Extrapolation is estimating a value which is out of the range including known values. Interpolation is estimating values within this range.[133]

Figure 4 The image on the left shows a faded-colour digital frame of the film *Nomades du Soleil* (Henry Brandt, Switzerland, 1954) and the image on the right shows it when colour-corrected. The image on the right has been obtained through estimation via extrapolation, as the colour values it includes, do not exist in the range of colours present on the faded image. They can only be estimated via an approximation of how the RGB colour curves should be. The correction made to the colours here is only an example carried out by the author in Photoshop. Courtesy of Cinémathèque suisse.

[132] Jenkins, 'The Restoration of Archive Film Using Digital Techniques'. Emphasis in the original.
[133] Source of the photo: Hans Lohninger, *Fundamentals of Statistics*, E-Book, accessed 16 April 2021, http://www.statistics4u.com/fundstat_eng/ee_inter_extrapolation.html.

Regarding the first question, the result of the digital intermediate method was compared with that of photochemical duplication. In archival terminology, a camera negative (or a camera reversal film) is considered the first generation of a film, then this element is duplicated into another, an interpositive or internegative, which is of generation two, and similarly, subsequent elements in the chain are of later generations.[134] Within archives, as well as the technical wing of the film industry, it was well known that any duplication of film elements would create an image slightly different compared to the generation before it. This difference is characterised as generation loss, because it inevitably reduced the sharpness and fine details of the image. In this understanding, the loss, considered as a result of the "nature of photographic reproduction",[135] has often been an area of concern for film manufacturers and technicians; as they have historically demonstrated a preference for reducing it.[136] Archives, as well, look regularly for elements of earlier generations when doing restorations,[137] in order to obtain a sharper, more detailed image (which is closer to the source image being duplicated rather than the contemporary prints). This loss was discussed among cinema technicians as early as the 1930s, when it was described as dependent on several factors:

1. Photosensitive material of the destination element: its latitude, grain structure, etc.
2. Original source material: its graininess, sharpness, fine details, etc.
3. Type of printer employed: uniformity of contact, adjustment of the printer (which would ensure the even density in the print), steadiness of the operation
4. Processing methods
5. Developing methods[138]

The technological progress in any of these aspects could lead to a reduction of loss during the duplication of an element. For example, the research by Kodak during the 1960s in sensitometry "resulted in precise setup procedures" for film printing technologies;[139] or, finer-grain film stock attenuated the graininess of the duplicated image in later applications. However, generation loss, although reduced progressively, was never eliminated and it remained a

---

[134] For these definitions, I am applying the most frequent terms within the archival community. See notably the figures in Read and Meyer, *Restoration of Motion Picture Film*, 46–48. See also the glossary entry for "Generation loss: Degradation of picture quality resulting from successive printing, transfers or dubbing of film or video" in Read and Meyer, 327.
[135] Friend, 'Film/Digital/Film', 39.
[136] I will extensively discuss this matter in Chapter Two.
[137] See for example: Read and Meyer, *Restoration of Motion Picture Film*, 72.
[138] J.I. Crabtree and C.H. Schwingel, 'The Duplication of Motion Picture Negative', *Journal of the Society of Motion Picture Engineers* 19, no. 1 (July 1932): 891–908. From Research Laboratories of Kodak.
[139] Paul Read, 'New Technologies for Archive Film Restoration and Access: Film Image', in *The Use of New Technologies Applied to Film Restoration*, ed. Gamma Group (Bologna: Gamma, 1996), 37.

problem for film duplication in archival practices. As evoked before, FIAF TC was actively researching duplicating stocks and procedures from the late 1980s to counter this. When digital technologies became available, one of the first advantages that hit the archivists was the fact that multi-generation duplication could now be avoided, and a seemingly lossless duplication would become possible through DI (instead of the traditional methods of photochemical duplication). It was believed that from the original source film element to the final film element shot back on film from digital intermediate, there would be no loss. Of course, the digital intermediate also introduces a different look and certainly some kind of loss, but, as Jenkins' report indicates, by the mid-1990s, film archives believed that, if sampled with enough pixels, this loss would not be visible.

The second question is, what was this certain pixel count that, in archival view, would avoid loss? For that, some correspondence between photochemical and digital image was assumed, mostly based on Kodak studies.[140] Jenkins, for instance, stated that "the requirement is to scan each frame of film at a resolution (usually 3,000 x 4,000 pixels) which will not degrade the image".[141] This was in the case of an uncompressed image, in a format such as DPX as explained before. In 1996, Paul Read presented a correspondence table, suggesting "approximations" of pixel count for a few different types of film.[142] These approximations focused mostly on the image format (16mm or 35mm), colour system, and aspect ratio:[143]

> "The 4K resolution of Cineon, for example, is sufficient to handle the data in a modern 35mm Academy colour negative or print film. […] We have little information about the resolution of most old archival film stocks. An Academy frame of Technicolor is markedly less sharp than any modern film, and it is said that a resolution of about 1500 pixels per line 'is quite adequate'. However this information is not confirmed and there is only guesswork for all the many other stock."[144]

A few years later, in 2000, Read and Meyer presented another similar table in their *Restoration of Motion Picture Film*, but here they fully asserted that the comparison was estimated (and mainly based on Kodak observations).[145] Such tables, although providing a practical reference for scanning, could not be all-inclusive, given the number of different film stocks and modes

[140] Kennel, 'Digital Film Scanning and Recording: The Technology and Practice'.
[141] Jenkins, 'The Restoration of Archive Film Using Digital Techniques', 35.
[142] Read, 'New Technologies for Archive Film Restoration and Access: Film Image'.
[143] Read, 47.
[144] Read, 47–48. In this thesis, while I conserve it in citations, I will avoid employing the term resolution for pixel count. I will come back to the understandings of the term in the next chapter.
[145] Read, Meyer, *Restoration of Motion Picture Film, op. cit.*, p.220-221.

of production (which all influenced the technical quality of the image on film). Moreover, the idea of digital transparency which considered the digital transfer as a neutral operation depending uniquely on pixel count, was challenged later, notably in 1998 by Michael Friend:

> "Digital cloning, especially in images, is not necessarily transparent or without loss (error concealment, error correction, duplication, especially in a compressed data environment). This is one reason why film needs to be preserved as film."[146]

Theoretically, archives seemed to remain convinced that such a transparency through digital transfer could be possible, but gradually, through technical experiments, they came to believe that an exact correspondence between digital and photochemical images was more complex than initially imagined. What's more, I underline that the concept of transparency could not be defined solely based on pixel count. Other aspects, such as the characteristics of optics, were also crucial to that. Despite that, during the late 1990s, the idea of transparency in a DI workflow, from 35mm film towards a 4K uncompressed image and then back to 35mm film, was accepted in an approximative manner. This would come under scrutiny years later (under various terms, such as quality[147] or authenticity[148]).

2.2 Theoretical Reactions: The Promises and Threats of Changing Image Technologies

Up to here, I have illustrated how early technical discourses around DI methods were formed in conjunction with some archival experiments on machines conceived for industrial use. Since the mid-1990s, while the actual use of digital images technologies in film archives remained scarce, the theoretical discourses and studies surrounding it flourished. In this subchapter I will show how a two-fold theoretical reaction was established within the film archival community with regards to digital image technologies, based on their promises and threats. This reinforced and modified the existing discourses on ethics by inclusion of the technical aspect of the image.

What Can Digital Technologies Do?

> "The possibility of digital restoration of motion picture film is currently being tested by the Eastman Kodak Company which developed the so-called 'Cineon' system. Using this image computing workstation, it may be possible to reconstruct missing data or

[146] Michael Friend, 'Specificity of Film and Effects of Digital Restoration' (FIAF 1998 Prague Symposium, Prague, 26 April 1998). Notes of this presentation are available at the FIAF archives in Brussels in the folder dedicated to this year's FIAF Congress.
[147] See Chapter Two.
[148] See Chapter Four.

> eliminate data representing blemishes on digitised film and record the final information on high resolution intermediate film."[149]

Even before the mediatised restoration of *Snow White* was released, the FIAF Preservation Commission reported on the possibility of digital restoration, as tested on the Cineon machine by Kodak, at the FIAF Congress in Mo I Rana (Norway) in April 1993. While the Commission had no notable technical reference regarding the new technologies yet, it seemed to appreciate the possibility that they might enable the reconstruction of missing information and elimination of unwanted damages. They promised what the traditional technologies of restoration did not allow for. Two years later, the "New Technologies for Preservation" was part of the 1995 FIAF Symposium in Los Angeles, exploring the "First and Next 100 Years" of cinema, organised by Michael Friend.[150] Friend detailed how the new technologies could be useful tools, parallel to photochemical tools, as the culmination of an archival quest towards what they celebrated as a better image:

> "Rising expectation concerning image quality has been a forty-year trend brought about by technical and cultural factors […] we learn that in this world in search of the perfect image there is just no substitute for the original negative, and preservation technology continually improves, making it possible to improve the quality of materials derived from an original negative."[151]

For Friend, archives had progressively moved towards a point where they looked for reproductions resemblinh closely the "original" negative of a film, deemed by him as the best element of the film in terms of technical quality (sharpness, fine details, etc.). As I evoked in the first part of this chapter, the negative – when available – had been used since long as the source for further reproductions of a film, leading to the creation of new prints looking closer to negatives rather than the old prints. While this practice might seem contradictory to some understandings of the concept of "original", it was not contested, but accepted and formulated as an archival tendency. Moreover, he noted the same tendency towards watching "better"-quality films by the new audiences, shaped by new film stock technologies (with their sharper, more detailed images) and "the advent of videodisc (with its self-proclaimed interest in quality, better transfers and better film elements to work from)".[152] As I mentioned before, there was a general tendency within archives to provide sharper, cleaner, images with more details, in line

[149] Schou, 'Report from the Preservation Commission', May 1993.
[150] 'FIAF 1995. The World's Film Archives Come to Los Angeles', Press Release (Los Angeles, CA: UCLA, 1995).
[151] Friend, 'Film/Digital/Film', 36.
[152] Friend, 37.

with industrial manufacture of film stock. According to Friend, this could potentially advance further with the addition of digital methods to "high quality [photochemical] laboratory work".[153] However, the discursive trend of "better image" was not necessarily shared by all within archives, it was certainly not objective, and it considered the negative image as its original reference rather than the print (a point of view which was getting stronger with the perceived possibilities of digital technologies).[154]

Such discourses signalled a continuity in archival tendencies, promoted a positive image of the new technologies, and called for their adoption in archival practices. Despite this, Friend and other archivists, notably Mark-Paul Meyer (Nederlands Filmmuseum), who were open to new technologies, remained cautious towards it, warning archives against a misconception that these technologies were going to solve all archival problems:

> "Film restoration is an activity full of [dilemmas]. The main [dilemma] is probably that the traditional photographic technique has many limitations. It is often very difficult – and sometimes impossible – to obtain the result a restorer desires. Some kind of 'magic box' would therefore be welcome to every film restorer. Digital technology is often presented as this 'magic box' that will enable film restorers to overcome the limitations of traditional photographic technique. It is as if a dream comes true: finally everything will be possible. It is obvious that digital technology will open many new possibilities for film archives. […] But when we speak about digital technologies in relation to conservation and restoration: we have to stay awake and realistic and beware that we do not get lost in dreams."[155]

Although some discourses, within the industry notably,[156] claimed the omnipotence of digital technologies, the archival community remained sceptical. Of course, they did accept that they exceeded the possibilities of photochemical methods. It is true that what the new technologies offered would reinforce what was desired but technically less implementable before. Sociologist Dominique Boullier has proposed to identify the contribution of digital technologies as an "amplification" of something that existed before.[157] In the case of film restoration, with digital tools, image manipulation could level up considerably; it was truly amplified. A film could now be manipulated not only frame by frame, but even pixel by pixel,

[153] Friend, 42.
[154] See the subchapter 'In Quest of a Better Image' in this chapter, and notably the statement by: Friend, 38.
[155] Meyer, 'Film Restoration Using Digital Technologies', 33.
[156] For instance, see the discourses around the restoration of *Snow White*, in previous parts of this chapter.
[157] Boullier, *Sociologie du numérique*.

whereas traditional archival methods would rarely intervene at the level of such small portions of the single frame. The range of possibilities had thus been clearly widened (although by no means in an unlimited way). Aware of that, George Boston (BBC) advised the archives at the JTS 1995 to keep their feet on the ground while using digital technologies:

> "Remember the old adage 'All power corrupts; absolute power corrupts absolutely'. Do not corrupt the information in your care by misusing the powers given to you by modern technology."[158]

As described by Boston, the "power of modern electronics to change things in an undetectable way" presented a danger of "well-meaning but misguided enthusiasm".[159] Such ethical discourses resonated within the archival community, where the upcoming technological possibilities were deemed as too powerful amid a growing enthusiasm. Inevitably, they redirected, at least partly, the focus of ethics – and notably the concept of original – towards the technical manipulation of an image in pixels, rather than the conceptual part of film.

The Threat on Film

> "The traditional technical bases of film archiving are now subject to substantial alteration, and these changes have aesthetic ramifications which must be confronted by archivists. Archivists need to specify acceptable practices for restoration, and to define the limits of the new technical tools. Such standards must be based on a consideration of the historical and aesthetic paradigms of the films we are seeking to protect."[160]

As explained by Friend, ethical issues related to the use of digital tools were part of a bigger picture where films embodied a historical and aesthetical existence. This vision was to be reinforced over the years within the archival community, and I will come back to it regularly throughout the thesis. In this part, I will focus on its early steps.

In November 1993, the FIAF Executive Committee asked the Preservation Commission to include the study of new technologies for preservation purposes in its agenda.[161] These included, on the one hand, "new technology such as digitization of motion picture images and

---

[158] George Boston, 'Ethical Questions Relating to the Uses of New Technology in Audio-Visual Archives', in *Technology and Our Audiovisual Heritage. Technology's Role in Preserving the Memory of the World. Fourth Joint Technical Symposium*, ed. George Boston, Proceedings of the 4th JTS in London on January 27-29, 1995 (Downbarn: Stantonbury Parish Print, 1999), 17–18.

[159] Boston, 17–18.

[160] Michael Friend, 'Guest Editorial: An Introduction to the Fifty-First Congress of FIAF', *Journal of Film Preservation*, no. 50 (March 1995): 3.

[161] Henning Schou, 'Report from the Technical Commissions', FIAF 1994 Bologna Congress Report (Brussels: FIAF, April 1994), Appendix 5.3.1.

sound, used not only for the creation of special effects (for example in 'Jurassic Park') but also for restoration (for example of 'Snow White')". On the other, they englobed finally the "electronically generated, magnetically recorded material which more and more FIAF archives acquire"[162] in an official manner. The inclusion of analogue video and digital material corresponded more to the broad definition of film in Article 1 of FIAF's Statutes and Rules:

> "By film is meant a recording of moving images, with or without accompanying sound, registered on motion picture film, video-tape, video-disc or any other medium now known or to be invented."[163]

This definition, which existed in the 1991 version of the text, had already been subject to resistance during the FIAF congresses. When during the 1994 Congress in Bologna, the newly-renamed Technical Commission presented its report with this definition included, the latter came again to be disputed theoretically, and voices of disagreement rose against "electronic images". Peter Kubelka, co-founder and co-director of Austrian Filmmuseum, and a fervent supporter of photochemical film, expressed fear that by succumbing to the use of electronic tools, film archives might "lose the understanding of film's historical period and modify its original image by artificially improving it".[164] The so-called improvement was understood by Kubelka to be an artificial intervention which could erase the link between the film and its historical existence. The problem evoked by Kubelka concerned thus, in the first place, the changes brought by DI to the whole culture of film (re)production, which was historically bound, and would be harmed by digital interventions.

The critical context of the time within the film industry could have been, underneath this debate, a source of a more profound concern for the ontology of cinematographic image. These discussions conveyed the idea of a digital rupture in photography (and, by natural extension, cinematography),[165] and led to a re-questioning of the cinematographic image in the film archival community. It was also mentioned as an important factor in bigger strategic and political questions such as the role of film archives and the future of FIAF. In 1995, during the discussion on FIAF's future, Jan Christopher Horak (George Eastman House) joined Kubelka's view on the importance of film culture:

---

[162] Schou.

[163] Cited by Schou.

[164] Peter Kubelka, as cited in: *FIAF 1994 Bologna Congress Minutes* (Brussels: FIAF, 1994), 9.

[165] See for instance: Lev Manovich, *The Paradoxes of Digital Photography*, Photography after Photography Exhibition Catalogue (Germany, 1995), http://www.manovich.net/TEXT/digital_photo.html. Martin Lister, *The Photographic Image in Digital Culture*, 1st ed. (Hove, East Sussex: Psychology Press, 1995). Mitchell, *The Reconfigured Eye*.

> "[…] the new candidate members [should] be primarily focused on the film preservation project, whether at a national or a local level. […] membership in FIAF [should] be a commitment to film preservation on film. Those archives that are now 'preserving' films digitally or electronically would not be fulfilling the mandate of FIAF."[166]

In this view, the very definition of film was contested, and the photochemical film was placed as the centrepiece in archival practices (ruling out digital technologies as a replacement to film practices). The film had a history to which it was intrinsically related, a (production) culture within which it had acquired its status, and it was the source of the familiar appearance of cinema up to then. At the 1994 FIAF Congress, a discussion on "what is cinema today?" was organised as a "conceptual/ethical question". Providing an answer to the question, Robert Daudelin (Cinémathèque québecoise) argued "FIAF's strength lied in the specificity of its mandate, i.e. in *cinema*", and that the definition of film should not be expanded to include "audiovisual". Indeed, for many archivists present as the Congress, the object film seemed to be related directly to the "cinema experience", and thus any other audiovisual existence of moving images would weaken this position.[167] These discourses went beyond the use of DI methods, and considered the whole landscape of cinema, of which film was an undetachable part.

Thus, the coming technologies incited a mixed reaction of mistrust and intrigue in archival imaginary. While some would see advantages in the use of digital technologies as tools for restoration, others feared a denaturation of cinema experience induced by new technologies. These visions, although not necessarily contradictory, contributed to the formation of a polarised archival imaginary. This was constructed from within an existing (heterogenous) network of discourses, sometimes detaching itself from it by supposing a sort of newness, and sometimes modifying and building upon what was already there.

2.3 Towards a Mixed Technical – Theoretical Approach

As explained, technical discourses were accompanied by ethical and theoretical discourses within film archives. The actual adoption, rejection or development of technologies needed to conform to this episteme. Many archival research initiatives during the second half of the 1990s studied these aspects together, most notably those by Gamma Group (under the aegis of ACE, and funded by European Commission).

---

[166] Jan-Christopher Horak, 'FIAF: The Traditionalists' View', *Journal of Film Preservation*, no. 51 (November 1995): 16.

[167] *FIAF 1994 Bologna Congress Minutes*, 17–18. Emphasis in the original.

In the mid-1990s, Gamma Group started researching digital film restoration, as a side project[168] to a more general research on film restoration. The result of this research was published in 1996, but also presented and expanded through a number of presentations and collaborations with the archival community. The 1996 booklet, in three languages (English, French and Italian) presented the state-of-the-art digital technologies in the archival field: two articles were dedicated to digital sound restoration (which, in 1996, was considerably more advanced, and less polemic, than digital image restoration). Another article, by Mark-Paul Meyer, focused on the ethical questions raised by digital technologies; and finally, an article by Paul Read examined technical aspects of image restoration.[169] An introduction was provided by Nicola Mazzanti, who expressed the aim of the book as to "provide a working tool useful in beginning to move into a world that is almost completely unknown – that of digital restoration". He used the term "(r)evolution" to describe the modifications that film restoration was "destined" to undergo thereafter by digital technologies, and described the main goal of the book, as well as the main goal of Gamma group, to "[permit] film archives and laboratories to obtain even higher levels of restoration quality – in other words, to save ever more and even better the memory of our century".[170] Gamma Group's position indicated a desire to do "more" and "better" restorations, before the digital technologies become a reality for European film archives.

Indeed, in 1996, in Europe, there was almost no practical application of digital restoration, apart from fragmented experiments, but photochemical restoration was quite advanced. The publication of the booklet happened thus at a moment where a large body of technical discourse on traditional photochemical restoration technologies was available, and the discourse on digital technologies was nascent. The booklet did not start the discussion on restoration from scratch; it built upon what already existed. It confronted digital methods (which were on the way) with photochemical methods in order to explain the enthusiasm, but considered them both as part of a bigger practice in order to plea for a theoretical and ethical approach to film restoration. The oscillation between enthusiasm and fear was most visible in Meyer's article. He applauded what digital technologies could bring to the field: "the limitations of traditional

[168] It was funded through the Kaleidoscope program of the European Commission, which was devised for supporting artistic and cultural activities of the European community, notably projects with an innovative nature by European partners.

[169] The same structure of image/sound/ethics was also at the core of Gamma group's presentation at the festival Il Cinema Ritrovato on July 5, 1996, a pivotal moment in archival discourses on digital technologies in Europe.

[170] Nicola Mazzanti, 'Introduction', in *The Use of New Technologies Applied to Film Restoration*, ed. Gamma Group (Bologna: Gamma, 1996).

photographic techniques can now be overcome to some extent";[171] but at the same time, he deplored the lack of a theoretical framework in film restoration:

> "Today a restorer is aware of the fact that every restoration poses a complex set of problems, and that there is usually not just one ethical issue to consider. Every restoration is a problem which needs a well-considered solution.
>
> However, after ten years, a real restoration theory has not yet been developed."[172]

Here, evoking the multiplicity of film restoration practices did not refer to the technologies used, but to the more general cultural frameworks of why restorations were done, and how the practices might change with regards to that. Meyer mentioned "mere duplication" vs. "reconstruction", and "archival purpose" vs. "museological purpose". By museological purpose, he meant the recreation of "specific technical/historical information" which were part of the "original" film.[173] The museological role, as I will show throughout the whole thesis, became subsequently a recurrent archival theory (with some mutations according to the technologies discussed and the people involved). It was notably a position defended by Cherchi Usai, who, at the *Preserve Then Show* conference in 2001, pushed this concept much further by claiming that every film print was a unique object, a museological artefact with only a material existence,[174] while most other researchers and archivists considered material and conceptual aspects of film together.[175]

For Meyer, whose article in the Gamma group booklet concerned a general theory of restoration (through any technology), a specific ethical approach for digital reconstruction was necessary as well, because of "what [could be] achieved at the workstation" (to the image itself).[176] In his view, the ethical notions were to be expanded in order to include also the technical operations and their consequences. While Meyer's article was primarily a theoretical one, Read's article discussed the technologies at the core of film restoration practices, by replacing them within the theoretical discourses of archives. According to him, film restoration, functioning at the limits of "modern film stock", could aspire to recreate the "original" in two ways:

[171] Mark-Paul Meyer, 'Work in Progress: Ethics of Film Restoration and New Technologies', in *The Use of New Technologies Applied to Film Restoration*, ed. Gamma Group, Caleidoscopo (Bologna: Gamma, 1996), 13.
[172] Meyer, 15.
[173] In order to explain, he gave the example of *The Man Who Knew Too Much* (Alfred Hitchcock, 1956) which was presented in Bologna in 1994 in its original VistaVision and Perspecta equipment.
[174] Cherchi Usai, 'Film as an Art Object'.
[175] Casper Tybjerg, 'The Raw Material of Film History', in *Preserve Then Show*, ed. Dan Niseen et al. (Copenhagen: Danish Film Institute, 2002), 14–21. Fossati, *From Grain to Pixel: The Archival Life of Film in Transition*, 2009.
[176] Meyer, 'Work in Progress: Ethics of Film Restoration and New Technologies', 16.

1. To simulate the characteristics of the original film stock by manipulating granularity, sharpness, resolution of the image.
2. To repeat the original production method as far as possible.

Regarding the first option, "the 'electronic intermediate' of Digital Restoration could provide this facility using modern film stock for the final image".[177] This state-of-the-art approach would combine the best of digital and photochemical technologies to simulate the original film. This original, while not expressed so by Read, sounds closer to be the negative or the element being copied – a common approach within the archival community historically. The second option was to repeat the original production method, which he deemed almost impossible as film technologies had always changed throughout film history and bringing back old technologies could hardly be realisable. This understanding of the original insists more on the photochemical processes and methods of the time, which would create a new print similar to the old ones. This had rarely been a discursive (or practical) trend within the archival community before, but was receiving attention in confrontation with digital technologies.

Read, before becoming an expert in digital technologies, was an expert in photochemical film technologies. He was a Kodak film technologist, commissioning Eastman Colour laboratories and teaching laboratory staff to control the chemistry and sensitometry of films.[178] He was thus writing "from the point of view of a film technologist struggling to provide film archivists and presenters of archive programmes with what they want". His article in the Gamma Group booklet drew a summary of the photochemical situation; where the same equipment used for new films in film laboratories (post-production) were used for film restoration. He also detailed the two families of new electronic technologies: video or digital intermediate. These, according to him, would be alternatives to where photochemical methods would falter; even though "[digital restoration would] also be able to produce irrelevant and inaccurate figments of imagination as well".[179] His viewpoint as a technologist involved directly with film archives was for a number of years an important contribution to the archival community, as he tried to clear doubts and misconceptions about digital technologies by providing technical information, and therefore help clarify technical and ethical standpoints. His paper, "Digital Image Restoration – Black Art or White Magic?", at the conference *Preserve Then Show* in 2001, commented on the archivists' dilemmas on how to ensure digital technologies' transparency

[177] Read, 'New Technologies for Archive Film Restoration and Access: Film Image', 38.
[178] Information extracted from Paul Read, '"Unnatural Colours": An Introduction to Colouring Techniques in Silent Era Movies', *Film History* 21, no. 1 (June 2009): 9–46.
[179] Read, 'New Technologies for Archive Film Restoration and Access: Film Image'.

(i.e. "sufficient" definition as well as the right "look") and the automation of processes, which he deemed unacceptable.[180]

The nuanced view of Read joined Meyer's, where digital technologies' technical advantages were damped out with their too strong ability to alter the image. The Gamma Group book demonstrated clearly that the use of digital technologies would bring about a twofold view. On the one hand, digital technologies would willingly be applied to film restoration, as some problems could not be solved using exclusively photochemical methods. On the other, digital technologies could aggravate some already-existing ethical problems in film restoration. By traditional methods, old films were regularly restored with newer equipment, on newer material and by different labs. The results of restoration, dependent upon the technologies and processes used, always looked different. If the original element of the restoration was the negative, newer technologies could extract more details in it compared with the original reference prints. Thus, restorations in fact moved gradually somehow further from the reference prints, and closer to the negative (which was never seen by spectators); and the power attributed to digital technologies could widen this gap. In the same way, if the source material to be duplicated was a print, the digital reproduction could retain a greater closeness in terms of image sharpness and details, while inevitably it differed in look from what photochemical reproduction would have provided. This dialectical relation to digital technologies called for new research dynamics, more scientific, which would benefit from a collaboration with universities (as Meyer noted), and with film technologists and lab technicians (as Read noted), as well as an expansion of the discourse network to include more parties within the archival community itself.

Expanding the Network: Archimedia, *The Reel Thing* and FIAF Technical Commission

The same dialectical view was crystallised in Archimedia's programme in its debut year, 1997, where one of the earliest sessions was dedicated to the "prospects and risks" of digital restoration.[181] Archimedia was an archival training programme which was launched within the European MEDIA II framework by Cinémathèque royale de Belgique and Université Paris III, in collaboration, as Meyer and Read had hoped, with a network of European institutions.[182] It

[180] Paul Read, 'Digital Image Restoration – Black Art or White Magic?', in *Preserve Then Show*, ed. Dan Niseen et al. (Copenhagen: Danish Film Institute, 2002), 158–67.

[181] 'Restoration in the Era of New Technologies: Prospects and Risks' (Archimedia Seminar, London, September 1997). For more information, see: https://web.archive.org/web/20010421194114/http://www.ledoux.be/archimedia/oldsession_en.htm, accessed 23 March 2021.

[182] Universities: Goethe University in Frankfurt, Université Libre de Bruxelles, Utrecht University, University of Amsterdam, University of Udine, etc. Film archives: CNC, Nederlands Filmmuseum, National Film and Television

was born out of necessity for conservation of cinema heritage – in the same line as other archival training programmes of the 1990s;[183] at a time when it coincided with the development of discourses and technologies of digital restoration. The digital technologies, as well as a collaborative frame of action for archives, were named as principal drives behind Archimedia:

> "Continued information on the development and the potential of the latest digital technologies and close interaction between the actors concerned are prerequisites for a modern and efficient management of film archives."[184]

In September 1997, a session organised in London was specifically dedicated to the subject of new image technologies in restoration:

> "Two tutorial papers will look at the way film was made in laboratories in the past, and later this is related to modern restoration technique. The extended use of multiple pass printing system and Technicolor restorations are preceded by a tutorial on photographic colour reproduction. Digital restoration is preceded by a session on digital image technology."[185]

The session included several presentations on film processing and printing; as well as (fewer) presentations on digital restoration by Gamma Group members. The introduction given by Paul Read to the session was entitled: "Introduction to how little we know"; reminding his views from his 1996 article where he regretted that much information about "originals" had disappeared, and the fact that film restoration, photochemical or digital, faced still many unsolved problems and many unknowns. This shows again how the introduction of digital technologies led to a re-questioning of existing ethical notions; and underlines how the theoretical understanding of restoration, in the sense of returning to a historical reference, was further complicated by a new focus on technical aspects of the image.

In 1998, Gamma group invited Grover Crisp (Sony) and Michael Friend to organise an edition of The Reel Thing conference in Europe, during Il Cinema Ritrovato festival in Bologna, where Gamma group's first research on digital technologies were presented two years before in 1996. The Reel Thing, "a [successful] yearly appointment for new developments and achievements in film restoration domain", was supposed to expose in front of representatives from European

---

Archives, Cineteca di Bologna, Cinémathèque française, Cinémathèque of Greece. Film labs: Immagine ritrovata, Haghefilm, Soho Images.

[183] Whose forefather, in a sense, was the FIAF Summer school, which had been taking place since 1973.

[184] The presentation text on Archimedia's official website in 2001: https://web.archive.org/web/20070506143905/http://www.ledoux.be/archimedia/presentation_en.htm, accessed 23 March 2021.

[185] 'Restoration in the Era of New Technologies: Prospects and Risks'.

film archives what was being done in the field of digital restoration in the US, according to the organisers:

> "If the lack of communication is a problem in Europe, it becomes a dramatic issue when we refer to United States; in this case, the results of the works carried out on one side of the Ocean is completely invisible for all people active on the other side. […] Thus, the idea of having a sort of Reel Thing dedicated to the European audience of professionals, scholars and interested audience was born, and we are grateful to Michael and Grover who accepted the idea and worked hard to set up this program, […] We are also happy to offer the audience of the festival a unique opportunity to come to know some of the most recent and interesting results in film restoration practice, both by digital and traditional techniques."[186]

The session included presentations by restoration experts and lab representatives,[187] as well as a number of practical demonstrations. It aimed to "define some of the problems and possible solutions offered by processing film through digital media"; which reinforced the discourse that digital technologies were supposed to alleviate the problems of photochemical restoration. In this way, the European network opened up more to the knowledge coming from the United States.

Moreover, Gamma Group also exchanged regularly with FIAF's Technical Commission – Noël Desmet (Cinémathèque royale de Belgique) being a member of both at that time. Henning Schou (head of TC) and Noël Desmet were to act as intermediaries between Gamma Group and FIAF TC regarding the research on digital restoration. In February 1996, Schou chaired a one-day seminar organised by Paul Read for the Gamma group at Pinewood Studios, UK. The seminar, sponsored by Soho Images, Kodak and the BKSTS, followed the same structure as Gamma group's presentations, by reviewing, first, photochemical restoration technologies before getting to the core subject of digital restoration. During this meeting, Cineon machine was presented by Paul Watkins (who had also presented it at JTS 1995), and "Old and New Film Laboratory Practices for Restoration" were confronted again. But this confrontation did not oppose photochemical and digital technologies; in fact, it reported on several new practices, whether digital or photochemical.[188] Indeed, by that time, the search for technological solutions

[186] *Il Cinema Ritrovato 1998*, Festival Programme (Bologna: Cineteca di Bologna, 1998).
[187] Grover Crisp, 'Digital Film Restoration at Sony' (The Reel Thing, Il Cinema Ritrovato, Bologna, July 1998); Steve Wiskochil, 'Digital Restoration at EDS' (The Reel Thing, Il Cinema Ritrovato, Bologna, July 1998); David Tames, 'Film Restoration at Cineric' (The Reel Thing, Il Cinema Ritrovato, Bologna, July 1998).
[188] *FIAF 1996 Jerusalem Congress Minutes* (Brussels: FIAF, 1996), 6.

was not limited to digital, and included photochemical technologies as well. Digital was only one technological mean among others.

Digital restoration was also included at the FIAF Symposium in Prague in 1998. One part of the symposium, entitled "Digitalisation of Archival Material", saw Nicola Mazzanti of Gamma Group making "Some Remarks on Digital Restoration of Film". Interestingly, the second part of the symposium that year was dedicated to the ethical problems of restoration of different art forms, including film restoration. This gave Michael Friend the opportunity to present a paper on "Specificity of Film and Effects of Digital Restoration", in which he agreed with Nicola Mazzanti "with respect to the highly under-developed and inadequate state of our understanding of digital technology for preservation of film", and emphasised on the fact that the use of digital technologies needed to be accompanied by a thorough understanding of photochemical film.[189]

In sum, at the dawn of 2000, the subject of digital restoration technologies had become a controversial subject within the archival community, despite the fact that practically it remained still very limited. A lot of uncertainties continued to reign, not only because of a lack of comprehensive photochemical knowledge, which would presumably answer many ethical and technical questions, but also about digital technologies themselves: how they functioned, what they could and could not do, and how they could be adapted to archival needs and frameworks. This was mentioned by archivists, for instance Thomas Christensen (Danish Film Institute), who suggested a better documentation and knowledge of the digital technologies in order to reduce the "large degree of 'black box' uncertainty" of what the image has gone through during the processes.[190] This view reinforced the tendency from a number of archivists to reduce the gap between different actors involved in the field of digital film restoration.

This discussion, which depicts how the rich archival episteme of the time was on the verge of integrating digital image technologies, prepares the terrain for me to go deeper into the technical details of digital restoration projects devised in Europe. I will argue that through these projects and an active engagement with the technical scientific community, the archives reacted upon their desires to uncover the "black box" uncertainties, and obtain suitable technologies for digital film restoration. My analysis of the scientific basis of digital image manipulation technologies will shed light on how the technologies were developed, refined and implemented into a form usable for archives; and enables me to investigate how the scientific discourses coincided conceptually with the dynamic archival discourses, both mutating in the process.

---

[189] Friend, 'Specificity of Film and Effects of Digital Restoration'.

[190] Thomas Christensen, 'Restoring a Danish Silent Film – Nedbrudte Nerver', in *Preserve Then Show*, ed. Dan Niseen et al. (Copenhagen: Danish Film Institute, 2002), 141.

3 Research and Development: Conceiving Digital Restoration Technologies and Systems

In previous sections of this chapter, I argued how the archival episteme was enriched by a mix of technical and theoretical discourses on digital image manipulation technologies; and how a polarised imaginary was formed from early on which responded to their possibilities and threats. I identified a historical tendency towards an ever-more extraction of details from the original negative (instead of a reconstruction of reference prints), which was intensified when digital image manipulation technologies became available (on a small scale) to archival experimentation through the machines developed primarily for digital post production. The archives became gradually aware that specific machines were needed for restoration, fulfilling a degree of automation and transparency. They would enable a film-digital-film workflow, remedying the perceived limitations of traditional technologies. Based on these, archives seemed keen on adapting the available digital technologies and machines to their own use, and conformed to their theoretical frameworks. This rich polysemic imaginary evolved in parallel to a scientific imaginary, which existed almost independently. The two crossed paths during this period, and shared many concepts, leading to a change in both. In this part I will present the scientific imaginary, most importantly through its connections and intersections with the archival imaginary by the early 2000s, and argue how that provided a basis for technological developments and adoption.

During the 1990s, scientific research on digital image processing, specifically with regards to film restoration, was on the rise all over Europe, notably in the University of Basel's Image and Media Lab, Laboratoire d'informatique et d'imagerie industrielle (L3i) of La Rochelle University, Trinity College Dublin, Joanneum Research (Austria), etc. A scientific discourse network on film restoration within technical universities was created and nourished regularly, which worked on image manipulation from a mathematical and computer science point of view. It proposed different mathematical models for specific restoration problems, and developed several methods and algorithms for image manipulation. This mathematical basis of scientific discourses, although presented partially to archives on some occasions, was seldom detailed by archivists themselves, while the broad outlines of the methods (such as interpolation), were sometimes evoked. Instead, the archival and scientific discourses met on a conceptual level; they both focused on the categorisation and correction of film restoration problems, and they both pursued the goal of constructing an efficient restoration machine. Despite this closeness, the archaeology of image processing methods as used in film restoration has never been integrated into scholarly studies on the history of archives or restoration. I intend to do that in this part, aiming to underline their mutual influence in the development of technologies.

At this time, technology companies were also interested in digital film restoration. These included companies implementing film image technologies of all types. Some were specialised in mechanical, optical and photochemical film technologies such as those who manufactured film printers, viewing tables, developers, etc., while others came into existence precisely to implement digital image technologies. The latter notably included start-up companies, which were often spin-offs from university research groups. An example is HS-Art, deviating from Joanneum Research, which was responsible for the implementation and marketing of projects FRAME and DIAMANT. While the conception of digital restoration systems such as DIAMANT has never been included in scholarly studies, their use has been the subject of research from a pragmatic point of view,[191] their software or hardware has been presented by technologists or lab experts, and a considerable literature on restoration case studies with the help of these software exists which focuses on the possibilities offered by them as well as their ontological or ethical implications.[192]

Archives, universities and tech companies had each their own approach, but they did dialogue with each another. At the time, a political interest existed on the European level for digital technologies in view of the construction of a so-called "Information Society",[193] which enabled the funding of several projects with the collaboration of all three types of partners. The projects, either funded directly by the European Commission or sometimes by European national governing bodies, were broken down into smaller parts, and each part was entrusted to a partner specialising in that field. Moreover, several conferences on the continent also brought people from these different fields together, facilitating interdisciplinary dialogue regarding digital image technologies: the most important ones being the Joint Technical Symposium 2000 in Paris organised by CNC, the IEE Seminar on Digital Restoration of Film and Video Archives[194]

---

[191] Fossati, *From Grain to Pixel: The Archival Life of Film in Transition*, 2009. Arianna Turci, 'The Use of Digital Restoration within European Film Archives: A Case Study', *The Moving Image* 6, no. 1 (2006): 111–24. Julia Wallmüller, 'Criteria for the Use of Digital Technology in Moving Image Restoration', *The Moving Image* 7, no. 1 (2007): 78–91.

[192] For examples, refer to *Journal of Film Preservation*'s DVD section, articles on films, *The Reel Thing* presentations, Restoration case studies at festivals such as Il Cinema Ritrovato (Bologna) or Toute la mémoire du monde (Paris).

[193] I am borrowing the term from the Fifth Framework Programme (FP5) of the European Commission, entitled "Programme for research, technological development and demonstration on a 'User-friendly information society, 1998-2002'". See: https://cordis.europa.eu/programme/id/FP5-IST, accessed 3 June 2022.

[194] The Institution of Electrical Engineers (IEE), a British professional engineering society, was renamed Institution of Engineering and Technology (IET) in 2006.

in 2001 in London and finally Preserve Then Show, an archival conference organised by Danish Film Institute in 2001 gathering film archivists, technologists and university researchers:

> "One of the main purposes was to bring two worlds together whose aims ought to be the same, but whose starting points differ. On one hand we have the scientist speaking of preservation from the conservationist's point of view, and the other, the film historian dealing with the philosophical details in the restoration of a single film."[195]

These larger discourse networks shaped the conditions of adoption (and adaptation) or rejection of certain technologies. From the scientific developments to the technological adoption of digital image manipulation, there was a long way which would not have been realised at this point if it were not for a close collaboration between universities (scientific research), tech companies (implementation) and archives (user group). This process is reminiscent of what French sociologist Henri Hubert had written in 1903 regarding the study of technology:

> "Invention does not simply solve a mechanical problem. Between the problem and the solution are wedged a whole series of trials, not to forget extraneous data: it is on all these that sociological research should be carried out."[196]

The "extraneous data" such as political and (trans)national frameworks, as well as cultural practices would also need to be included in such a study. Similar theoretical concepts have been explored by researchers who study the integration of innovative technologies in the history of cinema, from Brian Winston in 1996,[197] to Benoît Turquety[198] and Technès group[199] more recently.

In this part, I aim to explore digital restoration experiments through scientific research and technological implementation in an attempt to follow how different digital image technologies were developed and adopted by film archives. By going into the technical details of image manipulation methods, I will explain how film restoration problems and solutions were envisaged within the scientific community, how that coincided or not with archival conceptions, and how it was adapted. This discussion paves the way to show how, following the collision with the scientific discourse network, the archival imaginary was also modified.

---

[195] http://shop.dfi.dk/shop/preserve-then-show-601p.html, accessed 5 April 2018.

[196] Henri Hubert, 'Technology. Introduction', in *Marcel Mauss. Techniques, Technology and Civilisation*, ed. and trans. Nathan Schlanger, 1st ed. (New York, Oxford: Durkheim Press, Berghahn Books, 2006), 33–34. Originally published as: Hubert, Henri, 'Technologie. Introduction, *Année sociologique* 6, 1903, 567-68.

[197] Winston, *Technologies of Seeing: Photography, Cinematography and Television*.

[198] Turquety, *Inventer le cinéma. Épistémologie: problèmes, machines*.

[199] Laurent Le Forestier, Gilles Mouëllic, and Benoît Turquety, eds., *Techniques et machines de cinéma, objets, gestes, discours*, Ecrans 13 (Paris: Classiques Garnier, 2020).

3.1 Scientific Discourse: Image Processing Research Applied to Film Restoration

Image processing is a field at the crossroads of mathematics, statistics, signal processing, computer science, engineering and applied sciences. Its applications are also very diverse, from diagnostic medical imaging,[200] space images and geographical studies to military guidance, surveillance and information technology systems. It concerns, put very broadly, the analysis and manipulation of different types of images in order to prepare them for a specific goal. For instance, in diagnostic medical imaging, an image acquired via X-Ray may undergo image processing to detect abnormalities such as tumours. Images obtained by surveillance cameras may benefit from image processing methods such as sharpening or object recognition in order to aid police or criminal justice departments to find evidence in them. In film restoration, image processing techniques may be used to remedy mechanical, chemical or biological damages inscribed on a digitised image and restore it into its presumed original state. In this part, I will first cover the scientific concepts of image processing, before getting to the scientific research done on film restoration by specific labs in collaboration with archives. This helps to understand how image processing field and archival film restoration came to meet conceptually early on when digital technologies became available; while they had existed independently of each other through optical and photochemical technologies up to then. I also underline here the subjectivity and approximation embedded in sciences due to different modelling and implementation methods and understandings, as well as the decisions involved in scientific developments; which, in turn, deconstruct the illusory omnipotence of sciences.

3.1.1 The Underlying Concepts of Image Processing Science

Historically, images were mathematically processed from the 1950s along two main lines: optical and electronic. In optical image processing, an image is an object composed of points distributed over a surface, each holding a density.[201] Both spatial and density (light intensity) distributions could be manipulated through optical methods (i.e., the use of light).[202] Thanks to

[200] During the 1960s and 1970s, there was a lot of research on image processing for medical imaging, much of which was published in the journal *Nuclear Medicine*. These focused mostly on “radio images” and not photographs, encoded analogically and serving an informative goal. The image processing methods took an existing radio image as input which, by its fabrication and goal, had different problems compared to cinema images. But the concepts of manipulation, restoration and enhancement could indeed also be applied to other types of images with minor changes in the initial modelling.
[201] This point will be further developed in Chapter Two, section 2.1.1.
[202] William Swindell, ‘Progress in Analog Image Processing’, Technical Report (Tucson, Arizona: Optical Sciences Center, University of Arizona, 1969).

this deconstruction, an image could be modelled as an optical three-dimensional signal. In electronic image processing, on the other hand, the image was described via electric signals. The spatial information of a spatial image was scanned line after line into a continuous signal, mapping samples of image points to values on one axis. In other words, the two dimensions of the spatial image (x-y) could be described via a one dimensional line signal (t), whose amplitude and phase carried the density and frequency information respectively.[203] Electronic image processing was, from the mid-1950s, applied to television imaging.[204] Machines of analogue computer type were built which could manipulate the images.[205] These machines continued to be in use in the broadcast and video industry up to the early 1990s. Optical image processing was developed more importantly from the 1960s, following the development of laser, a device that could direct a point light. Before that, images could of course be manipulated optically via lenses, light, etc., as was done in creating special effects for cinematographic films, but their mathematical description and development, which could permit more complex operations, date back to the 1960s. Although a technological possibility, these methods were rarely applied in film restoration by archives and labs, and no specific machine existed for such application. The scientific field of optical image processing, thus, did not meet directly with the archives before, while it brushed against the special effects field within the film industry. I suspect that it was probably due to a lack of mutual interest, as well as a lack of a technical consensus on film restoration within archives at the time. But, as mentioned in the previous parts of this chapter, I believe that it also had to do partly with the specificity of available optical technologies, which, when digitised could be applicable more widely.

Considered in one way or another, in image processing, images are modelled as signals for which mathematical operations may be defined. While the two aforementioned approaches were closely related to their technological implementation via optical or electronic tools, they did share similar mathematical processing concepts. Mathematically, image processing is comprised of “Image Transformations [which] are performed using Operators. An Operator takes as input an image and produces another image”.[206] In the case where an image is defined by its density within its two spatial dimensions, it can be modelled statistically. Indeed, the

[203] L. S. G. Kovasznay and H. M. Joseph, ‘Image Processing’, *Proceedings of the IRE* 43, no. 5 (May 1955): 560–74.

[204] Peter C. Goldmark and John M. Hollywood, ‘A New Technique for Improving the Sharpness of Television Pictures’, *Proceedings of the IRE* 57, no. 4 (October 1951): 382–96.

[205] John K. Russell, ‘A Visual Image Processor’, *IEEE Transactions on Computers* C–17, no. 7 (July 1968): 635–39.

[206] Maria Petrou and Panagiota Bosdogianni, *Image Processing. The Fundamentals* (Chichester: John Wiley and Sons, 1999), 6.

image points are scattered on the image surface, whose distribution can be estimated statistically. Obtained in this way, an image function D=f(x,y), which gives the density (D) of each point according to its spatial coordinates (x,y), can then be manipulated through operators, which perform different functions (Figure 5, Figure 6). In the case of a linear image, the image function is defined as dependent upon the phase, amplitude and position (t) of its sampled points (Figure 5, Figure 7).

Figure 5 A digitised frame of *Grauzone* (Fredi Murer, Switzerland, 1979). Transcoded from the original restored DPX to JPEG.

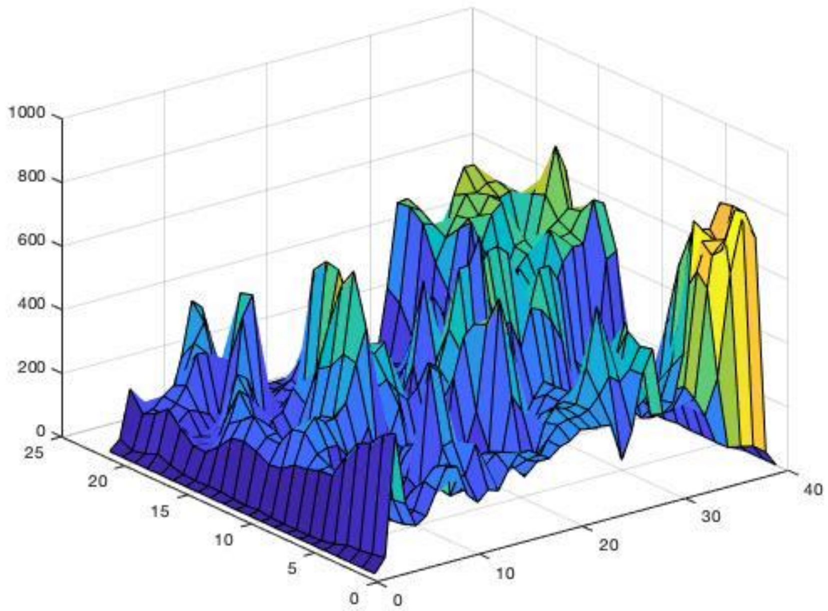


Figure 6 The same image of Figure 5 as represented through its spatial coordinates (x-y) and its brightness values (on the z-axis). The dimensions of the image have been reduced to 22x40 pixels in order to enable a better visualisation.

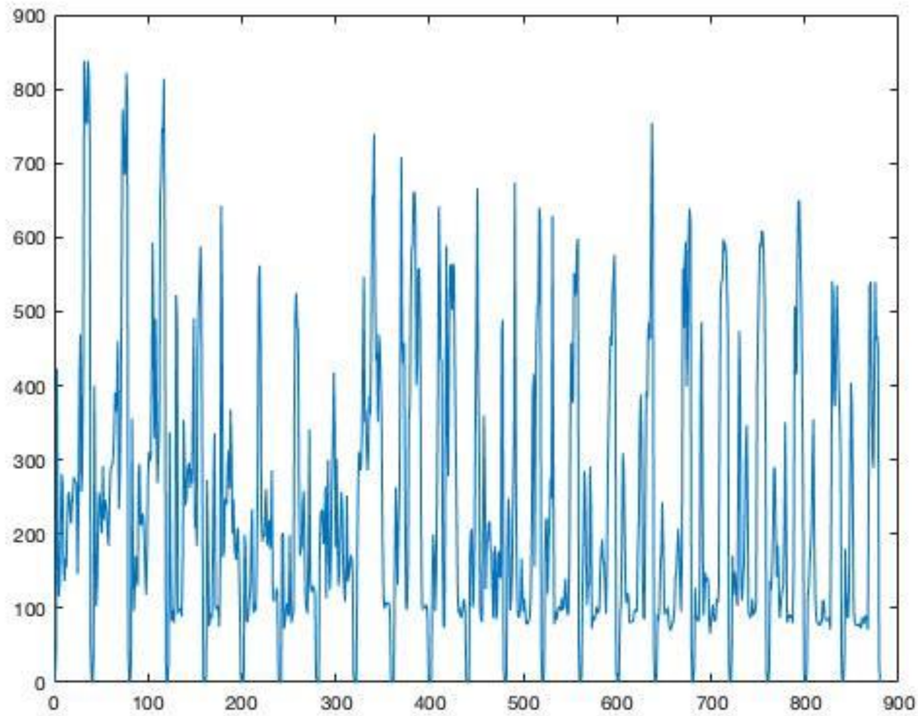


Figure 7 The same image of Figure 5 when represented as a line scan: the brightness values (on the y-axis) follow one another continuously. The values on the x-axis correspond to the position of each point on the image, read line per line from left to right. The dimensions of the image have been reduced to 22x40 pixels in order to enable a better visualisation (thus 880 image points in total on the x-axis). The parts where the curve value is zero (at regular intervals) correspond to the black pillarboxes on the two sides of the image.

The operators are defined through their own functions, and when combined with that of the image, they produce a new image. Mathematical modelling can be used to generate functions which correspond to specific problems in image manipulation: a blurry image can be sharpened, a noisy image can be denoised, objects can be detected, recognised and extracted with the use of matching masks, the light intensity can be manipulated, etc. The mathematical operations could intervene on the spatial or linear image models themselves, or on their frequency equivalent. Frequency is “the number of times something happens within a particular period”,[207] or a particular space in the case of spatial frequency. Indeed, with statistical or calculus methods, it can sometimes be complicated to perform some manipulations. If images are modelled through their frequency instead of their spatial or linear coordinates, other mathematical operations can be enabled, which can modify their spatial distribution, i.e., intervene on the coordinates of image points through some kind of filtering: create more image points, reduce them, move them, etc. The filter, here, is the operator which transforms the

[207] As defined by Cambridge dictionary, see: https://dictionary.cambridge.org/dictionary/english/frequency, accessed 2 July 2021.

image.[208] The image processing operations offered thus a large range of possibilities of manipulating the image – while remaining limited:

> "Of course, one cannot 'make a picture of one thing into a picture of something else' in all conceivable cases; but it is possible to define a large, nontrivial class of such operations which can, theoretically, be performed."[209]

Then, "the required mathematical operations [could] be performed either by digital-electronic computation or by optical-analog computation".[210] During the 1960s and 1970s, research on all these different technologies, or a mix of them, was flourishing. In some studies, the methods were also compared.[211] From the 1980s, digital methods gained more momentum, pushing the optical methods to the side-lines, while the analogue-electronic image manipulation machines remained in use in the television industry until the 1990s at least. In sum, while reigned by similar mathematical concepts, different technological implementations provided relatively different ways to manipulate the images. Digital implementation of image processing techniques and concepts could yield other manipulation ways, some of which were amplified versions of existing optical and electronic methods and some others, as I will show, were enabled uniquely because of digital implementation. I qualify these processes as representative of a bi-directional relationship between sciences and technologies; and claim that their expansion at a moment where discourses on film restoration were also flourishing might explain why the scientific and archival imaginaries ended up to meet and interact.

Some Purposes of Image Processing: Enhancement and Restoration

The operations in image processing were conducted for a variety of reasons: analysis, enhancement, restoration and reconstruction, or yet compression of images. From early on, the two purposes of image enhancement and image restoration drew a lot of attention.[212] There

[208] For the mathematical details of analogue optical image processing, see: Joseph W. Goodman, 'Analog Optical Signal and Image Processing', in *Handbook of Optics. Volume I: Geometrical and Physical Optics. Polarized Light, Components and Instruments*, ed. Michael Bass et al., 3rd ed. (New York: McGraw-Hill, 2009), 30.1-30.24. For operations on spatial frequency, see also: W.D. Hall and N.G. Massey, 'Optical Spatial Filtering', in *Quantitative Organ Visualization in Nuclear Medicine*, ed. P.J. Kenny and E.M. Smith (Miami: University of Miami Press, 1971), 619–49.

[209] D. H. Kelly, 'Image-Processing Experiments', *Journal of the Optical Society of America* 51, no. 10 (October 1961): 1095.

[210] George W. Stroke et al., 'Image Improvement and Three-Dimensional Reconstruction Using Holographic Image Processing', *Proceedings of the IEEE* 65, no. 1 (January 1977): 39.

[211] Thomas S. Huang, 'The Use of Digital Computer in Optical Image Processing', *IEEE Journal of Quantum Electronics* 3, no. 6 (June 1967): 245–245.

[212] See for example: James L. Harris, 'Image Evaluation and Restoration', *Journal of the Optical Society of America* 56, no. 5 (May 1966): 569–74.

have been different definitions for each one, which do not necessarily coincide with the archival understanding of the same terms. Image enhancement is defined as a "process by which we try to improve an image so that it looks subjectively better".[213] It could be considered as an attempt "to improve the quality of the image or to emphasise particular aspects within the image. Such an objective usually implies a degree of subjective judgement about the resulting quality and will depend on the operation and the application in question".[214] The term "subjectivity" implies a high degree of liberty in the application of methods which are not tied to a particular historical perception. Scientifically, image enhancement does not provide a definitive answer which can be applied unconditionally. Rather, it needs to be adapted for each use case by carefully considering its goal, and might be applied to variable degrees according to the operator's preferences and decisions. For image enhancement, the transformation that the image goes through does not aim at the recreation of a particular pre-existing image, and in this way, it neglects the historicity of the image:

> "We do not really know how the image should look, but we can tell whether it has been improved or not, by considering, for example, whether more detail can be seen, or whether unwanted flickering has been removed, or the contrast is better etc."[215]

I argue that the reference for a "better" image in enhancement is entirely subjective: for an image, while one might judge that it needs to be sharpened, another might decide that a blurring could do it good. But the general tendency nurtured by film manufacturers to celebrate sharper, more detailed, unflickered images, which was often accepted within film archives as I have been stressing throughout this chapter, joins this technical understanding of image enhancement. Its upper limit was decided by technological possibilities until the early 2000s, when the theoretical reflections on digital technologies gained more ground within archives. From then on, the term "enhancement", probably borrowed from the scientific field, or "improvement", was to be treated with more caution within archival community (as shown in the previous parts of this chapter).

Through image enhancement, several tasks may be conducted: noise removal, flicker removal, contrast modification, definition upscaling, sharpening, de-blurring, etc. For example, definition upscaling is obtained if high spatial frequencies of an image are increased. This means that the image points are closer to each other, and the definition is mathematically higher – although this may not hold true from a visual perspective. There are of course technical limits

[213] Petrou and Bosdogianni, *Image Processing. The Fundamentals*, 125.
[214] G.J. Awcock and R. Thomas, *Applied Image Processing* (London: MacMillan, 1995), 90.
[215] Petrou and Bosdogianni, *Image Processing. The Fundamentals*, 125.

when the image is enhanced too much, as “some defects or artifacts appear”.[216] The subjectivity, in the case of image enhancement, means that there is no definitive goal towards which these methods move. It is upon the human operator to fix the degrees of processing. When these methods are implemented for film restoration operations, this remains the case: an operator, or a restorer, needs to decide which method should be applied, or determine the upper limit of intervention. The results are highly dependent of these decisions.

The second term, image restoration, applies to when “we are trying to reverse a specific damage using objective criteria”.[217] The objectiveness of image restoration, as understood by scientific discourses, is that the damage can be modelled mathematically, and thus its effect is included the calculations:

> “The aim of image restoration is to recover the original image after it has been degraded by ‘known’ effects such as geometric distortion within a camera system or blur caused by poor optics or movement. In all cases a mathematical or statistical model of the degradation is required so that restorative action can be taken.”[218]

When applied to the film archival perception of restoration, a problem arises: most often, the original image is not precisely known, only imagined. The marks of time have definitely changed the original image, whichever original is chosen: should the image be restored to its negative state or its print state (or else)? This signifies that a level of estimation and subjectivity is also involved in this task, despite the claimed mathematical “objectivity”, which, by the way does not necessarily hold true either because of approximations involved in its modelling and implementation methods. In order to detail this statement, I remind that image restoration needs to include two distinct operations: first, to model the degradation, and second, to devise a solution to remove or reverse it. This means that every type of film image degradation needs its own mathematical models and solutions, and subsequently its own technological implementation for both of these tasks. This is how automation should mathematically be achieved. The complication is that there are so many ways that film damages may manifest themselves on the image. Moreover, the detection of problems is based on a certain modelling of them, which cannot be universal nor error-proof. A computer treats the images as a set of digital data, on which it applies some transformations. For instance, to detect dust, it performs a comparison of pixels in their neighbourhood: if one or a few pixels present a radically different

[216] William F. Schreiber, ‘Image Processing for Quality Improvement’, *Proceedings of the IEEE* 66, no. 12 (December 1978): 1643.
[217] Petrou and Bosdogianni, *Image Processing. The Fundamentals*, 193.
[218] Awcock and Thomas, *Applied Image Processing*, 90.

value compared to what is around them, they are detected as dust. However, it might have been a raindrop in the image.[219] The threshold value might also be different, giving different end results. Considering this workflow, an error-free full-automatic software for film restoration, which would include all different types of damages, would never come to exist; although at one point it was imagined in the scientific discourses.

In cinematographic film restoration, methods belonging to both groups of image enhancement and image restoration are applied. Some of the damages are modelled mathematically, and restored considering the effect of the damage. For instance, line scratches or dust can be modelled (in different ways, as I will mention later) and these models are included in the algorithms and solutions for their removal. Enhancements, such as noise-removal (de-graining) or sharpening may also be used. They have been integrated into film restoration software that I will introduce in the next parts of this subchapter. Their use, again, depends on decisions taken by a human operator.

What is important to note at this point, is that the mathematical basis of image processing has been developed for different use cases, from NASA images and surveillance cameras to cinematographic film, and the notion of quality improvement does not have a unique meaning in all of them. What is considered as an improvement to a medical image of a brain, such as sharpening, can be a disaster in the case of cinematographic film restoration. Electronic noise removal is a popular and routine process for television images, while de-noising in the case of film restoration touches the grain, creating more often than not unwanted artefacts. In other words, the reference framework within which an image is judged for its better or worse quality is not the same, neither culturally, nor historically, even within one episteme. The notions might not have been the same within the two networks of film archival and scientific discourse; but their different understandings did influence each other. While some scientific methods developed for specific archival problems ended up being adopted (over others) due to their efficiency, some notions of improvement in scientific understanding have also contributed to forming the subjective archival view of how an improved image should look like.

[219] An example of this can be found in Nederland Filmmuseum (EYE)'s video of the restoration of *Beyond the Rocks* (Sam Wood, 1922), where parts of a dog are mistakenly identified as dust and removed. *Beyond the Rocks* was found in the Netherlands, and in the early 2000s it was restored under the supervision of Giovanna Fossati: https://www.youtube.com/watch?v=-Y7CPvtg6O4, accessed 22 June 2020. A complete account of the restoration can be found in Giovanna Fossati, *From Grain to Pixel: The Archival Life of Film in Transition*, 3rd ed. (Amsterdam: Amsterdam University Press, 2018), 297–307.

Digitisation of Image Processing: What is a Digital Image?

Earlier, I mentioned that image processing methods became interesting for archival applications when they were digitised. Here, I will go into the technical details of this transformation, in order to argue for this newly-found proximity between scientific and archival imaginaries of the time.

Digital image processing techniques were explored at Bell Laboratories from the 1960s, and they gained more importance from the 1970s onward in many universities around the world. These had one main advantage: on a numerical level, it was much easier to calculate the necessary functions with digital computers. When applied to film restoration, an image on film was digitised into a code stream, and visualised on a computer. In order to understand the digitisation effect of image processing, I explain what, exactly, becomes digital when photochemical film images of any kind are digitised as a spatiotemporal entity. Film images have always been temporally discrete.[220] This means that instead of having an infinite number of images per second to represent a continuous time and movement, there are only a limited number of images per second (16, 24, etc.). Thus, a film makes a temporal sampling to register the images; that is to say, in order to represent the movement, the film breaks it down into a number of still images at regular intervals. This characteristic remains unchanged in digitisation when images are digitised as distinct uncompressed files, as it was done dominantly in post-production and restoration by this time.

Spatially as well, the photochemical image on film has always been discrete. The elements which form the image on the film are grains or dyes which exist in the emulsion. Not all the surface area of the emulsion can contribute to image formation, only discrete points or parts can. Moreover, the process of photochemical recording is also spatially discrete:

> "Samples of light energy, known as 'quanta' of light, are emitted from points of an object. A small fraction of these samples is collected and directed by the camera lens to form an instantaneous image of the light distribution at the object. The degree of continuity in the image information is obviously dependent on the number of samples; with respect to an area, continuity depends on the sample density."[221]

---

[220] Sean Cubitt has noted this, and called the frames "temporal pixels": Cubitt, *The Practice of Light: A Genealogy of Visual Technologies from Prints to Pixels*.

[221] Otto H. Schade, 'Image Gradation, Graininess and Sharpness in Television and Motion Picture Systems. Part I: Image Structure and Transfer Characteristics', *Journal of the Society of Motion Picture and Television Engineers* 56, no. 2 (February 1951): 139.

If the sample density is high enough, the human vision can of course perceive it as continuous, either when on film or projected. The spatial discreteness, however, remains valid from a mathematical point of view. The composition of samples on a photochemical film, which forms the image structure, does not follow a specific geometric pattern and changes from one image to the next. When digitised, the image is spatially sampled again, and the densities recorded on film are mapped into a fixed structure of a great number of pixels juxtaposed as a grid.[222] By digitisation, each pixel is mapped to a small surface on the photochemical image, as shown in Figure 8 (discrete spatial sampling). The higher the digital pixel count, the smaller the surface of each pixel, and the more accurate the sampling of the photochemical source image. A pixel holds one value, which applies to all the surfaces inside it. This represents one level of estimation involved in the discrete spatial sampling.

What is continuous in a photochemical image and becomes discrete after digitisation is the density, whose continuous value is quantised (with an estimation, naturally) – or discretised – to fit into a digital system (Figure 9). The value of each pixel, corresponding to the luminosity of that part of the photochemical image, is described by a number held by a number of bits (8, 10, 12, 14 or 16 in the case of archival applications). The latter is called the bit depth. Every bit can hold the value of 0 or 1, it has thus two states. A bit depth of 8 means that the pixel can represent 2^8=256 values of density, while a higher bit depth, such as 16, can represent 2^{16}=65536 values. If this number is higher, the discrete values may seem continuous to the human vision (Figure 10). Nevertheless, mathematically, they are discontinuous. This is the second level of estimation by digital discrete sampling.

[222] When the source image is in colour, three sets of grids are produced, each one corresponding to one colour channel (red, blue and green).

Figure 8 An example of how a grid of pixels is superimposed on a (digitised) photochemical image. Original photo courtesy of Cinémathèque suisse. The smaller the surface of each pixel, the more accurate the sampling.

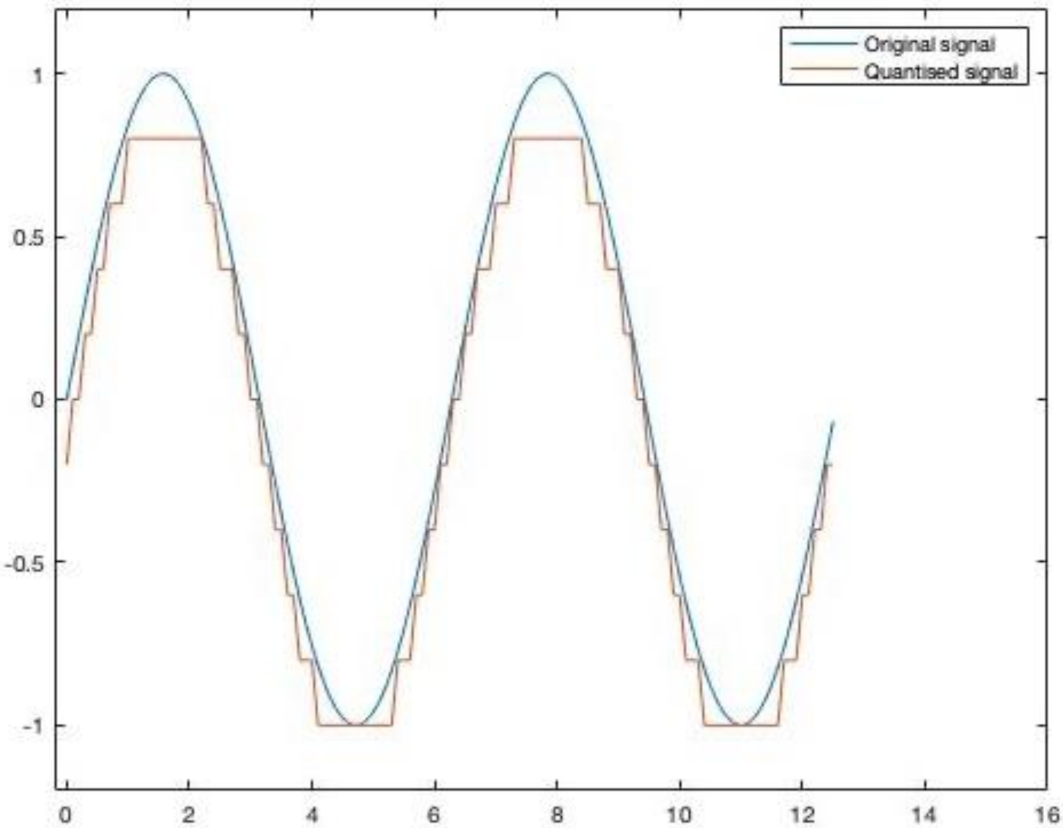


Figure 9 The continuous signal (in blue) is quantised at regular intervals, creating the discretised signal (in red). This figure shows well the estimation involved in the quantisation process. Naturally, the smaller the intervals, the better the estimations.

Figure 10 A digitised frame of *La Paloma* (Daniel Schmid, Switzerland, 1974) in two different bit depths. In the second image, the colours have been compressed with only 256 shades possible. Original image courtesy of Cinémathèque suisse.

A digital image can be visualised in different forms: a sequence of ones and zeros, a 2- or 3-dimensional matrix of pixel values, an image on a computer screen. Materially, the digital image exists only as a sequence of ones and zeros (implemented on a digital carrier such as a hard disk). Every one or zero is constructed by a switch (a transistor) which can be on or off to electrical current (Figure 11). The amount of current circulating through the switch is not important, it only counts if the switch is on or off.

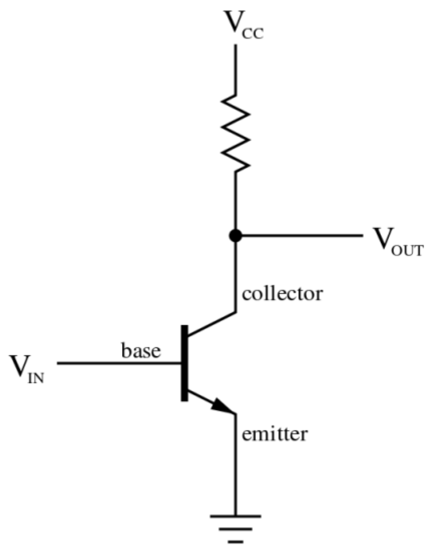


Figure 11 The schematic representation of a transistor as a switch. If the input voltage (V_{IN}) is higher than a certain threshold, the switch is closed, and current circulates between emitter and collector, amounting for an output voltage (V_{OUT}).[223]

An image can also be represented as a matrix,[224] which offers a visual way of representing image information (point values). Its rows correspond to the x coordinate, and its columns correspond to the y coordinates. The information D=f(x,y) represents the value of that point (Figure 12). As the number of rows and columns need to be a natural number (1, 2, 3, …), the representation of the image as a matrix implies its spatial discreteness. Schematically, every matrix cell corresponds to one pixel.[225]

[223] Source of the image : https://en.wikipedia.org/wiki/Transistor#/media/File:Transistor_Simple_Circuit_Diagram_with_NPN_Labels.svg, accessed 27 April 2021.

[224] For a history of matrices, see: Frédéric Brechenmacher, 'Les matrices : formes de représentation et pratiques opératoires (1850-1930', in *CultureMATH – Site expert ENS Ulm / DESCO*, 2006, 1–6, https://hal.archives-ouvertes.fr/hal-00637378/document, accessed 20 May 2020. A. Bernardes and T. Roque, 'History of Matrices', in *Mathematics, Education and History. ICME-13 Monographs*, ed. K. Clark et al. (Cham: Springer, 2018).

[225] In the case of a black and white image. If the image is in colour, one matrix exists for each colour channel.

0	50	79	27	36	61	70	48	37	44	48	62	62	55	57	64	70	67	71	42	60	115	82	64	120	206	192	188	203	212	77	0
0	43	74	23	37	54	51	51	59	65	60	62	54	41	45	69	76	73	85	131	109	110	87	65	86	146	182	173	177	216	75	0
0	39	70	21	27	27	23	102	96	31	36	36	31	45	56	60	70	73	80	91	83	75	129	65	57	85	150	165	175	142	30	0
0	28	64	20	21	21	29	77	79	20	23	23	15	89	150	54	48	63	62	69	75	69	96	53	58	49	50	57	62	42	10	0
0	17	56	21	19	24	26	43	52	21	24	25	57	103	146	123	57	47	50	57	61	42	47	40	54	56	24	27	27	31	12	0
0	14	58	30	32	28	39	20	46	37	21	24	81	111	108	78	52	36	37	56	64	44	27	23	53	64	32	37	39	39	14	0
0	14	61	75	72	67	87	91	77	82	59	71	92	93	133	123	142	87	74	66	91	82	63	37	31	32	29	30	32	31	11	0
0	11	60	56	42	58	98	167	114	106	87	34	34	68	106	137	155	153	163	153	111	127	138	115	46	23	25	25	26	23	8	0
0	13	47	45	24	40	87	146	136	112	66	17	23	107	115	61	112	129	121	125	119	82	58	33	22	23	19	20	26	43	14	0
0	15	55	53	25	29	63	110	154	83	33	20	22	51	61	27	33	32	35	29	27	21	41	67	39	40	76	70	78	157	57	0
0	18	55	54	29	44	58	72	149	44	23	21	22	25	29	24	28	21	23	27	23	23	34	89	118	74	118	137	140	167	68	0
0	14	42	66	57	36	35	40	87	40	19	21	21	24	24	23	27	38	45	44	38	25	30	68	91	111	119	127	136	143	47	0
0	10	25	41	71	64	36	22	28	24	20	19	19	21	23	23	27	46	71	90	70	28	19	65	97	111	118	112	156	191	67	0
0	12	24	21	29	38	67	61	28	23	30	26	21	17	17	20	25	30	28	35	37	27	41	131	133	154	129	122	145	155	61	0
0	24	31	30	26	19	58	132	81	24	34	38	53	68	46	22	22	22	24	22	23	24	61	121	133	139	149	153	143	125	37	0
0	19	33	37	51	67	56	48	53	27	25	30	36	47	80	56	20	21	23	22	21	20	90	127	114	153	163	148	129	96	26	0
0	15	33	35	42	56	87	62	33	21	20	19	19	19	23	28	22	20	21	21	20	25	115	133	94	95	122	125	101	96	35	0
0	22	37	26	26	41	88	92	51	21	19	19	19	19	18	18	22	20	21	22	20	27	117	135	97	74	92	127	109	118	43	0

Figure 12 The image seen in this figure is represented by the matrix. It is the same digitised frame of *Grauzone* as in Figure 5, whose dimensions have been heavily reduced to 18x32 so that the matrix can fit into this figure. As it can be seen in the matrix, the brighter parts have a higher brightness value.

When a digital image is represented as a matrix with pixels holding the image information, image processing methods are more diverse, as it becomes easier to manipulate each pixel. The digital operators can intervene on only one pixel ("point operators"), while also fulfilling the tasks analogue and electronic could achieve. They can consider the pixel with regards to its neighbouring pixels ("neighbourhood operators"); manipulate the density distribution of all the pixels of the image ("global operators"); modify the pixel value "according to the structural content of the image" ("geometric operators"); or include the corresponding pixel values from preceding and succeeding frames ("temporal (frame-based) operators").[226] This way, several mathematical tools were at disposal, which could make up diverse solutions to image manipulation needs; hence their interest for film restoration at a time where archives were eager to experiment. In what follows, I will detail how these possibilities were put to use within the scientific community in order to solve specific film restoration problems.

[226] Terms and categorisation come from: Awcock and Thomas, *Applied Image Processing*.

3.1.2 Film Restoration at the Heart of Technical Research at European Universities

As evoked before, from the early to mid-1990s, a growing number of researchers in European Universities started working on image processing techniques for application to film restoration. In this part, by investigating the main research lines undertaken during this time, I will analyse how different concepts and problems of film restoration were understood in the scientific imaginary, and how this understanding was dynamic, changing through time, on the road towards technological development and when crossing paths with archival imaginaries.

Restoring Archives Film and Video Images: Anil Kokaram, 1993

The first major work to model specific film damages, and propose algorithms for their detection and correction was Anil Kokaram's PhD. thesis in 1993 (University of Cambridge). His research was inspired by two subfields of image processing popular at the time: still images (which was rooted in the concepts of optical image processing) and video (which made use of electronic image processing methods). At the time, the main approach of the previous studies on image sequences and film restoration, which constituted a rather small literature, was to do "temporal filtering alongside motion trajectories",[227] by using a filter to remove noise and "impulsive distortion"[228] (dirt, dust, sparkle or blotches). Kokaram proposed to combine all these approaches for a spatio-temporal manipulation of film and video images. He considered the image sequence as a 3D entity, the third dimension being that of time: "an algorithm that can take advantage of the high temporal correlations that exist between frames, has the potential to reject more distortion than a 2D operation".[229] This view enabled him to model damages in a more complicated manner:

> "Dirt and Sparkle can be effectively modelled as randomly distributed Impulsive distortion which replaces the image information in selected regions. These distortions are not limited to single pixel impulses but can also occur as variable sized patches of uniform grey level which are highly contrasted with the surrounding image. These patches represent regions of missing information in the frame."[230]

[227] Stuart Geman, Donald E. McClure, and Donald Geman, 'A Nonlinear Filter for Film Restoration and Other Problems in Image Processing', in *CVGIP: Graphical Models and Image Processing*, vol. 54, 1992, 281–89.
[228] As described by Anil C. Kokaram, 'Motion Picture Restoration' (PhD Thesis, Cambridge, University of Cambridge, 1993).
[229] Kokaram, 5.
[230] Kokaram, 87.

The dirt and sparkle, that Kokaram called "blotches", were identified in his work as shapes or regions which had radically different data compared to its neighbouring spatiotemporal regions. Kokaram's algorithm was a 3D "autoregressive model", which statistically modelled time-varying processes depending on their previous state with a degree of imperfect prediction. In this way, it identified approximately the regions that needed to be filtered instead of applying filters to the whole image. In his approach, damages were first detected, then corrected, contrary to the previous methods where the detection was conducted visually (if any), and the correction was applied to the whole image.[231] Kokaram's method did not rely on the individual treatment of pixels, and modelled film or video image based on their visual characteristics, both in the same way as moving images in compressed formats (similar to how previous non-digital methods of image processing functioned). Here, the contribution of digital image processing seemed to be its easier calculability while remaining conceptually similar to before.

When the damages were modelled and identified as such, image restoration, as understood scientifically, could be conducted. For recovering the identified missing image information, Kokaram's proposal was 3D interpolation. The latter is a statistical method, which estimates a value between two or several known values. The missing image values would be estimated in association with their neighbouring spatiotemporal pixels. According to different interpolation algorithms, slightly different values could of course be suggested as correction.[232] There is, thus, not one unique scientific answer to any restoration method; estimation and approximation are necessarily part of it. As Kokaram envisaged it, interpolation was to be automated, but in later restoration software, it can also be carried out manually. Interpolation remains the main method of restoring missing image information in digital film restoration.

After his PhD, Kokaram was a research fellow at the University of Cambridge for four years before joining Trinity College in Dublin, where he founded the Signal Processing and Media Applications (SIGMEDIA) research group. The group was involved in more film restoration research and it notably collaborated with Irish Film Archive during the early 2000s to do restorations of some Irish silent films.[233] The first of the restored films, *Rory O'More* (Sidney Olcott, 1911), underwent an automatic film restoration through algorithms developed by

---

[231] Anil C. Kokaram et al., 'Interpolation of Missing Data in Image Sequences', *IEEE Transactions On Image Processing* 4, no. 11 (November 1995): 1509.
[232] Kokaram et al., 'Interpolation of Missing Data in Image Sequences'.
[233] Kevin Rockett, 'Dublin – Irish Film & TV Research Online', *Journal of Film Preservation*, no. 87 (October 2010): 85–86.

Kokaram's team and "implemented as computer programs" in 2002.[234] The film was scanned on a telecine machine and recorded onto BetaSP. The operations applied to the film were deshaking, deflickering and deblotching. For all of these operations, the damage was first detected by a set of algorithms, then removed by another set. The two-step detection-correction workflow indeed enabled a possible automatic restoration from a scientific point of view (whether the results satisfied archival film restorers or not). As mentioned before, the automation was also an important goal of European projects on film restoration by television archives, AURORA and BRAVA (which produced in the end the restoration machine Archangel), in which Kokaram participated during the 1990s and the early 2000s, alongside other university partners such as Delft Technical University in the Netherlands.[235] AURORA, notably, aimed to automate restoration, providing an all-inclusive machine for film and video:

> "There is a need for an automated tool for image restoration due to the vast amounts of archived film and video and due to economical [sic] constraints. The term automated should be stressed because manual image restoration is a tedious and time-consuming process."[236]

Focus on Colours: University of Basel

Automation was also a main concern in the University of Basel's Imaging and Media Lab from the early 1990s, most importantly for the problem of faded colours. In the 1980s, the lab, called the Institute of Physical Chemistry at that time, was specialised in scientific study of photography. Then, under the supervision of Rudolf Gschwind, the lab started working on digital photography, and their first papers on digital colour restoration appeared in the late 1980s. Up to then, photochemical colour restoration had been subject to much study, notably by Kodak,[237] but it remained complicated and not very effective in practice. Through the chemical study of photography, Gschwind proposed a model for bleached photographs using "electronic imaging" since 1989. The idea was to reconstruct the original colours from faded

[234] Anil C. Kokaram et al., 'Restoring Rory O'More', http://www.mee.tcd.ie/~sigmedia/Research/RoryOMore, accessed 22 May 2020.
[235] J. Biemond, P.M.B. Roosmalen, and R.L. Lagendijk, 'Restoration of Old Film Sequences, AURORA Project', in *CERN School of Computing*, ed. Carlo E. Vandoni (Egmond aan Zee, The Netherlands, 1996), 1–9.
[236] P.M.B. Roosmalen, 'Restoration of Archived Film and Video' (PhD Thesis, Delft, Delft Technical University, 1999), 2.
[237] See: Eastman Kodak Company, 'Restoring Faded Transparencies by Duplication (White Light Printing Methods)', *Current Information Summary (CIS)*, no. 22 (July 1979); Eastman Kodak Company, 'Restoring Faded Transparencies by Duplication (Tricolor Printing Method)', *Current Information Summary CIS*, no. 23 (August 1979); H.C. Bradley, 'Corrective Reproduction of Faded Color Motion Picture Prints', *SMPTE Journal* 90, no. 7 (1981): 591–96.

colours and information about the bleaching. The optical density of the faded film was calculated, the chemical information regarding the bleaching (which depended on the type of the film), as well as the "historical climatic considerations", were also modelled. With this information, a mathematical reversing would reconstruct original colours (or a version close to them). However, he noticed:

> "In most cases though, the only piece of information available is the degraded photograph itself and a few rough estimates from photographic analysis. Therefore, restoration has to be carried out interactively, under visual control and judgement by a human operator."[238]

Basel research was at first conducted on still image colour restoration, but later, from 1994, they adapted their models for both "color photographs and color movies".[239] The optical densities needed for the method were obtained with a densitometer, an opto-chemical device. In 1998, they also developed a scanner which could register these densities directly.[240] The Lab's colour reconstruction method could indeed achieve a reconstruction automatically, but it did permit (and promote) the intervention of a human operator to visually correct the colours further by modifying familiar characteristics such as "contrast, brightness, colour cast, and saturation".[241] I underline here how an initial search for automation within the scientific developments, was transformed into a more hybrid approach.

Researchers in Basel also worked on "computer vision methods" that could remedy films degraded by dust and scratches. Lukas Rosenthaler, Gschwind and others presented a paper called "Restoration of Old Movie Films by Digital Image Processing" in 1996,[242] which showcased their in-house restoration software to remove dust and scratches. The lab was provided with a faded movie trailer in 1995 by Cinémathèque suisse. The result of this featured on the news on German-speaking Swiss national television,[243] but there was no real collaboration between the lab and the archive. Rudolf Gschwind was a regular contributor to

---

[238] Rudolf Gschwind, 'Restoration of Faded Color Photographs by Digital Image Processing', in *Proceedings of SPIE 1135. Image Processing III*, vol. 1135 (Paris: SPIE, 1989), 27–30.

[239] Rudolf Gschwind and Franziska Frey, 'Electronic Imaging, a Tool for the Reconstruction of Faded Color Photographs and Color Movies', *Journal of Imaging Science and Technology* 38, no. 6 (1994).

[240] Werner Graff et al., 'New Scanning Approach for Motion Picture Digitizing', in *Proceedings of SPIE 3409. Electronic Imaging: Processing, Printing, and Publishing in Color*, vol. 3409 (Zurich: SPIE, 1998), 194–201.

[241] Rudolf Gschwind, Franziska Frey, and Lukas Rosenthaler, 'Electronic Imaging: A Tool for the Reconstruction of Faded Color Photographs and Color Movies', in *Proceedings of Spie 2421. Image and Video Processing III*, vol. 2421 (San Jose, USA: SPIE, 1995), 57–63.

[242] Lukas Rosenthaler et al., 'Restoration of Old Movie Films by Digital Image Processing', in *Proceedings of IMAGE'COM 96* (Bordeaux/Arcachon, France, 1996).

[243] https://www.srf.ch/play/tv/mtw/video/filmrestaurierung-digital?id=0f72db54-8c9e-4eb8-a307-b0498b8fc0c5, accessed 23 May 2020.

archival conferences, detailing what was in the digital black box, and attentive to the archival preoccupations. In his work, the tension between the automatic and manual treatment of images is apparent: while for colour correction he proposed a more interactive software, for "temporal discontinuities" (damages such as spots, dust and fingerprints), he preconised an automatic restoration thanks to the "robust" algorithms they had developed.[244]

The research work conducted at Basel did not turn into a concrete and usable software available to film archives, and the lab did not directly engage in any interdisciplinary software development research, but its work enriched the scientific discourses and was often cited by subsequent research work elsewhere – even in a patent granted to Kodak in 1998 for "Restoration of Faded Images".[245]

High-Definition Uncompressed Image Manipulation: Research and Collaboration with Film Archives

Unlike Kokaram's research, which modelled film and video together, and Basel, which adapted methods developed for still image to the case of moving images, two research laboratories in France and Austria focused specifically on the restoration of high-definition image sequences for cinema films, elaborating algorithms different from those for video or still images. They were both involved in the development of several film restoration software in collaboration with film archives. This line of research corresponded to the growing tendency within the archival community to combine restoration methods with high-definition digital imaging. I will cover their research in this part, and the implemented systems to which they contributed in the next subchapter.

In France, the "laboratoire d'informatique et d'imagerie industrielle" (L3i) of La Rochelle University was created in 1993. Bernard Besserer, who had just finished his PhD. in electronics, joined the lab in November 1993 and started research on image analysis, and more particularly focused on "image sequence treatment and large-size digital image manipulation".[246] The lab collaborated closely with Laboratoires Neyrac Film (LNF, headed by Bruno Despas), which was involved in early European restoration projects, such as LIMELIGHT. L3i's work focused on high-definition uncompressed images (2K or 4K) during LIMELIGHT project. Besserer and

[244] Lukas Rosenthaler and Rudolf Gschwind, 'Restoration of Movie Films by Digital Image Processing' (IEE Seminar on Digital Restoration of Film and Video Archives, London, 2001), 6 1-6 5.

[245] Geoffrey John Woolfe, Bruce Harold Pillman, and Michael James Barry, Restoration of Faded Images, US Patent 5,796,874, issued 18 August 1998.

[246] Bernard Besserer's CV as presented on the website of RETOUCHE project: https://web.archive.org/web/20020112172507/http://retouche.free.fr/present/equipe.htm, accessed March 17, 2021. My translation.

the team at L3i (Olivier Buisson, Laurent Joyeux, Samia Boukir) covered a wide range of applications of image processing in film restoration for detection and correction of damages:

> "[Previous methods] consider the 'blobs' as impulse distortions or noise. Thus, deteriorations are restored using filtering techniques. These 'blind' filters are applied to the entire image, removing deteriorations, but also deteriorating the regions which are not corrupted. A solution to cope with this problem consists in isolating first the regions with defects[247] and then treating only these regions".[248]

Their method in 1996 combined the spatiotemporal motion-compensating detector (similar to Kokaram's) with a morphological detector. The latter was developed in another French laboratory, Centre for Mathematical Morphology at Ecole Nationale Supérieure des Mines de Paris, which also worked on film restoration. The scientific concept of mathematical morphology[249] was developed from 1964 onwards by George Matheron and Jean Serra (Ecole des Mines) for binary images, and is based on Boolean logic. In this method, the image is scanned by a "structuring element" (in different forms), which transforms parts of the image according to the requested operations and the shape of the element. In the 1960s, the research group at Ecole des Mines focused on texture analysis of minerals, and image processing helped them detect the texture in photos taken of minerals. If the structuring element was defined as a tiny sample of the texture of a mineral, morphological operations could detect this texture in the image. Mathematical morphology, patented in 1966 in France and in 1969 in the US, was generalised since the 1970s to include also greyscale images.[250] In 1968, Matheron and Serra created "Centre de Morphologie Mathématique" (CMM) at Ecole des Mines, where, almost 30 years later, a PhD. research was conducted by Etienne Decenière on the application of mathematical morphology to film restoration. This led to the development of a restoration system called SARSA, although it never made it to any systematic archival use nor commercialisation.[251] But Decenière continued his research on film restoration still for a few

---

[247] Regarding the use of the word "defect", scientific discourse and archival discourse do not correspond. In the scientific discourse defect is in fact synonymous to damage; the origin of the problem and its ethical implications did not matter much for researchers who worked on digital image processing.

[248] Olivier Buisson et al., 'Deterioration Detection in a Sequence of Large Images', in *IWISP'96, 3rd International Workshop on Image and Signal Processing* (Manchester, UK, 1996), 593–96.

[249] Morphology, etymologically, concerns study of shapes.

[250] Historical information about mathematical morphology were presented by Serra and Matheron in 2000: Georges Matheron and Jean Serra, 'The Birth of Mathematical Morphology' (ISMM 2000, Xerox Center, Palo Alto, California, June 2000).

[251] Etienne Decencière Ferrandière, 'Restauration automatique de films anciens' (Paris, Ecole Nationale Supérieure des Mines de Paris, 1997). SARSA stood for *Système Automatique de Restauration de Séquences Animées* (Automatic Restoration System for Animated Sequences).

years, and was among researchers who communicated with archives in interdisciplinary conferences.[252]

Mathematical morphology presented methods for detection of the damages, whereas spatial and temporal interpolation methods were applied for their restoration. The morphological detector that L3i team used in their algorithms in 1996 used "spatial properties of the deteriorations to detect them", and it was complemented by a dynamic detector "based on motion estimation techniques".[253] This way, more characteristics of high-definition images were put to use: the direct connections between neighbouring pixels as well as more video-like modelling of motion. L3i also studied the detection and removal of line scratches around 1998. The idea behind their research, in general, was to automate film restoration while keeping the processing time short (despite the large image sizes).[254] In 1996, their algorithm had "a rate of 3 % of false detections and 5 % of undetected deteriorations",[255] and the paper promised to optimise this. However, detection of line scratches proved to be much more complicated, as any vertical line in the image could be detected as a scratch. L3i's paper in 2001 improved their detection system with a Kalman filter which tracked the detected lines to make sure they were indeed defects.[256] But the rate of undetected and false detection remained still unacceptable:

> "While the digital film restoration system might be tolerant up to 5% of false detections in case of impulsive defects, this tolerance is unacceptable in case of line scratches. Indeed, the removal of significant scene details would have disastrous conceptual effects on the resulting restored movie. Human intervention is therefore indispensable to check the line scratch detection results prior to final restoration stage."[257]

An improved version of L3i's algorithm for line scratch detection and removal was integrated into different restoration software by the early 2000s,[258] such as RETOUCHE, which was conceived in collaboration with Laboratoires Neyrac (as part of Centrimage) and the archives of CNC since 1999 (and funded by them). Restoration of faded colours, was also touched upon

---

252 For example: Etienne Decenière, 'Restoration Quality Assessment' (IEE Seminar on Digital Restoration of Film and Video Archives, London, 2001), 1 1-1 6.

253 Buisson et al., 'Deterioration Detection in a Sequence of Large Images'.

254 Laurent Joyeux et al., 'Detection and Removal of Line Scratches in Motion Picture Films', in *CVPR'99, IEEE International Conference on Computer Vision and Pattern Recognition* (Colorado, USA, 1999), 548–53.

255 Buisson et al., 'Deterioration Detection in a Sequence of Large Images'.

256 Kalman filter is an optimal estimator which takes a number of noise measurements over time into account. See: Rudolf E. Kalman, 'A New Approach to Linear Filtering and Prediction Problems', *Journal of Basic Engineering* 82, no. 1 (March 1960): 35–45.

257 Laurent Joyeux et al., 'Reconstruction of Degraded Image Sequences. Application to Film Restoration', *Image and Vision Computing* 19, no. 8 (May 2001): 503–16.

258 Bernard Besserer and Cedric Thiré, 'Detection and Tracking Scheme for Line Scratch Removal in an Image Sequence', ed. T. Pajdla and J. Matas, *ECCV 2004* (Berlin Heidelberg: Springer-Verlag, 2004).

around 2000 by L3i PhD student Majed Chambah. Besserer and Chambah published a paper in 2000 that proposed two models for dye fading; the first one an "offset" model which supposed a constant fading, the second one a linear bleaching model which calculated the transform matrix to use based on several existing dyes and target colours.[259] The research aimed to automate colour restoration, but what film archives and labs would have needed, according to Paul Read, was a more precise chemical study of different film stocks, which would help them restore colours to their original state (thus a better definition of target colours according to photochemical properties):

> "Some software has been designed to cope with the lack of neutrality and 'cross contrast' as a result of faded dye images (eg Cineon) but the correction is carried out pragmatically with the aim of achieving a visually acceptable image. There is no software that aims to restore a faded image to the specific dyes, saturations and tonal response of a particular extinct colour print (Technicolor for example!) and then permit the image to be graded within these limitations."[260]

The L3i research was presented at the JTS 2000, through a paper, "digital colorimetric processing of old movie pictures",[261] and a poster, "digital tracking and removal of line scratches in motion pictures".[262] Both presentations were very technical, presenting the algorithms and models needed to achieve the desired results which interested the archives. The research was commented upon in the *Journal of Film Preservation*, in the JTS 2000 summary provided by Michèle Aubert and Richard Billaud, who explained in detail how film colours were captured through scanners, and how their fading was modelled and corrected by L3i's automatic algorithm, while conceding that "fading colours do not correspond to a universal model, but depend on manufacturers, development and conservation conditions of films, etc".[263] Visibly, this knowledge exchange made archives aware of the importance of better

[259] Majed Chambah and Bernard Besserer, 'Digital Color Restoration of Faded Motion Pictures', in *Proceedings of the 1st International Conference on Color in Graphics and Image Processing - CGIP'2000* (Saint-Etienne, France, 2000).
[260] Read, 'New Technologies for Archive Film Restoration and Access: Film Image', 48.
[261] Xavier Trochu, Majed Chambah, and Bernard Besserer, 'Restitution numérique des couleurs de films', in *Image and Sound Archiving and Access: The Challenges of the 3rd Millennium. Proceedings of the (Fifth) Joint Technical Symposium*, ed. Michèle Aubert and Richard Billaud, Proceedings of the 5th JTS in Paris on January 20-22, 2000 (Paris: CNC, 2000), 147–55.
[262] Laurent Joyeux, Samia Boukir, and Bernard Besserer, 'Digital Tracking and Removal of Line Scratches', in *Image and Sound Archiving and Access: The Challenges of the 3rd Millennium. Proceedings of the (Fifth) Joint Technical Symposium*, ed. Michèle Aubert and Richard Billaud, Proceedings of the 5th JTS in Paris on January 20-22, 2000 (Paris: CNC, 2000), 190–95.
[263] Michèle Aubert and Richard Billaud, 'Symposium Technique Mixte JTS, Paris 2000', *Journal of Film Preservation*, no. 60–61 (July 2000): 30. My translation.

knowing the photochemical original in order to enable a better digital and mathematical modelling of the damages. However, this archival desire to define more precise target colours in view of an automatic grading, as Read and Aubert had suggested, did not get realised. None of the proposed models for automatic digital colour restoration were ever adopted entirely, and digital grading during restoration remains – still today – highly dependent on visual control. The main reason for this is the lack of historical and chemical study of film stock, as well as the fact that there are too many factors involved which makes the scientific modelling of dye fading complicated.

In Austria, researchers at the Technical University of Graz (Institute of Computer Graphics and Vision) and Joanneum Research (Institute for Information Systems), were also involved in several restoration system developments, such as LIMELIGHT. Peter Schallauer's dissertation, in June 1996, was organised in two parts of "image sequence analysis" and "image sequence restoration"; the former presented damage detection methods (for dust and image vibration), while the latter presented dust removal, image stabilisation and noise reduction methods.[264] In 1999, Schallauer, alongside Werner Haas and Axel Pinz, presented another paper on "automatic and semi-automatic" digital restoration methods, with results of application on the films *Opernball* (Ernst Marischka, 1956) and *Le mort qui tue* (Louis Feuillade, 1913). This paper, which was written in relation to the project FRAME, (a follow-up to LIMELIGHT) started with a detailed overview of film damages: dust and dirt, image vibration, flicker, mould, scratches, heavily-disturbed or missing frames. However, they only presented automatic methods for some of these damages. For scratches, for instance, they proceeded manually.[265] As I will explore in the next subchapter, Joanneum Research went much further in research in a two-way collaboration with film archives by also assuming a commercialising role through its spin-off tech company, HS-Art.

Scientific Discourse Network: towards a Semi-Automatic Compromise

The archaeological overview that I have provided of the scientific research of the time shows how different directions and conceptions were explored, and how some of them lived on to be adopted further, while others were discarded along the way. An important initial goal to be achieved by algorithms was to automatically detect and correct the damages; and thus,

[264] Peter Schallauer, 'Digital Image Sequence Restoration' (Graz, Austria, Technical University of Graz and Joanneum Research, 1996).

[265] Peter Schallauer, Axel Pinz, and Werner Haas, 'Automatic Restoration Algorithms for 35mm Film', *Videre: Journal of Computer Vision Research* 1, no. 3 (Summer 1999): 60–85.

automatically restore films. The research, initially, was not interested in a software which provided a digital platform where film restoration could be done manually and via visual control. A simple digitisation, and use of computer for digital image manipulation did not suffice. It was, therefore, not the digital technology that was chased after neither by scientists nor by archives, but what it could supposedly offer in addition to other methods (automation, the possibility of working on every pixel, etc). However, the tendency to automate image manipulation operations was rendered very difficult by the fact that the algorithms had a false detection rate that was higher than what would be acceptable in a film image. A compromise had to be found in the semi-automatic notion. This technological limit seemed to incite, within the archival community, a consciousness of what digital image manipulation technologies could or could not achieve, leading to a tendency to exercise theoretical and ethical authority when restoring films. That also included a need to deepen the archival knowledge of the original photochemical film. On the other hand, and maybe somehow unconsciously, the meeting between the scientific discourse network and archival discourse network modified archival views of restored and improved images; a point which did not go unnoticed in technological developments of restoration systems, nor in archival-theoretical discourses, as I will argue in the two following parts.

3.2 Technological Implementation: From Machine to Software

By the dawn of the 2000s, a number of digital restoration systems had been developed in Europe. Some of these projects originated from pure research in universities such as SARSA at Ecole des Mines and University of Basel's system; and some others originated from a drive by entities close to film archives (television archives, film labs, film equipment manufacturers) such as AURORA and LIMELIGHT. European film archives were also involved in some projects aiming to construct a digital restoration system. The research-to-technology move was mostly enabled by funding from political instances at national and transnational levels; and responded to the greater digitisation challenge in the socio-cultural context of Europe at the time.

Of course, not all the attempts to provide technological solutions made it to an adoption step – which itself did not necessarily resemble what archives, scientists and tech companies imagined. Some projects remained exclusively available at a research level. Some others, which were supposed to provide a particular film restoration setting, failed to meet their own technical goals and were practically not available outside of the research sphere either. Others did get realised, and were adopted to different degrees, although they had to make compromises with regards to their initial goals. In this subchapter, I review these systems from an archaeological point of view by analysing their relation, on the one hand, to scientific technical discourses, and on the other, to archival discourses. Through this discussion, I aim to clarify how digital restoration systems went from an ideal machine to a compromised technological implementation of a series of algorithms, and how the technological developments crystallised the changes to both archival and scientific imaginaries.

LIMELIGHT

The first drafts of LIMELIGHT were prepared in 1992, when the main concurrent machines, Cineon and Domino were in their early, prototype states. Its aim was the development of a "New Generation of Fast and High-Resolution Digital System to Scan, Process and Print Cinema Quality Images". The newness of LIMELIGHT, back at the time, resided in the fact that it addressed directly "Cinema Quality Images", in a way that it "[preserved] the definition of the images of cinema".[266] This way, the digital transparency objective was already integrated into the concept of the system, and a fast 4K processing was desired. The 4K was considered equivalent to film: "The spatial resolution of modern color films (about 70 lp/mm) and black and white films (up to 100 lp/mm) leads to a digital spatial resolution of at least 4k (4096x2988 pixels) for one frame of the image sequence". [267] As I argued before, such correspondences between photochemical image resolution and digital pixel count were but estimations (and based on modern film stock), but in 1992, the discourse was heavily focused on a certain understanding of "cinema quality", distinct from television, which could potentially be achieved via a 4K digital transfer. In the early conception of LIMELIGHT, these notions were nourished from the archival episteme of the time, which was still to experience real technical implementations.

The project was funded by national governing bodies under the European label of EUREKA. It was coordinated by Joanneum Research and gathered experts from different fields: a photochemical film restoration lab (Laboratoire Neyrac Film in collaboration with CNC), university research centres (L3i and Joanneum)[268] as well as manufacturers of film and digital

---

[266] LIMELIGHT's project description on Eureka website, https://www.eurekanetwork.org/project/id/1041, accessed 2 July 2019. The same terminology was used in the French side's draft of the project.

[267] Heimo Muller, Walter Plaschzug, and Klaus Glatz, '3D Interpolation for the Digital Restoration of 35mm Film', in *Proceedings of SPIE 3309. Visual Communications and Image Processing '98*, vol. 3309 (San Jose, USA: SPIE, 1998), 287–96. This paper, by Joanneum Research (and HS-Art), which explains LIMELIGHT's image processing methods, was published at the end of the project.

[268] For algorithm and software development, Joanneum collaborated with Institut für Computergestützte Geometrie und Graphik at the Technical University of Graz.

equipment.[269] The goal was to create an entire system of digital intermediate – to “Scan, Process and Print”, not just one software. The illustrations (Figure 13, Figure 14) show how the system was imagined and how “digital film archive” was only an intermediate step.[270] To achieve an entire system, different technologies were identified to be used, divided into three categories:

- Optoelectronics and mechanics
- Data storage and communication
- Data processing[271]

Optoelectronic and mechanical technologies concerned the scanning and recording parts of the system. To ensure these, Debrie-CTM, a manufacturer of film equipment such as viewing tables, inspection tables, film cleaners, etc., was supposed to build the parts of machines (scanner and recorder) through which the film mechanically moved, while the Bertin company (licenced by Kodak to use laser recording technology) provided the optoelectronic technologies needed for scanning and printing. Data storage and communication technologies were to create the computer hardware needed to transmit and store high-definition digital images. The data processing part, which included the development of image processing algorithms and software were entrusted to Joanneum and L3i. LNF represented the user group, which would test the

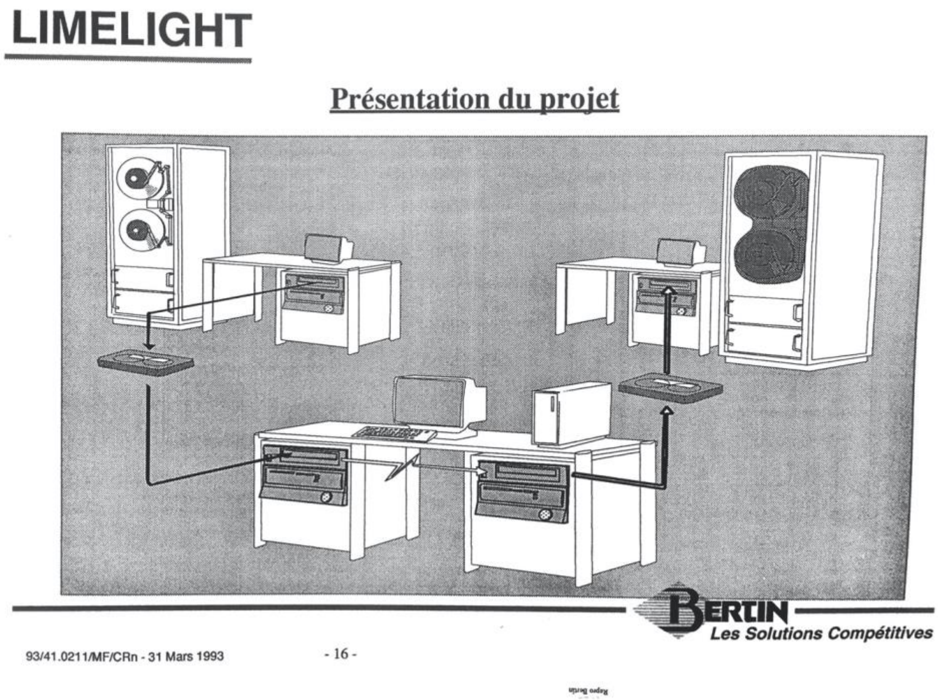


Figure 13 LIMELIGHT system as designed in French documents for funding request, March 1993.

[269] A complete list of LIMELIGHT partners can be found in the Appendix 2.
[270] Muller, Plaschzug, and Glatz, ‘3D Interpolation for the Digital Restoration of 35mm Film’, 288.
[271] LIMELIGHT’s project description on Eureka website, https://www.eurekanetwork.org/project/id/1041, consulted 2 July 2019.

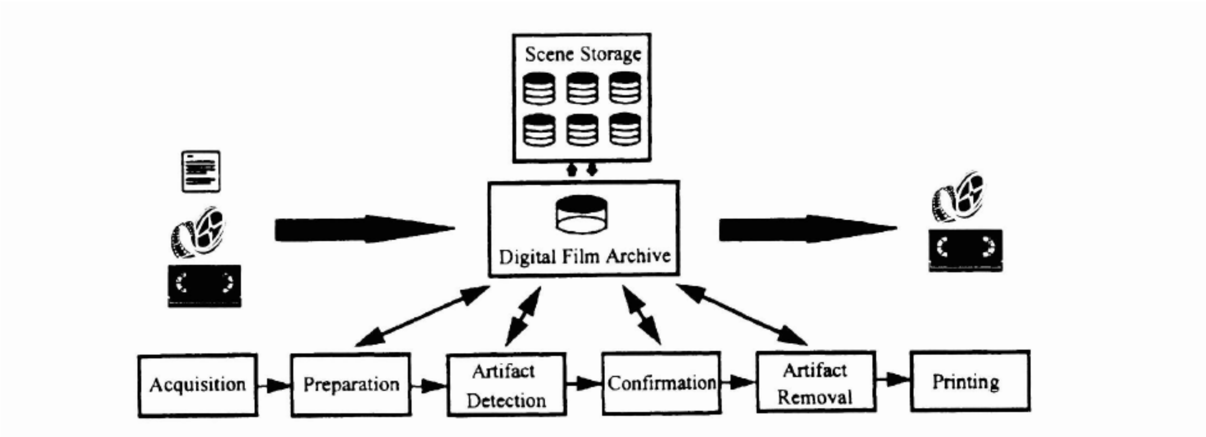


Figure 14 A more schematic presentation of LIMELIGHT system, considering the "Digital Film Archive" as the intermediate step.[272]

system with real examples. In this conception of a multi-partner project, digital technologies were added to an existing infrastructure in order to achieve a certain kind of work on images that was not possible before.

LIMELIGHT was designed as a modular system. In Joanneum's funding request to the Austrian Research Promotion Agency, heterogeneous and homogeneous systems were distinguished: the former included independent units (such as Oxberry scanner) while the latter concerned complete three-component machines (such as Cineon or Domino).[273] LIMELIGHT's approach was ground-breaking as it adhered to both; it was indeed supposed to be a complete three-component system composed of modules "which when assembled, [could] form several configurations".[274] The system was thus imagined to be flexible, where each module could be updated without disturbing the others. In this way, the software modules were developed (almost) regardless of the workstation (hardware). In reality, they were developed on a DEC ALPHA workstation, but could be adapted to all UNIX workstations. Towards the end of the project, they were also adapted to Windows NT workstations, as Windows NT (New Technology) was regarded as the operating system for the future at the time. Being modular, it was possible to commercialise only parts of the system, for example the graphic interface and software modules, for potential clients that only needed the surplus offered by digital manipulation, and were ready to outsource the other parts to external labs.

While on the French side, the three-way collaboration between LNF, L3i and CNC gave way to a possibility of directly testing the algorithms, Joanneum Research was also in contact with

[272] Muller, Plaschzug, and Glatz, '3D Interpolation for the Digital Restoration of 35mm Film', 288.
[273] 'Förderungsansuchen 1995', LIMELIGHT (Graz, Austria: Joanneum Research, 1995).
[274] LIMELIGHT's project description on Eureka website, https://www.eurekanetwork.org/project/id/1041, consulted July 2, 2019.

film archives such as Nederlands Filmmuseum[275] and Filmarchiv Austria in order to demonstrate the software's possibilities and ask for feedback. Joanneum restored an Austrian classic, *Opernball* (Ernst Marischka, 1956), a previously lost film, which was found in Munich in a very degraded state. Since the LIMELIGHT system was not yet entirely ready at this time, only software modules were used for this restoration, while scanning and imaging modules were done on other machines in the Taurus Film lab in Munich.

During the development of LIMELIGHT, there was already a tension between manual and automatic work as well. Scientific research, as explained in the previous subchapter, was focused on developing algorithms to automate restoration.[276] L3i and LNF hailed the automation of restoration, over a manual workflow, in an article published in 1997:

> "Obviously, film restoration can be done by presenting one by one the scanned images to an operator in possession of a graphical palette, retouching every image 'by hand'. A solution of this type is of course excluded for economic reasons."[277]

What Joanneum and L3i were hoping was to reduce the staff working on the restoration by providing automatic solutions, and thus reduce the costs,[278] compared to other systems such as Cineon, which relied on manual work by computer operators. But as explained in the previous part, scientific research seemed to acknowledge early on that not everything could be automated. A "semi-automatic" approach was preferred from the beginning of the project by Joanneum, which would offer three possibilities:

- Automatic for removal of damages such as scratches, dust and subtitles. According to Joanneum, the removal of dust and scratches were also "automatic" during analogue duplication thanks to wet-gate equipment.
- Semi-automatic: retouch of difficult parts, missing parts.
- Manual: complex reconstructions, insertion of new information. [279]

For implementation, the image processing tasks were divided into three categories of pre-processing, restoration process and postprocessing. For the first step, an automatic shot detection and automatic feature detection were run, but the grouping of shots according to the

[275] According to LIMELIGHT's report at the end of 1997, film experts from Nederlands Filmmuseum were sceptical in the beginning, but they became "convinced of the advantages of digital technology". My translation. See: 'Förderungsansuchen 1997', LIMELIGHT (Graz, Austria: Joanneum Research, 1997).
[276] See for example: Schallauer, 'Digital Image Sequence Restoration'.
[277] Olivier Buisson et al., 'Restauration des documents cinématographiques par des méthodes numériques' (3èmes Journées Internationales d'Etudes de l'ARSAG (Association pour la Recherche Scientifique sur les Arts Graphiques, Paris, 1997), 3. My translation.
[278] 'Förderungsansuchen 1995'.
[279] 'Förderungsansuchen 1995'.

damages would have to be done manually because "the decision which artifacts are dominant in a certain sequence can only be made by humans with sufficient reliability". At the restoration step, the algorithm would need to be selected manually, while its processing would be automatic. Lastly, the postprocessing step would offer the possibility of an interactive quality control as well as manual manipulation of frames that were not (or badly) restored by automatic algorithms.[280]

The LIMELIGHT system aimed a presence on two markets: digital film restoration and digital post production,[281] with more emphasis on film restoration (evident in its detailed modelling of film degradation). At this time, the post-production in Europe was not yet on the verge of becoming all-digital, but digital VFX and post-production labs were already there. Regarding restoration, it is important to note that LIMELIGHT was conceived during a period where the LUMIERE restoration project was on-going, and some European film archives and labs had already encountered the impossibility of restoring too-damaged films – for example, in the case of missing image parts due to nitrate decomposition. The LIMELIGHT project indeed cited these nitrate decompositions, alongside other types of mechanical, biological and chemical degradation, in order to justify its necessity: where photochemical technologies were falling short, the digital technologies could intervene. The scientific discourses and technological developments, in this way, were getting inspiration from the archival needs and problems; leading to a relative refinement of technological solutions in that direction.

FRAME

The LIMELIGHT project, which ran until 1998 in Joanneum, did not achieve what it had wished for, as the algorithms remained too slow and too expensive, and the whole system did not get realised. As a result, Joanneum initiated another project, FRAME, which picked up the LIMELIGHT software module, and aimed at reducing its processing time and costs. The main idea was to implement a parallelised method of data processing (which meant that the computer could process several operations at the same time). FRAME focused only on the software, and it did not include the modules of scanning and recording anymore. Like LIMELIGHT, it was a platform-independent semi-automatic software. While the processing of each image in LIMELIGHT software took 10 minutes, by parallelisation of the code, this time was reduced

[280] Peter Uray et al., 'Visualizing artifacts, meta-information, and quality parameters of image sequences', in *Proceedings of SPIE 3298. Visual Data Exploration and Analysis V*, vol. 3298 (San Jose, USA: SPIE, 1998), 145–52.
[281] 'Förderungsansuchen 1995'.

to 72 seconds in FRAME, thus considerably reducing the costs according to the project initiators:[282]

	LIMELIGHT semi-automatic digital restoration	FRAME semi-automatic digital restauration
High resolution film scanning	30 000 EUR	30 000 EUR
Processing	150 000 EUR	30 000 EUR
Film recording	30 000 EUR	30 000 EUR
Total	**210 000 EUR**	**30 000 EUR**

There is an original typing error in this table: the total sum for restoration via FRAME should be 90'000. This sum, calculated here for a feature film, was certainly reduced compared to that of LIMELIGHT, but has remained relatively stable since (the same goes for the scanning and recording prices). These prices have always depended on the amount of image manipulation, as well as the machines used to this aim.

Contrary to LIMELIGHT, FRAME was directly funded on a European level. The political role of the European Commission, here, went further by getting directly involved in the project's finances rather than by inciting national governing bodies to fund it. Starting in July 1997, it was again coordinated by Joanneum, as well as its spin-off company (by Walter Plaschzug), HS-Art who retained the rights to the software and notably, was responsible to market it. It had two partners, European Centre for Parallel Computing in Vienna (VCPC) as well as Quadrics Supercomputers World in Roma, both specialised in fast computing. LNF was also still attached to the project. FRAME was installed in Joanneum, LNF and fx. Center in Babelsberg by 1998 for tests and evaluation. While also marketed as able to "[correct] shooting errors thus eliminating the high costs of reshooting" for post-production, FRAME focused primarily on restoration, as a way to prepare old films for a new commercial life in the upcoming new media world:

> "There appears to be no end in sight to the sky-rocketing development in the communications and TV market. The business potential yields an increased demand for old film material and makes archive material commercially very attractive. According to estimates by the UNESCO there are about 2.2 billion meters of nitro-based film material stored world-wide in archives."[283]

[282] Snapshot of VCPC website page dedicated to the FRAME project, 11 April 2000, https://web.archive.org/web/20010411131954/http://www.vcpc.univie.ac.at/activities/projects/FRAME/, accessed 18 July 2019.

[283] Snapshot of VCPC website page dedicated to the FRAME project.

Like LIMELIGHT, FRAME was rhetorically interested in the restoration of nitrate material, although technically, it would not really have made a difference if the original film was a nitrate or triacetate or anything else. The software was exclusively concerned with already-scanned uncompressed digital images (in 4K), and it did not provide any different options for different types of film. Much of its software had already been developed by LIMELIGHT. In that, FRAME was not an independent project from its conception to its commercialisation. Its goal was rather to optimise the existing processes in terms of time-consumption and cost through other methods of data processing, while the main concepts of restoration remained unchanged. This change was needed so that the product could be more easily marketed, and made more affordable. To do so, Walter Plaschzug would present the software at archival conferences, for example, at the FIAF Congress in Prague in 1998. However, it still seemed to require a more active engagement from film archives and labs in order to succeed commercially.

RETOUCHE

Laboratory L3i of La Rochelle University, behind LIMELIGHT's algorithms alongside Joanneum, also continued its own research and development of a restoration software, but in a national framework.[284] Associated with Centrimage/LNF, L3i applied for a funding through the French PRIAMM programme (Programme pour la Recherche et l'Innovation dans l'Audiovisuel et le MultiMédia) and obtained funding by June 1999. The reason why L3i launched its move from research to technological solution through its new project, baptised RETOUCHE, was explained by Bernard Besserer to be the lack of "something usable", although the algorithms for detection and correction of many damages were indeed much advanced.[285] The project had three main goals:

1. "Accelerating the restoration calculations."
2. "Development of an interface and a 'viewing table' of high definition to integrate the algorithms."
3. "Manipulating colour images, particularly those that have faded."[286]

The first goal overlapped with that of FRAME, as the observation came from the same shortcoming of LIMELIGHT. This was to be done by "clustering calculation stations by using

[284] The rights to the French contribution to LIMELIGHT software were exclusively detained by LNF.
[285] Bernard Besserer, 'Retour d'expériences : Recherche et valorisation autour de la restauration numérique des images cinématographiques'.
[286] Besserer.

a SAN (Storage Area Network)",[287] which is a form of parallel computing where several computers divide the task of computing between them. Apart from cluster computing, L3i modified also some algorithms to achieve a higher speed. For example, for detection of scratches, as mentioned above, they were at first using a Kalman filter to track the results,[288] but then they replaced it with Viterbi tracking algorithm which did less computing as it could find the "most probable path" instead of screening the whole image.[289]

The second goal aimed to create a computerised "viewing table". Inspired by an existing machine which visualises the images on film thanks to opto-mechanical technologies, the computerised viewing table was to do the same with digitised images, in a sort of interface integrating the algorithms. The latter were realised during LIMELIGHT, but without an advanced interactive graphic interface. Lastly, the film restoration software packages till then were focused more on correcting dust, scratches, tears, etc; and they did not offer any particular automated correction of colours. Scientifically, this was implemented by Rudolf Gschwind's team in Basel, although their software was never commercialised nor used by archives. RETOUCHE intended to include this as well.

Due to a funding granted for "technology transfer", which indicated the step of going from research to technological implementation, L3i could employ an in-house development engineer for three years.[290] In total, four people were involved in RETOUCHE: Bernard Besserer, Majed Chambah (who worked on colour restoration), Cédric Thiré (the engineer) and Bruno Despas (head of Centrimage). When that funding ended in 2002, a supplementary funding from the CNC, as a result of a convention signed between the two, enabled L3i to improve the scratch removal module of RETOUCHE by September 2003.[291] RETOUCHE was not commercialised, its sale was forbidden, and L3i, which kept all the rights, installed it only in its partner institutions (Centrimage in September 2002 and CNC in June 2003). In the convention, Bernard

---

[287] Retouche Project Presentation: https://web.archive.org/web/20030411091350/http://retouche.free.fr/projets/retouch.htm, accessed 21 March 2021. My translation.

[288] Laurent Joyeux, Samia Boukir, and Bernard Besserer, 'Film Line Scratch Removal Using Kalman Filtering and Bayesian Restoration', in *WACV'2000, IEEE Workshop on the Application of Computer Vision* (Palm Springs, California, 2000).

[289] Besserer and Thiré, 'Detection and Tracking Scheme for Line Scratch Removal in an Image Sequence'.

[290] Besserer, 'Retour d'expériences : Recherche et valorisation autour de la restauration numérique des images cinématographiques'.

[291] Bernard Besserer and Cedric Thiré, 'Traitement des rayures dans les images cinématographiques' (Paris: CNC, July 2002), http://www.service1.culture.gouv.fr/sdx/crcbc/pdf_export.xsp?id=etude_cnc0203&db=etude&app=fr.tech.sdx.crcbc, accessed 1 June 2020.

Besserer included that the software could be used for nitrate, triacetate or polyester film.[292] Thus, no specific adaptation to film type was envisioned.

RETOUCHE was the software used for the mediatised digital restoration of *Bucking Broadway* (John Ford, 1917) whose only copy was found at the CNC in the early 2000s. Jean-Louis Cot (film restorer at CNC) described this restoration as a double event, because it concerned a previously lost film and it was the first time a feature film had benefited integrally from digital restoration in France. He judged the technical quality of the restoration with RETOUCHE simultaneously with ethical considerations:

> "It is satisfying to observe that, apart from the bad stability of the image, the main damages have been eliminated and that it has been possible to proceed to a specific grading. Of course, without ethical considerations, it would have been possible to go still further in restoration, to clean every pixel, but we judged that we should know when to limit the intervention."[293]

Neither the algorithms nor the software imposed any ethical consideration. It was indeed possible to push them to their technical limits, a process which would most probably create digital artefacts. The degree of intervention depended instead on the restorer's decisions.

DUST

In 1997, François Helt, a member of CST who was involved in project LIMELIGHT (1993-1997) on behalf of LNF, founded his own start-up company DUST Restauration SA, which not only developed digital restoration technologies and systems, but also aimed to become the "digital laboratory of the future".[294] Helt was a mathematician and technologist as well as a film restoration specialist,[295] the co-director Hervé de Canteloube came from the film production field, and the company was at the same time a tech provider and a digital film lab. With their in-house restoration software, the company offered digital restoration services, while it promoted its extensive knowledge of photochemical film:

[292] Besserer and Thiré. For the report of this project, see: Bernard Besserer and Cedric Thiré, 'Rapport d'activité - Actions effectuées dans le cadre de la convention de 2002 entre le CNC et le L3i, Université La Rochelle' (Paris: CNC, September 2003), http://retouche.free.fr/download/rec_rapport_cnc.pdf.

[293] Jean-Louis Cot, 'Bucking Broadway : Historique d'une restauration', *Positif*, no. 504 (February 2003): 90. My Translation.

[294] 'Dust ressuscite les films', Webtime Medias, 24 November 1999, https://www.webtimemedias.com/article/dust-ressuscite-les-films, accessed 12 June 2020.

[295] He had participated in CST's study of digital restoration in 1997.

> "On the market of digital image manipulation, DUST is currently more advanced compared to others because of its original position, that of gathering two types of knowledge: technological and cinematographic."[296]

DUST was therefore an archive-driven technological implementation project for digital film restoration, which aimed at closing the gap between the two worlds. Beyond the aforementioned damages, which were modelled via different algorithms by different researchers, labs and projects, DUST also modelled problems more specific to the original photochemical film. For instance, a research that Helt and Valérie La Torre[297] presented at the interdisciplinary IEE Seminar in 2001, focused on digital restoration of films affected by vinegar syndrome.[298] They emphasised that, as a result of the deformation of the base, when the film was digitised, a non-uniform blur would occur on the digital image, that could be mathematically modelled and corrected. Indeed, during the 1990s, vinegar syndrome was an important problem tackled by film archives. It had been subject to considerable studies, notably by Gamma Group,[299] and was discussed regularly at archival conferences. No less than four presentations at the JTS 2000 addressed vinegar syndrome, and proposed solutions to prevent it.[300] DUST's paper at the IEE 2001 explored first the specificities of vinegar syndrome, how it affected the films, and then proposed to model the photochemical damage. It thus combined the archival research on vinegar syndrome and digital image processing methods in order to offer a solution for a specific archival problem – which was not directly addressed by other projects and researches. François Helt presented this research and the tools developed for the digital treatment of vinegar syndrome's effects also at the Archimedia conference in July 2001 in Bologna, and although they were still conducting tests, he concluded that: "we think that our work will enable a good percentage of the affected films to be restored back to a very good viewing condition".[301]

[296] https://web.archive.org/web/20010307074827fw_/http://www.dust.fr/expert.html, accessed 12 June 2020.

[297] Valérie La Torre held a PhD. in Engineering sciences from Université de Nice-Sophia Antipolis. DUST Restauration was based in Nice, France.

[298] François Helt and Valérie La Torre, 'Advances in Digital Restoration for Addressing the Vinegar Syndrome Effects' (IEE Seminar on Digital Restoration of Film and Video Archives, London, 2001), 4 1-4 7.

[299] Gamma Group, *Vinegar Syndrome. A Handbook*.

[300] See for example: Jean-Louis Bigourdin and James M. Reilly, 'Vinegar Syndrome: The Effectiveness of Storage Conditions to Control Vinegar Syndrome', in *Image and Sound Archiving and Access: The Challenges of the 3rd Millennium. Proceedings of the (Fifth) Joint Technical Symposium*, ed. Michèle Aubert and Richard Billaud (Paris: CNC, 2000), 14–34.

[301] François Helt, 'Digital film restoration tools' (Archimedia Seminar, Il Cinema Ritrovato, Bologna, 2 July 2001).

DUST Restauration SA survived only five years, until 2002, but it remains an interesting case of how digital image technologies and film restoration practices were intertwined during this period.

DIAMANT

The film archives' implication in restoration systems culminated in the project DIAMANT. Launched in 1999, DIAMANT consortium featured not only Centrimage/LNF (involved in all previous major projects) but also Nederlands Filmmuseum (NFM). The latter had already acquired considerable experience in digital restoration by the end of 1990s, thanks, on the one hand, to Mark-Paul Meyer's research within Gamma Group, and on the other, to restoration experiments that they had done in 1997-1999.[302] LNF and NFM, as end users, were involved in the project from its early stages. With this stronger archival presence, the project dropped the rhetorical claim of aiming for the post-production market, a position held strongly by LIMELIGHT and FRAME, but with no technical nor commercial realisation.

DIAMANT (acronym for Digital Film Manipulation System) was again a public European Project, this time funded by the FP5-IST program of the European Commission for research, technological development and demonstration of a user-friendly information society. It ran from 2000 to 2002, and featured again the Austrian team of Joanneum Research and HS-Art (continuing their LIMELIGHT and FRAME adventures), as well as Technikum Joanneum. Three new research or industrial partners were also involved in DIAMANT: Dolphin Interconnect Solutions (Norway), Media Consult Buscher (Germany) as well as the IT Innovation centre of University of Southampton (UK). This heterogenous group facilitated dialogue between archivists and scientists:

> "One remarkable achievement of the Diamant project has indeed been that of bringing together IT professionals and film archivists in finding a common language and influencing one another."[303]

Instead of focusing on particular software achievements, the project plan, presented in June 1999, described in detail how, from a hardware point of view, the system was to be implemented:

[302] 1997: *Violettes Impériales* (France, 1952), colour fading, 1998: *Jenny* (The Netherlands, 1958), colour fading, 1999: *De verloedering van de swieps* (The Netherlands, 1967), just a tear. NFM's activities were presented by: Giovanna Fossati, 'The Nederlands FILMMUSEUM Walking Digital Ways to Film Restoration' (Le Giornate del cinema muto, Sacile, 2002).
[303] Fossati, *From Grain to Pixel: The Archival Life of Film in Transition*, 2018, 262–63.

> "Within the last years the processor clock rates and computational power have grown dramatically, which created together with the parallel implementation of algorithms new (commercial [sic] feasible) application domains."[304]

While software development picked up where LIMELIGHT and FRAME left off, the previous projects were not referenced by name in the project plan, although the latter did draw on conclusions and achievements from previous projects (LIMELIGHT's algorithm development, as well as FRAME's parallelisation efforts) to introduce its novel approach:

> "Four years ago RES1[305] started a R&D project for the digital film restoration and implemented a suite of restoration algorithms. After successful parallelisation of the algorithms it was encountered that (1) the data handling, I/O and data distribution and (2) the human computer interaction were the most critical factors in a digital film restoration system."[306]

This view brought in radical changes in the overall conception of the DIAMANT system. The system went from a three-component concept (with scanning, manipulating, recording modules), to a more nuanced concept, only focused on the manipulation part, but which made use of several digital technologies for hardware and software implementation (Figure 15). The digital system of DIAMANT included an Input/Output (I/O) cluster, processing/computing servers, storage, state-of-the-art digital networks ("a high-capacity interconnect infrastructure") to relate all the previous parts, as well as a user interface, which ensured the possibility of human-computer interaction (and thus, the possibility of a semi-automatic restoration). This conception resembles more a von-Neumann computer architecture, where different logic, processing, memory and I/O units are interconnected by an infrastructure of cable networks, supplemented by a user interface, rather than a mechanical machine as it had been imagined up to then (Figure 16). The conceptual evolution from LIMELIGHT (and its similar systems such as Cineon and Domino) to DIAMANT, meant going from a mere digitisation of the film restoration workflow, to a virtual system capable of interacting with its environment. The scanning and recording devices were outside of DIAMANT's limits, which envisioned the I/O cluster to permit the system to communicate with these machines. Via the I/O cluster, different

[304] 'DIAMANT (Digital Film Manipulation System). Description of Scientific, Technological Objectives and Workplan', Project Proposal - Part B, DIAMANT, 16 June 1999, 2.

[305] RES1, short for research partner no. 1, was Joanneum Research.

[306] 'DIAMANT (Digital Film Manipulation System). Description of Scientific, Technological Objectives and Workplan', 2. Technikum Joanneum and Dolphin Interconnect's participation in the project concerned these two new aspects, respectively building a user-interface for the human-computer interaction and improving the data handling.

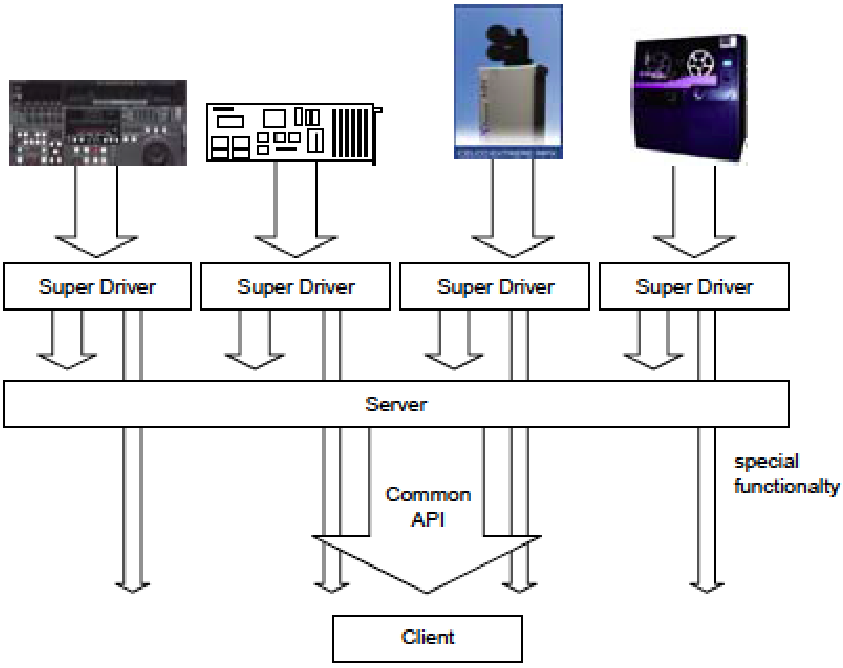


Figure 15 DIAMANT's architecture, which focused on the digital manipulation step and did not detail the scanning and recording steps. The system design illustrated in this photo was proposed in the project plan in 1999.[307]

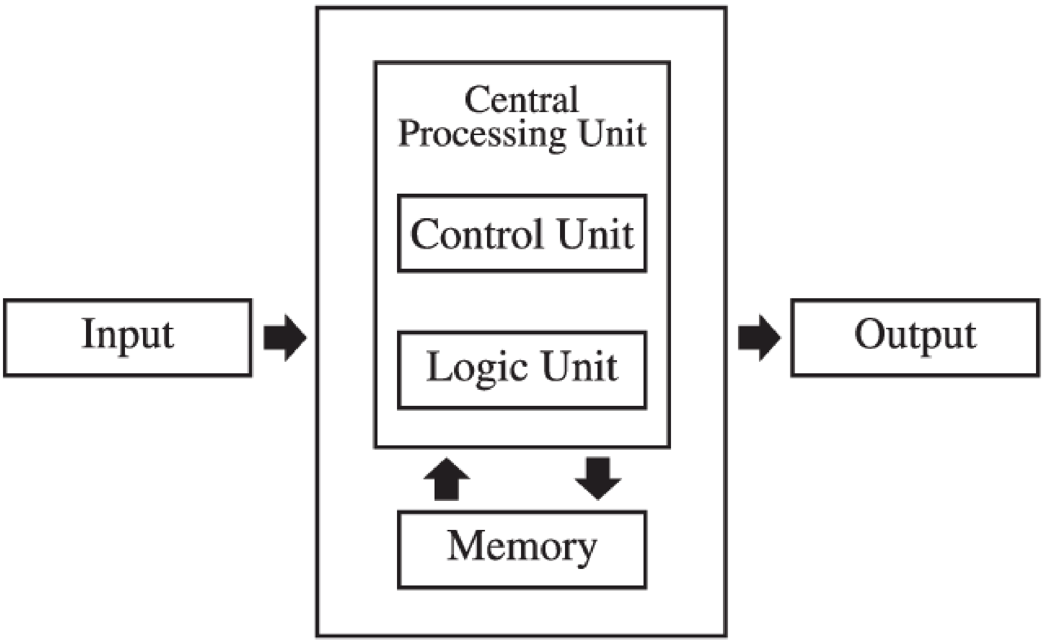


Figure 16 The von-Neumann architecture of a computing machine. This simple schema can be retraced back in DIAMANT's conception, where software and hardware were planned for all the tasks of control (and prioritisation), logic (the calculations) and the memory (where to keep all the data). The input and output are external modules to this computer architecture.

[307] 'DIAMANT (Digital Film Manipulation System). Description of Scientific, Technological Objectives and Workplan', B6.

external devices (such as scanners, tape drives, storage systems, etc.) could be connected to the system in order to make the images available.

From a hardware point of view, compared to FRAME which used a parallelisation cluster, DIAMANT had a hardware control unit, in the form of a Fibre Channel Switch, to which the other units (processing, storage, I/O workstations) were connected. While the architecture and the main infrastructure were crucial, the workstations and units could be commercial computers, servers, etc. The system was thus scalable in its performance, depending on the commercial products used in it, and in choice of modules. This architecture was the main goal of DIAMANT:

> "DIAMANT will build up a scalable digital film manipulation system by means of commercial off-the-shelf computation hardware (PCs) and high-speed interconnect hardware (SCI)."[308]

The software technologies of DIAMANT were principally developed during the precedent projects, even L3i's algorithm for vertical scratch detection and removal (which was developed during RETOUCHE) was used in DIAMANT system. The pieces of software used, as I have detailed before, did not yield perfect restoration results, but provided possibilities (with their mathematical approximations and modelling) for operators and restorers to clean the digitised images. As per LIMELIGHT and FRAME, digital film restoration was semi-automatic in DIAMANT. It was even marketed as such. The banner of HS-Art's website at the time was boasting this semi-automatic approach as well: "Restore, Convert and Manipulate Your Film digitally and nearly Automatically".[309] The semi-automatic approach was indeed an integral part of DIAMANT, and was stressed from the beginning in the project's workplan submitted to IST in 1999: "(Semi) automatic digital film restoration will be the pilot application for DIAMANT".[310] Indeed, DIAMANT's structure, as imagined and implemented, reinforced the rejection of a completely automatic film restoration. Instead of a three-component machine, which inputs film, manipulates them digitally and automatically, and outputs film again; an architecture was proposed which let the user interact with the machine and decide on jobs to delegate to it or not, while the machine could also decide on how to carry out those jobs.

---

[308] DIAMANT Factsheet, https://cordis.europa.eu/project/rcn/55433/factsheet/en, accessed 16 June 2019.
[309] HS-Art website, 29 September 2003, https://web.archive.org/web/20030929114316/http://hs-art.com/, accessed 16 June 2020.
[310] 'DIAMANT (Digital Film Manipulation System). Description of Scientific, Technological Objectives and Workplan', 2.

DIAMANT, having undergone tests and evaluation from end users, LNF and NFM, was made available in January 2002. It was marketed as an alternative to complex problems where traditional film restoration methods fall short, and focused on the "authenticity" of films, as desired by film archives. I detect here a discursive tendency towards a respect of the original film in the construction and commercialisation of DIAMANT, instead of an omnipotent digital machine. According to Joanneum in 2003:

> "In the course of the past fifty years, film has been restored by means of photochemical duplication. Although traditional methods can eliminate some types of damage (such as light scratches), the possibilities are very limited when it comes to treating severe defects.
>
> The digital film restoration software […] is able to eliminate practically all undesirable signs of decay and aging without sacrificing the authenticity of films. It allows for insertion of missing frames from alternative, partly damaged copies as well as to recreate electronically the original look of the film. Digitised films (in a resolution of up to 4000 x 3000 pixels per frame), are analysed with the help of image processing methods. Reconstruction and quality improvement can be done automatically or semiautomatically, thus varying the level of operator control to the user`s individual needs."[311]

DIAMANT succeeded in commercialising the result of the technological implementation of previous scientific research, which would be put to use in film archives and laboratories. It remediated what was available before it and defined a new machine conception which would realise what was needed by its users, thanks to a three-way collaboration between researchers, technologists, and archivists. It had fundamental differences from what archivists or scientists had imagined in the beginning as an ideal machine, but was a compromise to suit what was technologically realisable, functional and marketable. The technological implementation thus underwent a transition: at first, the whole workflow was digitised with the help of machines such as scanners, workstations, recorders as well as networks. The digital machinery was considered as any other type of technological machinery, like mechanical machines (projectors, printers, etc). Then, with DIAMANT, a virtualisation of the process happened. This new workflow created a virtual workspace (interface provided by software) which could correspond to all computer-type machines. Moreover, thanks to this shift, the costs of the restoration

[311] Joanneum Research website, 11 April 2003, URL: https://web.archive.org/web/20030411014428fw_/http://diamant.joanneum.ac.at/, accessed on 6 June 2020.

solution could be lowered considerably, making it more accessible for adoption. The previous machines were expensive notably because of their hardware, while DIAMANT used off-the-shelf computers, clearly less expensive, and worked on prioritisation of tasks and other aspects, an important aspect in going from hardware- to software-based systems. DIAMANT Suite remains currently one of the main digital restoration software in the field,[312] it is still marketed by HS-Art, and regularly goes through technical updates on its different pieces of software, which are also presented to film archives during international conferences.[313]

What archives needed and wished for did not always correspond to what was scientifically and technologically possible or available. This explains why a European project such as LIMELIGHT failed to be conclusive, and had to be redesigned and redone in different further declinations (RETOUCHE, FRAME and DIAMANT). On the other hand, scientific research did not always lead logically to a technological implementation and an adoption of technologies by archives. Digital technologies did not fundamentally revolutionise everything in film restoration, but enhanced what was existing before and progressively went into developing different types of workflows – corresponding more to the archival needs and their situation. At the same time, through this exchange of knowledge with the scientific discourse network, archival imaginary on film restoration was also modified and shaped in a different way. With a virtual system as DIAMANT, the link between the material image on film and its digitised version was weakened (despite the claim on authenticity). Of course, the software was developed in a way that it would simulate the film damages (such as dust or scratches), but these models were detached from the actual source image and the visual damages it presented (which were unique). In this way, the work on intermediate-step digital image restoration was perceived as an independent step in archival imaginary, losing touch with its material existence. As I will demonstrate in the next subchapter, this vision of digital technologies instigated an archival reaction, leading to a further polarisation of the archival imaginary.

[312] There are many other solutions available on the market (such as Phoenix by Digital Vision), but DIAMANT has the particularity of having been funded publicly and devised through a political will on the European level, in close collaboration with film archival community.

[313] For example: Franz Hoeller, 'DeepRestore – AI Techniques for Digital Film Restoration' (JTS 2019: Preserve the Legacy, Celebrate the Future, Hilversum, September 2019).

4 Towards a New Perception of Digital Image Technologies within Film Archives

As explained in previous parts, by the early 2000s, film archives had become engaged in three-way collaborations with image processing scientists and technology companies, which led to the development of a series of image manipulation technologies adapted to archival use. This process also modified the archival imaginary, with regards to technological changes as well as the concept of restoration. The digital technologies had initially struck archival opinions as a black box, shaped as a film-in/film-out machine, which was either hailed for enabling the realisation of what could not have been achieved through traditional technologies, or feared for its unknown configuration. This dialectical imaginary was described by Paul Read, who welcomed a deconstruction of the black box perception:

> "Over the last few years digital image technology has been variously ignored, vilified or treated with derision; or given a welcome more appropriate to the conjurer at a children's party. It has even been regarded, at worst, like a Messiah."[314]

Owing to the collision of archival and scientific discourses, the black box vision of digital restoration developed subsequently into a more complex, polysemic and heterogenous vision. The restoration machine was also adapted in archival imaginary to a more virtual system, as in DIAMANT, which could achieve certain tasks – and that, to different levels (thus requiring ethical and theoretical control). This brought about a change also in the concept of restored image (and its relation to its carrier), where the image to be restored seemed to exist only virtually and independently from its original. Its restoration was technically based on a generic categorisation of damages and a semi-automatic approach of detecting and correcting. Most tasks could not be entirely delegated to the machine and needed human supervision. The detachment of digital restoration from the material existence of film, as well as the possible degrees of the restoration tasks, deepened the ethical questions regarding restoration. At the JTS 2000, Harald Brandes (Bundesarchiv) illustrated the two-fold dilemma that the archives faced: on the one hand, some films, without digital tools, could not be properly restored; on the other, digital tools seemed to alarm some archivists, because "film gets separated from its original media and starts a new 'existence' on more or less complicated computer systems".[315]

---

[314] Read, 'Digital Image Restoration – Black Art or White Magic?'

[315] Harald Brandes, 'Digitilization: A Solution for Old, New and Current Restoration Deficits?', in *Image and Sound Archiving and Access: The Challenges of the 3rd Millennium. Proceedings of the (Fifth) Joint Technical Symposium*, ed. Michèle Aubert and Richard Billaud, Proceedings of the 5th JTS in Paris on January 20-22, 2000 (Paris: CNC, 2000), 156–63. [sic]

Since the earliest discussions on digital image technologies for restoration, these had been accompanied by ethical reflections. Mark-Paul Meyer (Gamma group) had called for a theorisation of archival approaches to restoration and digital technologies since the mid-1990s, which would generate clear ethical standpoints for archives. The R&D period during which the archival community exchanged with the scientific image processing community, reinforced the necessity of developing ethical and theoretical considerations in accordance with the perception shift regarding technologies and archival practices. This coincided, during the early 2000s, with the film industry's progressive adoption of multiple production and distribution routes, when digital access-oriented activities were on the rise, and an uncertain digital future was observed on the horizon.[316] In this part, I will critically analyse how the episteme around digital restoration went more polarised through the double integration of technical and ethical aspects.

The Double Life of Digital Restoration[317]

The new perception of restored image, still in line with the old archival quest of "better" quality but visibly detached from its materiality and in need of human decisions, disturbed the archival community, as I will illustrate hereafter. The new technologies, while compensating for the shortcomings of photochemical means, could do too much (or go wrong because of their embedded approximations) leading to unwanted artefacts or, worse, an alienation from the original. The double sides of digital image technologies were explored at an Archimedia seminar organised during the 2001 Il Cinema Ritrovato festival, where several restoration case studies were presented. Fossati and Eef Masson presented the case of *A Car Ride in the Pyrenees* (Pathé, 1910), which had confronted them with technical and ethical problems of digital restoration. Their presentation detailed the various steps of interaction between restorers and software, and underlined the multiplicity of ethical decisions that needed to be taken while doing digital restoration.[318] The same film was taken as an example by Bruno Despas (Laboratoire Film Neyrac) who, expressing the point of view of a film laboratory, used it to illustrate the fact that these decisions needed indeed to be taken by the archives in charge, faced

[316] See most notably: David Francis, 'Challenges of Film Archiving in the 21st Century', *Journal of Film Preservation*, no. 65 (October 2002): 18–23.
[317] The dialectical pattern has been remarked by several experts, such as: Meyer, 'Film Restoration Using Digital Technologies'. Read, 'Digital Image Restoration – Black Art or White Magic?'. Wallmüller, 'Criteria for the Use of Digital Technology in Moving Image Restoration'.
[318] Giovanna Fossati and Eef Masson, 'A Car Ride in the Pyrenees: The FILMMUSEUM's Approach to Digital Restoration and Its Contribution to the Diamant Project' (Archimedia Seminar, Il Cinema Ritrovato, Bologna, 1 July 2001).

with the wide range of possibilities offered by digital technologies.[319] Grover Crisp, detailing the restoration of *The Big Heat* (Fritz Lang, 1953), gave an example of how technical decisions, when taken automatically by the machine, needed to be refined by manual intervention; and how these created ethical questions for the restorers:

> "However, software created for the automatic removal of film damage by itself cannot always distinguish between true unwanted imperfections and inherent photographic situations, such as brief highlights, small indistinguishable objects that pop in and out of the frame or other items that are of a minor nature. White buttons on a jacket can be mistaken for minus density dirt and thus removed from the image. Creation of an artifact digitally is one of the areas of concern for restorers as we try to make the digital process work, but situations can also arise where the digital artifact created by the removal of damage is less egregious than the original film damage. Thus, there are ethical questions surrounding issues of whether to live with damage or with digital artifacts."[320]

Similarly, at the 2002 edition of Le Giornate del Cinema muto festival, where "digital was the buzzword", presentations by Fossati and Read "vividly demonstrated just how much can already be done, as well as how it is also possible to do too much".[321] At this point the approximations and estimations of digital technologies were not directly addressed, but the omnipotence of digital technologies were countered. Fossati, who was involved in the DIAMANT project on behalf of Nederlands Filmmuseum, underlined the need for a two-fold technical and theoretical understanding of digital processes:

- "don't be scared: it's a new tool
- don't be late: what if George Lucas wins?
- don't fall for the looks: potentials *vs* state of the art
- don't trust black boxes: understand the process
- keep an eye on the market BUT don't forget your ethics"[322]

The ethical questions populated many archival discourses during the early 2000s, without providing a definitive answer. Fossati's manifesto summarised indeed perfectly the dilemmas of digital restoration between theory and practice; corresponding to the vision that was also

[319] Bruno Despas, 'Leçons de 6 années d'expérience numérique d'un laboratoire de restauration' (Archimedia Seminar, Il Cinema Ritrovato, Bologna, 1 July 2001).
[320] Grover Crisp, 'Two Projects Exploring the Use of Traditional and Digital Technologies for Restoring Motion Picture Film' (Archimedia Seminar, Il Cinema Ritrovato, Bologna, 1 July 2001).
[321] Hillel Tryster, 'Le Giornate del Cinema muto 2002', *Journal of Film Preservation*, no. 65 (December 2002): 67.
[322] Fossati, 'The Nederlands FILMMUSEUM Walking Digital Ways to Film Restoration'.

implemented in DIAMANT: semi-automatic software under human supervision, with an important ethical endorsement.

In the light of all this, the archival community reacted in two different ways, by either focusing on photochemical or digital technologies. The 2000 London Congress was a pivotal moment as its two symposiums, "The Last Nitrate Picture Show" and "The Futurology of Film Archiving", presented the two possible ways ahead; archives adhering more or less to one or the other discursively. In the next two subchapters, I will detail these two directions, while arguing that technically they both needed to co-exist and aliment one another on the road to technological hybridity. First, I will highlight the strengthened attention (or look back) towards photochemical technologies, with emphasis on film as a material object. Then, I will show how the archival initial belief in a film-digital-film workflow was shaken and how a look to the future paved the way for the archival encounter with upcoming digital technologies, to which I will come back in Chapter Two.

4.1 Re-Focus on Photochemical Technologies

In the meeting between scientific and archival discourse networks, it seemed to become clear that not enough information was available on photochemical technologies of film, which could have served as a basis for the development of many digital technologies in correspondence with archival needs. Information was indeed missing regarding most archival film stock, older film practices and machines which all contributed to the aspect of images registered on film. Efforts were multiplied to undertake a more thorough study of photochemical film, a tendency ignited, in part, by an existing materialist vision of film, reinforced by the fact that digital restoration technologies considered the image detached from its original carrier. Such studies could lead to more precise modelling of photochemical damages and characteristics, influence the shaping of technological development, and frame better the ethical application of some technologies in lieu of others among all those offered by different restoration software.

A number of archivists, most notably Alfonso del Amo (Filmoteca Espanola), tried to re-establish the lost link between the restored image and its materiality. Del Amo did not counter digital technologies categorically; rather, he emphasised the study of photochemical film as a means of preserving better the cinema's past, for instance, as a prerequisite to digital restoration. A member of FIAF's Technical Commission, Del Amo initiated several studies on photochemical film, sometimes independently and sometimes within the TC around the turn of the century. The TC's work at this point was indeed very mixed: while Read[323] and Mazzanti would research more into digital technologies, Del Amo and Joao Socrates de Oliveira (BFI) would focus on photochemical studies, and Meyer and Brandes would engage in both. Del Amo's principal research projects were "History of Film Manufacture" as well as "Classification of Material for Preservation". A technical workshop over an entire day was organised by Del Amo, Michael Friend, Noël Desmet, Hisashi Okajima and the Gamma Group during the 1999 FIAF Congress in Madrid, which included a selection of papers on both these subjects, as well as one paper on restoration techniques. Histories and characteristics of different types of film stock such as Ferrania and Fuji were presented during the workshop, as were methods of "reading in the [film] material" and identification of marks and types of raw film stock". The paper on restoration techniques, presented by Meyer, Read and Desmet, focused on the "authenticity" of restoration (with either photochemical or digital methods) with regards to the original;[324] it thus reinforced the tendency to focus on an understanding of the original technologies in order to create new restorations which looked more like the film's historical appearance. Inspired by the need to deepen the photochemical knowledge, Del Amo proposed an ambitious project in 2001 to Gamma group under the title: "Recommendations for the elaboration of standards for the control of quality in the digital reproduction of movies originally filmed in photochemical supports, and for the conservation of the data corresponding to the treatments carried out in the digital reproduction". This project would pursue two goals:

1. "Establishing the technical characteristics of the movies filmed and reproduced on photochemical supports along the history of the cinematography"
2. "The elaboration of reference systems (numeric parameters, documentary indexes, models or simulations) valid to define the characteristics of the movies"[325]

Del Amo started working on the first part of the project almost independently, after facing resistance from other members of the group, notably Mazzanti who judged the project too big for Gamma Group and more suitable for a Eureka project with European partners. Later, Del Amo continued the project within FIAF TC, but it again failed to get realised as he had hoped and worked for. The first part of the project ended up being published by him in Spanish only.[326] His vision was also dominant in the December 2001 session of Archimedia in Madrid on

[323] It should not be forgotten that Paul Read, from the beginning, was calling for a more thorough study of photochemical film, which would clear many doubts on digital transparency or ethical questions.
[324] *FIAF Madrid '99*, Congress Programme (Madrid: Filmoteca Espanola, 1999).
[325] Christian Comte and Nicolas Ricordel, 'Compte rendu de Mission – Festival de Bologne 2001', Unpublished Report (Paris: CNC, 2001), 16–17.
[326] Alfonso Del Amo García, *Clasificar para preservar* (Mexico: Cineteca Nacional, 2006).

vinegar syndrome, where two panels out of four were entitled "classification of materials for conservation" where the speakers (including himself) discussed the criteria for the classification of film elements in the collections, as well as the criteria for constructing and equipping storage facilities. His research, in collaboration with polymer scientists, chemists and biologists, presented the technical aspects of film degradation,[327] which was more of a preventive nature, focusing on developing strategies for better conservation, rather than restoration.

4.2 Look to the Digital Future: Film-Digital-Film?

By the early 2000s, film archives had been faced with digital image technologies that intervened at an intermediate step for restoration. Considering this, I argue that, gradually, the archival community started to apprehend their complexity, risks and shortcomings, which called for a more rigorous theoretical and ethical framework, where film was understood not only with its conceptual existence but also as a historical and material entity. Therefore, the virtual approach towards digital restoration did not suffice and it needed to re-evaluate the relation of the restored image and its original source image. Some suppositions would thus come under scrutiny, such as digital transparency, which was challenged through archival practices of digital restoration, as it was indeed dependent upon the photochemical original. In 2000, Michael Friend, who was the head of FIAF TC, proposed that a study on the "issue of resolution" be conducted by Paul Read.[328] The problem of digital transparency was also raised by film laboratories which needed to decide on the pixel count in which they scanned the image.[329] Of course, the pixel count was not the only factor important in the digital transfer of the images (for instance, bit depth could be as crucial), but the discourses concentrated on the pixel count regularly. I will detail these in the next chapter. Similarly, the unlimited possibilities of digital manipulation technologies were challenged through the process of their development and early use. It had become obvious that these technologies could not solve all damages, and were even prone to creating new problems. Focusing uniquely on digital restoration was not going to be enough, as explained by Mark-Paul Meyer:

---

[327] Concepción Abrusci et al., 'Biodegradation of Motion Picture Film Stocks', *Journal of Film Preservation*, no. 67 (June 2004): 37–54. This research was already presented before in part: Fernando Catalina Lapuente and Alfonso Del Amo García, 'Cellulose Triacetate Motion Picture Film Bases. A Descriptive Analysis and a Study of the Degradation and Preservation - Related Variables' (FIAF 1999 Madrid Congress, Madrid, 1999). Concepcion Abrusci, 'Biological Degradation of Film Movies: Support and Gelatins. An Initial Study' (Archimedia Seminar, Madrid, December 2001).

[328] Michael Friend, 'FIAF Technical Commission Meeting Report', FIAF 2000 London Congress Report (Brussels: FIAF, 8 June 2000), 2.

[329] For instance, Guido Pappadà, 'Film in a Digital Environment: Basics of Theory and Practice' (Archimedia Seminar, Il Cinema Ritrovato, Bologna, 1 July 2001).

> "One could say that the greatest technical limitations of digital restoration are actually the input and the output processes. Apart from the fact that scanning is still very time-consuming and expensive, most equipment is not adapted to handle fragile archive prints. When a traditional duplication is required before a digital scan is possible, many advantages of digital restoration are already lost before the process is begun."[330]

The restoration of *Das Boot ist voll* (Markus Imhoof, Switzerland, 1981) illustrates this problem well. The project started in 2000, was conducted by the film's director and Swiss Effects laboratory (which coordinated the technical work done in seven different labs), and it took more than three years to complete. Indeed, the original 16mm negative was found to be in compromising condition only around 20 years after its production because of the adhesive tape that was used for splices. The repairing of the element did not help either: the film could still not go through a scanner. After three unsuccessful attempts, it was decided to first make an interpositive that could be scanned. The digital image manipulation could thus be performed finally on the scanned interpositive. According to Markus Imhoof:

> "Then it was a matter of automating the restoration of the innumerable small damages. The grain was processed in the same operation. Then the images that were partially lost because of mould and image jumps [due to splices] had to be retouched by hand."[331]

The image jumps were in fact photographed on the interpositive when the negative was duplicated. These were thus added to the other damages already present on the film (also photographed on the interpositive). As a result, digital restoration was further complicated, as more manual tasks needed to be done. Examples of this type were not rare in archival restorations by the early 2000s. At that time, archives which practiced digital restoration, such as CNC or Nederlands Filmmuseum, were generally equipped with manipulation workstations in-house, while they outsourced the scanning and recording processes. But, as explained by Meyer, scanning services, as they were provided by post-production laboratories, were not sufficient for archival use, and archives needed to include those in their reflections too.

Furthermore, by this time, apart from their own experience with digital technologies in restoration, archives were witnessing a growing interest in the film industry for digital technologies. During the 2001 Archimedia session, Read underlined the multiplication of production and distribution routes inside the film industry, which concerned not only post-production digital intermediate methods but also the modest beginnings of digital video (DV)

330 Meyer, 'Film Restoration Using Digital Technologies', 34–35.

331 Markus Imhoof, 'Von der römischen Kapelle zurück ins Kino', *Memoriav Bulletin*, no. 11 (May 2004): 6–7. My translation.

cameras in shooting as well as digital projection, insisting that digital technologies were inevitably part of modern film technologies.[332] It seemed to be the beginning of a period where "photochemical image was on the verge of transitioning to digital".[333] This was believed to change the archival landscape considerably:

> "Digital filmmaking will drastically change the film archives' self-understanding and lead to tremendous preservation problems. Traditional filmmaking is a well-known process, which produces a number of intermediate materials until the final print is ready for screening in a theatre."[334]

The perspective of a digital future, coupled with archival experiences and discourses, meant that archives needed to broaden their scope with regard to digital image technologies, which would not be limited anymore to restoration. The supposition that considered digital only as an intermediate step to remedy the limits of photochemical technologies in image restoration was shaken. As a response to this growing concern, a new publicly-funded project was launched by the European Commission, and coordinated by Cinémathèque Royale de Belgique, called FIRST (Film Restoration and Conservation Strategies, 2002-2004) which aimed at studying all these different aspects of digital film technologies; from digitisation to conservation. The latter was also discussed, albeit in a hypothetical manner, within the archival community, creating a considerable amount of concern.[335] Moreover, the rise of access-oriented activities indicated that the output of restoration processes would not remain limited to film. I will come back to the subject of access in Chapter Two, and that of conservation in Chapter Four.

In conclusion, there was a new interest redirected towards other types of digital image technologies, beyond image manipulation, which shook the position of digital as an intermediate step, and opened the door to more digital applications.

5 Chapter Conclusions

In this chapter, I have investigated how film archives adopted digital technologies in order to manipulate film images for restoration. Over a little more than a decade, this technological adoption process modified how the archival community perceived the new technologies, and

[332] Paul Read, 'Film Production and the Digital: What Is Changing in the Archival Perspective' (Archimedia Seminar, Il Cinema Ritrovato, Bologna, 1 July 2001).
[333] Comte and Ricordel, 'Compte rendu de Mission – Festival de Bologne 2001', 5.
[334] Thomas Christensen, 'Preserving Digital Film', *Journal of Film Preservation*, no. 64 (April 2002): 38.
[335] See: Christensen, 'Preserving Digital Film'. Nicola Mazzanti, 'Archives Going Digital: The Issues on the Table' (Archimedia Seminar, Il Cinema Ritrovato, Bologna, 1 July 2001).

how these were integrated into the already-diverse field of restoration, the latter being a multi-practice and multi-definition concept.

By the early 1990s, the European archival community was experiencing a thriving period, on the road to more intense professionalisation and theorisation of archival practices. During the years that followed, through early interactions and experiments with digital technologies, as well as several technical studies, the archival episteme was enriched by new, different visions, defining archival desires which needed to be addressed by the technological developments in progress at the time (the concept of an ideal digital restoration machine, with characteristics such as digital transparency and automation). Already back then, a dialectical imaginary was formed within the film archival community, which hailed the possibilities offered by the digital, while it warned against the potential loss of film's historicity and materiality induced by it.

At the time, there was a lot of encouragement on the political and financial levels within Europe, which provided an auspicious context to the proliferation of research on film restoration. Thanks to that, by the end of the 1990s, archives became involved in the technological development of image manipulation software, such as LIMELIGHT and DIAMANT, in partnership with scientists and technologists, leading to the establishment of a knowledge flow between archival and scientific discourse networks (which had not crossed paths much up to then). Among the several scientific methods proposed, some made it into technologies which were adopted and some did not. As I have argued, this encounter brought considerable changes in the early perceptions of technologies, refined the archival and scientific visions of image manipulation technologies, and helped both archives and scientists settle for compromised, technologically-feasible solutions corresponding more or less to their visions. As my analysis shows, the technological adoption is not a question of adopting the best technologies, but it's their efficiency which makes them candidate to be adopted at a certain time, in a certain context and by a certain community; here, software performing some tasks in a semi-automatic manner and reigned by ethical rules, instead of an all-powerful restoration machine. By analysing these epistemic processes, I have shown how the dialectical imaginary moved in two directions: new assessments of photochemical technologies, as well as expectations of upcoming further digital image technologies. This way, both photochemical and digital technologies came under scrutiny, and their understanding in archival perceptions changed.

The collaboration between archives and image scientists lasted for a few years at the turn of the century, but then it was considerably reduced; notably because of the discontinuation of the financial and political support. However, it did not stop entirely. For example, Alessandro Rizzi's research team (University of Milan) has focused on colour film restoration, aiming for automation with better algorithms, notably by including a model of Human Visual System (HVS) in the algorithms and the use of Image Quality Metrics to decrease the gap between the mathematical models and reality.[336] Technologically, other restoration systems were developed during the 2000s, but with less implication from archives and mostly as private ventures (such as the Phoenix restoration software by Digital Vision). Other technical and scientific research has proposed to apply AI (Artificial Intelligence) to film restoration,[337] or to simulate the photochemical technologies via digital manipulation.[338]

The discourses on restoration ethics, theories and practices have since been on-going. Determinist views presenting a clear distinction between right and wrong (adhering to a unique theory of restoration)[339] have been confronted with more dynamic and nuanced views, considering ethics as a function of several variables.[340] Indeed, a multiplicity seems to be established which does not provide the only answer, but provides frameworks to consider an answer on a case-by-case basis. The technologies, alone, are not game-changing decision-makers in the dynamics of archival practices; but the complex heterogeneous archival imaginary around them is.

---

[336] Alice Plutino and Alessandro Rizzi, 'Algorithms for Film Digital Restoration: Unsupervised Approaches for Film Frames Enhancement', in *Moving Pictures, Living Machines: Automation, Animation and the Imitation of Life in Cinema and Media. Conference Proceedings Series*, ed. Greta Plaitano, Simone Venturini, and Paolo Villa (Udine/Gorizia: Mimesis Edizioni, 2020), 265–72; Alice Plutino, 'Transformation of Film Experience from Analog to Digital' (Udine/Gorizia FilmForum, Online, 2021); Alessandro Rizzi, 'Alternative Methods for Digital Colour Restoration' (Fourth International Conference Colour in Film, London, 2019). Both of these concepts, HVS and Image Quality Metrics, will be discussed in the following chapters.

[337] Hoeller, 'DeepRestore – AI Techniques for Digital Film Restoration'.

[338] Giorgio Trumpy et al., 'Reconsidering Rigid Procedures of Color Film Digitization: Toning, Lenticular Processes, Chromogenic Stock, and Mroz-Farbenfilm' (Orphan Film Symposium: Radicals, Vienna, June 2019).

[339] See for example: Wallmüller, 'Criteria for the Use of Digital Technology in Moving Image Restoration'. Lenk, 'Pour une théorie de la restauration de films'.

[340] Fossati, *From Grain to Pixel: The Archival Life of Film in Transition*, 2009; Ross Lipman, 'The Gray Zone. A Restorationist's Travel Guide', *The Moving Image* 9, no. 2 (2009): 1–29. Caroline Fournier and Jeanne Pommeau, 'The Idea of Progress in the Restoration and Dissemination of Film Heritage: Utopias and Perspectives' (FIAF 2019 Lausanne Symposium, Lausanne, April 2019).

Chapter Two. Hybrid Image: The War of Grain vs. Pixel

By 2004, film archives across Europe had been involved in or were aware of digital image manipulation technologies. Several projects had been conducted aiming to refine available technologies corresponding to some archival needs, formulated through a practical, cultural and historical context. In Chapter One, I discussed the possibilities offered by digital image manipulation technologies, and covered a period when the digital's *raison d'être* was considered to be its ability and potential to clean the images from the signs of wear and tear; something that archives had wanted for a long time in their restoration activities. The scanning and recording phases generated less discourse in the archival community as archives intervened primarily in the intermediate step, while labs operated the machines of scanning and recording. The digital manipulation remained necessarily an intermediate step, as the images were always recorded back on film afterwards. But this perception of digital was about to change throughout the next decade, as I will argue in this chapter. Indeed, this chapter follows the period between 2004 and 2011, where a digital future was imagined, although not there yet, and archival community was living through a hybrid period, waiting for a transition to digital cinema.

From 2002 to 2004, a European research project called FIRST was conducted by ACE with the participation of Cinémathèque royale de Belgique, TV archives and other stakeholders, and financed by the European commission. FIRST intended:

> "[…] to improve knowledge of archive film, its transfer, restoration, preservation, cataloguing and distribution in the digital domain. And, vice-versa, to improve knowledge on the possibilities already offered in the Digital domain, along with its limitations, and its possible, future developments".[1]

The report promoted the idea that all audiovisual material on film or video carriers needed to become digitised. This vision differed significantly from what archives had in mind up to then, which considered digital technologies as an invisible tool leading from unrestored to restored image: the same way that photochemical restoration tools had remained practically invisible.[2] Now, all films were caught in a discursive push towards a move into the digital era: a view reinforced by the so-called digital future in a more general socio-cultural context.[3] However,

[1] FIRST, 'State of the Art Report', Project FIRST. Film Conservation and Restoration Strategies, June 2003, 3.
[2] John Belton, 'Painting by Numbers: The Digital Intermediate', *Film Quarterly* 61, no. 3 (2008): 58–65.
[3] See for example: Negroponte, *Being Digital*.

while the political discourses, influenced by a more global visibility and availability of digital technologies, were abundant, there was not solid funding opportunities, neither clear ideas of how to proceed. The decade can thus be characterised by a huge discursive whirlwind, while practically, not much was going on (apart from a few national projects, most importantly Images for the Future in the Netherlands).

Project FIRST and the early push towards digitisation coincided with an industrial popularisation of digital motion picture imaging. By the mid-2000s, film and TV production methods were converging and newer cameras and equipment were becoming available. For national film archives, the changing production routes did not necessarily represent a direct change as yet, since they still received film prints as deposits.[4] Indeed, what did change for archives was the fact that the presence of digital imaging in cinema and culture was felt more and its weight became impossible to ignore. A constant regime of comparison between digital and photochemical, represented via their supposedly constituting elements pixel and grain, was established. The idea of transition and the increasing importance of digital imaging led to an identity crisis within archives. Were archives to digitise everything? How could pixel rival the grain? In this chapter, I cover this period of uncertainty and its consequences in the archival discourses, and question the dialectic vision of film vs. digital, deconstructing it with the aid of a technical study of image quality.

The multiplication of production and distribution routes in the film industry blurred the boundaries between film, television and digital media. The distinction in terms of media was common within the archival community, which, according to Michael Friend and Grover Crisp, was to "move media of the past into the new" and also "preserve the new century's media".[5] Cinema's place in a world of "new media" was re-examined by archivists and scholars alike. On the one hand, the aesthetic and ontological implications of introducing digital technologies in production and distribution were considered, for instance, in the representation of reality: how film images look and perform differently compared to digital images.[6] On the other hand,

[4] The consequences of this was felt in archives a few years later, when the production material of the films from the 2000s ended up deposited in archives. Instead of one edited negative, the material could include reels and reels of unedited negative as well as digital master video tapes.

[5] Grover Crisp and Michael Friend, 'Welcome to JTS 2004', in *JTS 2004 Programme*, ed. AMIA, JTS 2004: Preserving the Audiovisual Heritage – Transition and Access, Toronto, 2004.

[6] See for example: Lev Manovich, *What Is Digital Cinema?*, 1995, http://manovich.net/content/04-projects/009-what-is-digital-cinema/07_article_1995.pdf, accessed 21 January 2021; Rodowick, *The Virtual Life of Film*; Barbara Flückiger, 'Das digitale Kino: Eine Momentaufnahme', *Montage/av* 12, no. 1 (2003): 28–51; Holly Willis, *New Digital Cinema : Reinventing the Moving Image* (London and New York: Wallflower Press, 2005); Markos Hadjioannou, *From Light to Byte: Towards an Ethics of Digital Cinema* (Minneapolis and London: University of Minnesota Press, 2012).

the subject was vastly tackled in media studies with a focus on technologies and their social and cultural implications.[7] This approach considered how old and new media came together, co-habited, merged or were distinguished from one another; and explored concepts such as media convergence and remediation in this regard. This chapter follows a double approach based on both these directions. It follows how new technologies were received and put to use in the archival field, and how they functioned in interaction and comparison with older, existing technologies in shaping the look of films; and simultaneously, how the concept of "film look" changed the course of the socio-cultural construction of technologies. To do so, in this chapter I will question the dialectical view of film vs. digital technologies, by categorising them all as co-existing, parallel cinema technologies rather than contradicting or successive ones. The goal is to depict that different digital technologies did not in fact have an invasive nature, as some archival discourses suggested.[8] Contrary to the belief from the more general socio-cultural context that the archives functioned within, which imagined a move into a so-called digital future, the technologies were long discussed and adapted to the archival imaginary of the time before being applied or rejected.

This chapter is structured in three main sections. The first subchapter presents the industrial technological changes in image (re)production, and the machines behind them, that were developed and adopted during the 2000s. It demonstrates how the newly-produced or transitioned images were constantly compared to their predecessors, formulating the dichotomy of grain vs. pixel. With these new technologies supposedly replacing old ones, archival identity faced a crisis, which will be discussed in the second subchapter. The crisis was articulated around two main axes, which respectively questioned the basic definitions of film and film archives. Debates concerning film included technical quality comparisons between film and

---

In the archival context, the subject was addressed notably at 'Du film au numérique. Vies et mort de la pellicule' (Journée d'études, Paris, Cinémathèque française, 2008).

[7] Martin Lister et al., *New Media: A Critical Introduction* (London: Routledge, 2008); Nicholas Gane and David Beer, *New Media: The Key Concepts* (Oxford and New York: Berg Publishers, 2008); Kelli Fuery, *New Media: Culture and Image* (New York: Palgrave Macmillan, 2009); Lev Manovich, *The Language of New Media* (Cambridge, MA and London: MIT Press, 2001); Thomas Elsaesser, 'Early Film History and Multi-Media. An Archeology of Possible Futures?', in *New Media, Old Media. A History and Theory Reader*, ed. Wendy Hui Kyong Chun and Thomas Keenan (London: Routledge, 2006); Glen Creeber and Martin Royston, *Digital Culture: Understanding Digital Media* (Berkshire: McGraw-Hill Open University Press, 2009); Henry Jenkins, *Convergence Culture: Where Old and New Media Collide* (New York: New York University Press, 2006); Peter Lunenfeld, *The Digital Dialectic: Essays on New Media* (Cambridge, MA: MIT Press, 1999); David Thorburn and Henry Jenkins, eds., *Rethinking Media Change: The Aesthetics of Transition* (Cambridge, MA: MIT Press, 2003); Bolter and Grusin, *Remediation: Understanding New Media*; Thomas Elsaesser and Kay Hoffmann, eds., *Cinema Futures: Cain, Abel or Cable? The Screen Arts in the Digital Age* (Amsterdam: Amsterdam University Press, 1998).

[8] Robert Daudelin, 'Editorial: Spirit of the Times', *Journal of Film Preservation*, no. 71 (July 2006): 2–3.

digital images, which I will deconstruct here through a historical and socio-cultural analysis of the image sciences. Simultaneously, the role and future of film archives also came under scrutiny in archival discourses, reinforcing the dialectical archival reaction. I will contextualise this identity crisis, ignited by the changing technological landscape within the larger archival history, and analyse its consequences on the archival imaginary of the time. Finally, the third subchapter explores how the ensemble of theoretical approaches and changing technologies brought archives to consider the digital image as inferior to the photochemical image, and thus relegated it exclusively to access practices. My critical analysis will show how this dialectical vision could hardly be maintained in practice. Overall, the chapter will depict the polysemic archival imaginary from roughly 2004 to 2011, which was oscillating between diverse understandings of digital image technologies: as shown in Chapter One, the digital image could be a threat or an opportunity, and archives would need to adhere to one or another viewpoint. This chapter will build on the discussions in the previous one, and pave the way for the archival reactions to the generalisation of digital cinema after 2011, which will be addressed in Chapters Three and Four.

1 Transition Ahead? Facing New Image Technologies in Cinema and Archives

Image technologies in cinema have constantly undergone modifications since its early days. While film, as a photosensitive strip, was soon established as the image carrier within the growing cinema industry, it did not use the same technologies throughout cinema history, nor did it remain historically unrivalled as a medium of recording motion pictures. The cinema field crossed paths with electronic image production and television from the 1910s onwards, and with digital electronic images from the 1960s. The machines of image production were also constantly changing, integrating new technologies. By the 2000s, a rising culture of media convergence began to be felt increasingly in the cinema industry, and by extension in film archives. Faced with new technologies, a scenario of transition into a new world was depicted, which included a constant comparison between new and existing technologies. The following subchapters depict how the industrial and archival epistemes were enriched through encounters and interactions with these new technologies, within an existing dynamic technological and discursive culture, which in turn influenced the development of the technologies. I will, then, argue theoretically whether such comparisons between image technologies can be scientifically possible.

1.1 Film Production in a Hybrid State

> "Movies are the permanent record. Television is the more advanced way of getting the picture. As time goes by, the pictorial quality of televised images will improve steadily until it is on a par with motion picture film."[9]

In 1946, a few years before going bankrupt, Allen B. DuMont (DuMont Laboratories) predicted that if the "pictorial quality" of an electronic image equalled that of a photochemical image, it could replace the more traditional technology as a means of capture. This was also what Albert Abramson (CBS technician and television historian) called in 1955 a "great revolution" in the making, which would see the introduction of electronic cameras to motion picture production.[10] Beyond the practical advantages such as being lightweight and allowing easy electronic image manipulation, Abramson hailed the "super light sensitivity" of the television camera at low lights (which supposedly surpassed film)[11] and hoped for a "high-definition" image quality which could generalise the use of electronic cameras in film production.

The use of television and video technologies for image capture did become an alternative practice in film production.[12] The archives were not ignorant to this fact: as explained in Chapter One, at the FIAF Congress in Brighton in 1978, comparisons between film and video image were conducted. The film, within the industry (and archives), was believed to have a higher image quality. This assumption was of a mixed nature, where some scientific notions co-existed with a high degree of subjectivity. The industry had established a certain understanding of quality, based on image characteristics such as resolution, sharpness, tone scale, contrast, graininess, etc., which promoted cleaner, sharper images as being of better quality. This understanding imagined a linearly-ascending image quality in mainstream cinema, attributed to the 35mm standard film (or 70mm), which was subjectively believed to be superior not only compared with other film technologies, but also with other means of recording and projecting images such as video technologies. This so-called "tradition of quality" of film was perpetuated by the industry: it partly directed the tendency to develop newer film stock and camera technologies from the 1970s (film stock which could better record image details at low lights or film cameras which would capture more stable images, even in movement),[13] while at

---

[9] Allen B. DuMont, 'The Relation of Television to Motion Pictures', *Journal of the Society of Motion Picture Engineers* 47, no. 3 (September 1946): 238–47.
[10] Albert Abramson, *Electronic Motion Pictures: A History of Television Camera* (Berkeley and Los Angeles: University of California Press, 1955), 149.
[11] Abramson, 155.
[12] Especially for experimental and documentary filmmaking.
[13] Charles Eidsvik, 'Film Technology in the Age of Video', *Film Quarterly* 42, no. 2 (1988): 18–23.

the same time it was nourished from the same industrial patterns. Given the vagueness of the term "quality", cinema's quest for quality, which resulted in the adoption or rejection of certain technologies, needs to be understood with regards to these discourses. I will come back to the definitions and details of the historically-constructed concept of quality, as well as its possible calculations later in this chapter.

The concept of "high-definition" did not originate with digital technologies and was in fact related to analogue electronic image technologies. Abramson, in 1955, mentioned experiments since the 1930s, which aimed at creating high-definition pictures defined as "having a large number of scanning lines, low flicker level, correct contrast, sufficient brightness, and a high 'signal-to-noise ratio'".[14] These factors are either subjective (what is sufficient? Or correct?), or should be considered in comparison with other previous systems (how many lines would make an image high-definition?). Hence, the concept is historically dependent, and at each historical moment, its characteristics are determined differently. In the 1980s, some high-definition systems were designed,[15] with a 1125-line video system, which included a higher number of distinct lines in the height of the image than the usual 625 or 576-line video image definition,[16] and could be implemented both in digital and analogue. In 1981, these technological developments were even called "a step towards 'perfect' resolution" and it was claimed that the high-definition video image (whether analogically or digitally implemented) could rival "35-mm film in quality".[17] In the mid-1980s, newer digital video formats were introduced, and most importantly, standardised by the Society of Motion Picture and Television Engineers (SMPTE), including D-1, albeit in standard definition (SD). Other later formats, and the later generations of D-series supported though higher definitions (D5, released in 1994, had a 720x1080 definition and D6, released in 2000, 1080x1920).[18] These discourses focused solely on definition in comparing film and video images, which is not enough in quality comparisons, as I will detail later.

[14] Abramson, *Electronic Motion Pictures: A History of Television Camera*, 74.
[15] See for example: Takashi Fujio et al., 'High-Definition Television System — Signal Standard and Transmission', *SMPTE Journal* 80, no. 8 (August 1980): 570–84. In this paper, the researchers presented an 1125-scanning-line system which had been tested by the NHK (Japan Broadcasting Corporation).
[16] This means that the height of image is sampled as 1125 horizontal lines.
[17] Nicholas Mokhoff, 'Towards a Perfect Resolution', *IEEE Spectrum* 18, no. 8 (July 1981): 56–60.
[18] The concepts of "high definition" and "resolution" have been studied critically in scholarly media studies, see: Francesco Casetti and Antonio Somaini, 'Resolution: Digital Materialities, Thresholds of Visibility', *NECSUS*, July 2012, https://necsus-ejms.org/resolution-digital-materialities-thresholds-of-visibility/, accessed 1 February 2021.

In the 1990s and 2000s, the standard projection format remained 35mm, while the search was on for a digital projection standard.[19] On the other hand, home entertainment thrived further with new digital means of viewing images, such as DVD replacing VHS in the market, as well as online viewing (both of which will be addressed in the last part of this chapter). The gradual adoption of some of the new capture technologies and imaging systems, as well as the rising accessibility of digital post-production, and the diverse possibilities of digital distribution, all opened the door to a multiplication of production routes for different access modes. Up until the early 2000s, production routes englobed mainly different film technologies, but then, hybridity was expanded to electronic and digital imaging in professional cinema production as well.[20] Writing in 2006, David Walsh underlined the changes that the industry has gone through, and predicted that the move to digital shooting was also close:

> "The film industry is eagerly embracing the new technology, with all the freedom and flexibility it offers. They clearly cannot wait to be rid of film in post-production, and even film's supremacy for shooting is beginning to be eroded."[21]

Filming on digital video (DV) created a different image look compared to that of an image shot on film. For the technical part of the film industry (such as film manufacturers) and even within archives dominantly, this image was considered as inferior to film image, while artistically it was embraced by some precisely for its different look. Indeed, from the 1990s onwards, video capture had become an alternative for new means of expression, considered sometimes as "more humane and more familiar aesthetically".[22] Video capture was notably the chosen practice for the Scandinavian film movement Dogma 95, although this was not explicitly stated in their "Vows of Chastity".[23] The group's tendency to use handheld cameras and banish artificial production modes could have contributed in practice to the use of digital videos in capture (without imposing it), while the projection format was fixed to be 35mm. Some other arthouse films, such as Abbas Kiarostami's *Ten* (2002), also adopted DV filmmaking to correspond to different aesthetic decisions.[24] Despite that, the majority of film industry actors

---

[19] This will be addressed in the next chapter.

[20] For examples of different production routes possible by the early 2000s, see: Read, 'The Digital Intermediate Post-Production Process in Europe'.

[21] David Walsh citing Paul Read's intervention 'Cinema Images: What's in a Name?' at the FIAF Symposium 2006. David Walsh, 'Technical Symposium - FIAF Congress 2006 São Paulo: Film Archives in Transition', *Journal of Film Preservation*, no. 72 (November 2006): 71.

[22] Nick James, 'Digital Deluge', *Sight & Sound* 11, no. 10 (October 2001): 20–24.

[23] Reprinted in: Lars von Trier and Thomas Vinterberg, 'Dogma 95. Vows of Chastity', in *Technology and Culture. The Film Reader*, ed. Andrew Utterson (Oxford: Psychology Press, 2005), 87–88.

[24] Kiarostami explained in his 2005 documentary *10 on Ten* that he preferred filming on digital video as "the artist can work alone again", although his approach was not necessarily welcomed by all critics, see for

seemed to remain convinced of the film's tradition of quality. According to film scholar Stephen Prince, writing in 2004, a digitally-shot image looked "too sharp", and some professionals shooting digitally asked to add grain in post-production to make it look like film. As Prince noticed, the industry seemed to follow a tendency to recreate film look with DV cameras: "the aesthetic design that many filmmakers bring to a DV film is oriented toward overcoming the video 'look' and simulating a more filmic look".[25]

By the mid-2000s, the technological development of new digital cameras seemed to meet the industry's tendency towards a "filmic look" and its "tradition of quality" on two levels. Firstly, instead of producing a compressed digital video (DV), the newer cameras could yield uncompressed individual images,[26] commonly referred to as the "24p cameras", meaning that the camera output was 24 individual frames per second. The "p" stands for progressive, which, here, indicated that the frames remained separated and were not encoded together. In this way, they adapted to cinema's traditional technology of temporally-discontinuous movement recording and reconstruction. Secondly, instead of using a prism and three sensors to record the colour information separately, the new cameras used a single sensor chip that successively recorded the colour information three times. This enabled "the use of existing 35 mm film lenses, which have reduced depth of field over current HD cameras",[27] thus producing images that looked more like film images. Cameras with these characteristics did exist before, they were notably used in film scanners such as Cineon and Domino (and already in 4K),[28] but they were not fast enough to record 24 frames per second. Cineon and Domino took indeed a considerably longer time to record one frame.

The technical quality of the output images of these new digital cameras was judged in comparison to previous film imaging technologies, with a focus on Super-35mm. For instance, the camera Panavision Genesis (2004) had a sensor chip in Super-35mm format with an over-4K definition. Its lens was a regular photographic lens used in Panavision film cameras. Similarly, when DALSA Origin was introduced at NAB 2003,[29] its 35mm-film-sized 8-

---

example: Manohla Dargis, 'An Iranian Director's Film Class, but without Film', *The New York Times*, 25 February 2005, https://www.nytimes.com/2005/02/25/movies/an-iranian-directors-film-class-but-without-film.html, accessed 6 January 2021.

[25] Stephen Prince, 'The Emergence of Filmic Artifacts: Cinema and Cinematography in the Digital Era', *Film Quarterly* 57, no. 3 (2004): 31.

[26] In the next two chapters, I will come back to compression and its technical details. Here I am talking about spatial compression, as some of these digital cameras did compress the color information (by subsampling).

[27] Lasse Svanberg, ed., *The EDCF Guide to Digital Cinema Production* (Burlington/Oxford: Focal Press, 2004), 38.

[28] See Chapter One, part 2.1.1.

[29] NAB = National Association of Broadcasters.

megapixel[30] sensor was praised as it seemed to capture a more "film-like" image quality, even believed to be an "ideal archival-quality master".[31] The same goes for the Arri D-20 camera (2005), the first digital camera produced by film camera producer Arri which also used film lenses, promoted as able to provide much better critical images.[32] The closeness to film was an important discursive element in the promotion of these cameras: "No film but still on Arri".[33] Digital cinematography seemed to move towards a democratisation from 2007, thanks to the Red One camera, which not only had an almost Super-35mm sensor and a 4K definition, but also considerably lower price compared to earlier film and digital cameras (by orders of magnitude). The low prices of Red, while conforming to the desired quality requirements, made digital cinematography more accessible (and attractive) to many other filmmakers. In 2010, Arri Alexa, equipped with a Super-35mm sensor, also became a sensation: some cinematographers, such as Roger Deakins, considered that its tonal range, colour space and latitude[34] exceeded the capabilities of film: "this camera has brought us to a point where digital is simply better".[35] As it probably appeared to Deakins, the Arri Alexa was offering wider possibilities in terms of contrast and colour representation in cinematography than existing film cameras. It is difficult to compare these characteristics within different technological systems that are film and digital cinematography, however the fact remains that despite the differences, the technological developments aimed to replicate certain characteristics of film cameras with the digital ones. This familiar look seemed to convince some cinematographers such as Deakins, while others remained sceptical,[36] maintaining previous discourses which believed film to provide "more colours, more latitude, more texture".[37] The views on the subject were strongly divided (and have remained so), amid the technological developments.

---

[30] 4096x2048=8'388'608 pixels were implemented on its sensor chip (4K resolution). At some technical presentations, the pixel count was given in megapixels, similar to digital photo cameras which preceded the digital moving image cameras.

[31] Jim Slater, 'BBC R&D Open Day', *Image Technology* 85, no. 5 (October 2003): 31.

[32] Jim Slater, 'Looking at Digital Cinema from All Aspects', *Image Technology* 89, no. 1 (February 2007): 20.

[33] Jim Slater, 'IBC 2004', *Image Technology* 86, no. 5 (October 2004): 10.

[34] Tonal range, sometimes also called tone scale, is the range of tones between lightest and darkest parts of an image. Colour space indicate the range of different colours which can be presented on film. Latitude is the range of densities that can be recorded.

[35] Jay Holben, 'Roger Deakins, ASC, BSC Adopts Digital Capture on the Sci-Fi Thriller In Time', *American Cinematographer* 92, no. 11 (November 2011): 32–38, accessed 17 February 2021.

[36] Such as Guillermo Navarro, cinematographer of *Pan's Labyrinth* (2006), who participated in campaigns for saving film. I will detail these campaigns in the next chapter.

[37] 'The Future of Filmmaking: The Future as Seen by Cinematographers', *American Cinematographer* 81, no. 9 (September 2000): 2–9. Texture probably refers to the specific visual grainy structure of film image, which seemed more agitated than the digital image which lacked graininess.

Beyond the different lenses, different digital cameras did not have the exact same sensor technology either. For example, the DALSA Origin had CCD (charged coupled device) sensor,[38] while Arri's sensor used CMOS technology. The CCD type has silicon-based capacitors at each of its pixels, and its output analogue signals need to go through an Analogue-to-Digital (AD) convertor subsequently in order to be rounded up to the closest discrete value and translated into binary language. Its luminosity values become quantified/digitised at this point. On the other hand, the CMOS model (active-pixel sensor) uses transistor as pixel cell, which amplifies and quantifies the voltage directly. Both systems absorb light and change it into electrical voltage, but their technologies are not the same, and neither are their quantisation methods.[39] The look of the images as recorded by these sensors are thus not identical. The two sensor technologies have been implemented not only in cameras, but also in scanners.

In sum, a certain look and quality seemed to be sought after that would potentially enable a wider adoption of digital cinematography. The technologies that were privileged by a group of film professionals and manufacturers were those recreating the characteristics of film images. Other views and practices (various film and DV cinematography) did not cease to exist either. The hybridity, which had existed before thanks to the multiplicity of film formats, stocks and cameras, was reinforced by the addition of video and digital technologies.

1.2 Archives in the Hybrid Technological Landscape

What, then, was the position of archives in this dynamic technological landscape? While archives were experimenting with digital image manipulation technologies themselves, they had also been observing the growing presence of digital technologies in different aspects of the film industry since the late 1990s. Through their exchange with the industry, the archives were concerned by these novelties, particularly the changing materiality of cinema. Moreover, the digital technologies had amplified the possibilities of alternative film distribution, which, in turn, also ignited a series of archival discourses pushing towards a more systematic digitisation. At this time, digitisation was understood as a way of giving access and valorising archival collections.[40] In 2004, although doubtful about the technological possibilities of the time, the

[38] These devices were invented at AT&T Bell Labs in 1969. See: W.S. Boyle and G.E. Smith, 'Charge Coupled Semiconductor Devices', *Bell Labs Technical Journal* 49, no. 4 (April 1970): 587–93.

[39] For a simple technical study of the differences between these two technologies, see: Stefano Merolli, 'Active-Pixel-Sensor vs. CDD. Who Is the Clear Winner?', accessed 6 January 2021, https://meroli.web.cern.ch/lecture_cmos_vs_ccd_pixel_sensor.html.

[40] FIRST, 'State of the Art Report', 206.

FIRST report imagined a "transition into the digital environment".[41] As the report was financed and promoted publicly by the European Commission, its political weight was considerable within the archival community. It covered all aspects of this transition with regards to archival material, from scanning to restoration, conservation and digital distribution. Of course, the report did solemnly emphasise the importance of keeping the originals, but according to it, a visible archive of the future seemed to be a digitised archive, and, it predicted that such a move towards (mass) digitisation would be inevitable. Such digitisation projects, designed to widen access to film heritage, had already been conducted by archives, for instance by the Nederlands Filmmuseum (1997-2004): inspired by the project "Digital Film Center",[42] the archive digitised 1000 hours of film on Digital Betacam tapes. This project intended to create a digital library of films, through which the films could either be sold to customers, or made available on the internet; in other words, films were to be prepared for a parallel digital life. At the Joint Technical Symposium in 2004 (organised by Michael Friend and Grover Crisp)[43] entitled "Preserving the Audiovisual Heritage – Transition and Access", such a transition into a new digital "world" was envisaged:

> "The urban legend of a digital mediasphere has become an implemented reality, and we are faced not only with increasingly urgent need to absorb the artifacts of the last century's media into this world, but also with the myriad problems of conserving a host of new media forms."[44]

This push towards digitisation for access was also reinforced by the report *The Digital Dilemma* published in 2007 by the Academy of Motion Picture Arts and Sciences (AMPAS). Concerned with film archiving in the "digital era" (from the point of view of industry and studio archives), the report stated: "the digital era is not approaching – it's here".[45]

At this point, digital cinematography might have seemed of less importance directly to archives, because, as explained, the world of national film archives collided with that of industry above all in the deposit of film prints, which, at least up to 2011, remained primarily photochemical. But it did affect them in two ways. Firstly, the industry discourses on the evolution of cameras

[41] The term comes from FIRST, 'European Film Heritage on the Threshold of the Digital Era. Full Report (Part One).', Project FIRST. Film Conservation and Restoration Strategies, June 2004, 17. The meaning is inherent everywhere in this report.

[42] 'Digital Film Center', Project Proposal, 1995. This document and more on Digital Film Center are preserved at the Film-Related collections of Eye Filmmuseum in Amsterdam.

[43] On behalf of Association of Moving Image Archivists (AMIA).

[44] Grover Crisp and Michael Friend, 'Welcome to JTS 2007', in *JTS 2007 Programme*, ed. AMIA, JTS 2007: Audiovisual Heritage and the Digital Universe (Toronto, 2007).

[45] Academy of Motion Picture Arts and Sciences, *Digital Dilemma* (Los Angeles: A.M.P.A.S, 2007).

and the comparison of a photochemical vs. digital image echoed also within the archival community. The discourses emphasised on how a photochemical image could be "authentically" duplicated into a digital image;[46] for instance, the FIRST report questioned the required scan characteristics, offering a comparison of the film and digital images.[47] Already evoked some years before notably by Paul Read,[48] the search for a digital image that could be considered as an equivalent to film was nurtured by the long-existing archival understanding of better images, and their tendency to extract more details with less graininess from an old negative compared to its contemporary prints.[49] Secondly, digital cameras shared many technical aspects with scanners, the machine necessary for any digitisation. Up until then, archives had been digitising their films for restoration on industrial scanners conceived for the Digital Intermediate processes.[50] The efforts of projects such as LIMELIGHT to develop specific scanners for an archival workflow had not reached applicable results (and was in fact abandoned in favour of the more conceptual manipulation-based model of DIAMANT). But the intermediate status of digital image technologies was about to change.

Between 2002 and 2004, CNC commissioned the development of an archive scanner "to get ahead of time",[51] called SACHA, which could handle fragile, damaged and deformed elements as well as different formats at a pixel count of 3500x2300.[52] SACHA squeezed the film image to be scanned between two pieces of mirror, forcing it to remain stable while going through the machine. Thus, the problem of image deformations, which arose when heavily-damaged films were scanned, would be solved at the scanning level; eliminating the need to correct them further at the manipulation step. SACHA was a prototype, and designed specifically to answer the needs of an archive, that of CNC. It was never commercialised but remained in use at CNC until 2012, when it was sadly disposed of. Other archival scanners also came to be developed during the second half of the 2000s; which were mostly modified versions of existing machines (cameras, post-production scanners or telecines), integrating specific technologies to make them more adapted for archival use (meaning, at the time, able to handle mechanically-challenged film material). While sharing some similarities, these scanners were designed for

---

46 FIRST, 'European Film Heritage on the Threshold of the Digital Era. Full Report (Part One).', 47–50.
47 FIRST, 35–39.
48 Read, 'New Technologies for Archive Film Restoration and Access: Film Image'.
49 See Chapter One, 1.1.
50 Or on telecine machines for access.
51 Christian Comte and Nicolas Ricordel, 'Sacha, un Scanner pour s'affranchir du temps', *Lettre no. 9 des AFF du CNC*, January 2009, http://www.cnc-aff.fr/Internet/LettreInfo/Lettre09/lettre_09.html, accessed 22 July 2018.
52 Christian Comte and Nicolas Ricordel, 'SACHA : un scanner spécifique pour les films anciens aux Archives Françaises du Film', *Journal of Film Preservation*, no. 68 (December 2004): 20–24.

different use cases. They originated in commercial projects from manufacturers and industry players, sometimes through collaboration with archives or entities close to them (such as labs). In 2008, the company Kinetta, in collaboration with the Library of Congress, introduced the Kinetta Archival Scanner, a low-cost machine, along with a "manifesto" which read:

> "The important thing is to scan everything – rather than decide some films merit preservation, and others do not. This is only possible if the cost of scanning is truly affordable. If scanning is inexpensive, more films will be preserved. That's the point."[53]

This approach, named "non-judgmental preservation", went along in the same direction as discourses on mass digitisation, and its lower prices could indeed contribute to a democratisation of film digitisation. Kinetta promoted thus a discourse of generalisation of digitisation for all films, "at a high resolution, before they deteriorate further".[54] A later version of Kinetta's manifesto emphasised this point again:

> "When scanning becomes affordable, […] it will become standard practice for archives to scan and restore every film on their shelves, not just those that are well-known or have a patron. The hope is that those mystery-cans will yield unknown treasures."[55]

Technically, the implementation of cameras and scanners shared many parts. Kinetta had at first produced a digital camera in 2004 with a pixel count of 1920x1080 with a sensor nearly the size of a 16mm frame, but one which was "sensor-agnostic": designed to accept sensors with a higher pixel count.[56] The sprocket-less, format-agnostic scanner came afterwards. It went the same for Arri, which at around the same time that the D-20 camera was released (2005), also developed and revealed the first Arriscan, "sharing similar technology and the same sensor as the D-20 camera",[57] although this scanner was not yet adapted to archival needs and was designed for industrial post-production. Towards the late 2000s, Arri started working together with the restoration laboratory l'Immagine Ritrovata on an archive scanner. The scanner was presented at Il Cinema Ritrovato 2010, in a presentation called "Pixels for Nitrate" and at IBC 2010.[58] It had been equipped with an "archive gate" which could capture perforations as well,

[53] Jeff Kreines, 'The Kinetta Manifesto', Version 2, 2008, http://www.kinetta.com/manifesto/KinettaManifesto2008v2.pdf, accessed 7 January 2021.
[54] Kreines.
[55] Jeff Kreines, 'A Few Notes on Affordable Non-Judgmental Preservation with the Kinetta Archival Scanner', 2010, http://www.kinetta.com/download/files/KinettaNonJudgmentalPr1.pdf, accessed 7 January 2021.
[56] https://web.archive.org/web/20080626092145/http://digitalcontentproducer.com/mag/video_nab_12/, accessed 7 January 2021.
[57] 'History of ARRI in a Century of Cinema', *Film and Digital Times*, September 2017, sec. Special Issue, http://www.filmanddigitaltimes.com/wp-content/uploads/2017/09/FDTimes-ARRI-Centennial-84-3.05-200m.pdf, accessed 3 January 2021.
[58] https://www.youtube.com/watch?v=vvd5WiIZjow, accessed 3 January 2021.

it was sprocket-less, and benefited from a custom-made lens. At IBC 2011, Davide Pozzi (l'Immagine Ritrovata) underlined what this commercial joint venture could offer to archives.[59] According to him, the new Arriscan would enable the scanning of original material without the need to pass through the photochemical duplication step. In this way, "no compromise with quality" was needed.[60] Pozzi was referring to the extraction of image information from the most original element, possibly the camera negative. This had not always been possible. For instance, for the restoration of *Das Boot ist voll* in the early 2000s, as I evoked in the previous chapter, it had proved impossible to scan the film's fragile 16mm negative, leading to an alternative workflow of duplicating it first and then scanning the interpositive, which already included a loss in image details compared to what could have been achieved by scanning the negative directly.[61] Such problems were too common at the time.

By the late 2000s, other manufacturers, such as DFT (Digital Film Technology) which was behind Spirit Datacine scanner (1995) in a joint project with Kodak, also produced scanners adapted to archival use. DFT's Scanity, dating back to 2009, was promoted as a "versatile" scanner whose soft film transport could also suit archival material "with a solution that reproduces the pristine quality of film and image quality [required]".[62] Two points came up regularly when scanners were promoted within the archival community: one was their mechanical adaptation, and the other the closeness of their image to the original photochemical element being scanned, notably through the use of similar technologies of lenses. The pixel count was of less interest, as 4K scanners had already been available technically since the early 1990s, and applied since 1993 within the film industry.[63] But at this time, no study was done by the archival community to technically compare scanner performances in terms of image reproduction: only the images were compared, not the machines. The scanner comparisons would be conducted in the second half of the 2010s, as I will detail in Chpater Four.

To sum up, during the 2000s, there was a political discursive tendency resonating within the archival community to massively digitise films for access, to keep up with the upcoming digital future. At the same time, different technologies (and machines such as scanners) were being

[59] It is interesting to note that Immagine Ritrovata, despite the fact that his previous director Nicola Mazzanti was very active in discourses on digital technologies, did not own a scanner until the late 2000s.
[60] https://www.youtube.com/watch?v=-caey0mexk8, accessed 3 January 2021.
[61] See Chapter One, 4.3.
[62] 'Scanity Product Data Sheet' (Digital Film Technology (DFT), 2009), https://web.archive.org/web/20090731065416/http://www.dft-film.com/downloads/datasheets/DFT-SCANITY-Datasheet_04_09.pdf, accessed 7 January 2021.
[63] For a more in-depth study of scanners' function by the early 1990s, see: Kennel, 'Digital Film Scanning and Recording: The Technology and Practice'.

adapted to archival needs and desires to create digital images which looked similar to their film image counterpart. Their commercial development crossed paths with discussions on image quality within both discursive networks: the film industry and the archival community. In what follows, I will try to deconstruct the nature of this transition and the constant comparisons between film and digital technologies.

1.3 From One Technological System to Another: Comparing Images

As I have previously argued, for the adoption of new camera or scanner technologies, an important criterion for archives and industry was that of technical image quality. Up until then, notably because of the visual differences between video and film image, the video image was judged insufficient within many discourses. With the digital technologies of the early 2000s, the new developments were designed in a way that the uncompressed digital image out of a camera or a scanner would resemble the photochemical image as recorded on film during shooting. By this time, the comparison between film and digital seemed to be more present, and the imaginary that digital might one day surpass film became dominant. The term "quality" became a catchword, indicating several different significations in this regime of comparison. But an important question can be raised here: how do the differences between technological systems complicate the comparison of their produced images?

I will argue that the image comparison, out of film, video or digital technologies, is indeed complicated because each technological system has its own frameworks and visual references, and thus its own logic and mathematical models. There is no shared technical framework within which a comparison can be conducted; and from one framework to another, too many factors may change, preventing the establishment of a scientific comparison. In order to explain how these systems create their own images, I resort to the Model Theory, a concept developed in mathematics and subsequently applied to other field such as social sciences and linguistics. Indeed, images can be considered as models, and the imaging can be likened to modelling, so the Model Theory can be an efficient pragmatic tool to analyse the technological frameworks of different imaging systems. According to this theory, models have three properties:

- "Mapping": a model maps information from the original to its representation.
- "Reduction": a model is not an identical copy, in the way that it does not capture all attributes of the original it represents, but only those that are deemed relevant.
- "Pragmatism": a model is not uniquely assigned to its original; different models may correspond to one original according to the function they need to fulfil.[64]

[64] Herbert Stachowiak, *Allgemeine Modelltheorie* (Vienna: Springer, 1973).

The photochemical film is composed of a film base and a photo-sensible emulsion. The latter is comprised of silver grains and/or colour dyes held together by gelatine.[65] Film base is the transparent plastic part that carries the emulsion layer, and can be nitrate cellulose (celluloid),[66] triacetate cellulose (safety film), or polyester.[67] A photochemical image is a result of chemical actions when film is hit by light. When the light comes through the lens of the camera (or a printing machine), it hits the photochemical film and impresses the silver grains or colour dyes,[68] creating a latent image where the light intensity is mapped to the densities on film. The spatial composition of the objects in front of the camera are mapped to a new spatial composition, 3D becomes 2D but the relative distances in the 2D domain are preserved. The film is then developed in chemical solutions, and this makes the image appear. Reproducing an image photochemically would be a similar transformation, which can either scale the image (optical printing when changing gauge or image format) or not (contact printing). The "pragmatism" of the photochemical model concerns how and towards which goal the reproduction is done; for example, when duplication is conducted with a wetgate (if scratches and dust need to be removed) or without wetgate, the newly-reproduced images would not look the same and each corresponds to a wanted effect. The same goes with the use of different film material, different lighting, different lenses, different printer settings, etc. The photochemical reproduction entails obviously reductions. Because of the limits of chemical, mechanical and optical technologies involved in the photochemical modelling, the output image is never identical to its source. Most importantly, not every little detail can be (re)recorded on film. There are also unwanted absorptions of lighting by different layers of photochemical films which may change the aspect of the image.

In the case of video (re)production, the model comes from an electronic encoding of the image information. The image in this case is recorded line by line. Its luminance and chrominance values are carried by video signals, accompanied by pulses for line and frame synchronisation. The mapping is more complicated than that of photochemical (re)production, as it is an

---

[65] For a more detailed description of film layers, see: Kodak, 'Film Structure', in *The Essential Reference Guide for Filmmakers* (Kodak, 2007), 29–34, https://www.kodak.com/content/products-brochures/Film/kodak-essential-reference-guide-for-filmmakers.pdf, accessed December 21, 2020.

[66] The word celluloid, which is in reality the mix of nitrate cellulose and camphor, has come to be regularly used to designate any cinematographic film. For a short history of celluloid, see: Earl Theisen, 'The History of Nitrocellulose as Film Base', *Journal of the Society of Motion Picture Engineers* 20, no. 3 (March 1933): 259–62.

[67] There are also other types of film base, sometimes regrouped under the label "diacetate". The three mentioned in the text are the most frequent ones.

[68] A process such as Technicolor printing uses dye transfer, and its image is not created by light. I focus on the images created by light. For more information on Technicolor from an archival perspective, see: Ruivo, 'Le Technicolor trichrome : Histoire d'un procédé et enjeux de sa restauration'.

electrical signal recorded on magnetic tape, which needs to be translated at every playback. Video (re)production provides thus an image that can be visualised either as the video signal itself (plotted on a diagram) or an ephemeral moving image on a screen (Figure 17). According to the video formats, different images may be generated. Again, they all include reductions: as video reproduction reads the image information line per line, it ignores what may exist between those lines. Similarly, for each line, it also applies a sampled phase, which picks up a part of the information, while leaving others. The electrical noise also generates another source of reductions in this type of imaging.

Finally, a digital image, as explained in Chapter One, encodes the information in a sequence of zeroes and ones. The mapping provides a link between source image attributes and the binary sequence, as well as information on how to visualise the sequence as an image. This binary sequence is of course not unique, and different digital samplings give different binary codes. Moreover, the 0 and 1 sequence may be translated differently by a computer depending on their format.[69] The digital image can also be visualised in various ways: a sequence of 0s and 1s, an image matrix in the case of an uncompressed image, as presented in Chapter One (see Figure 12), an image on a computer screen, etc. David Walsh presented one such visualisation of a DPX image in his article in *Journal of Film Preservation* in 2018, in which he called it an "interpretation" of an image.[70] Beyond the electro-mechanical and optical technologies used in digitisation, the pixels, digital sampling and quantification all leave out or modify some details while recording and representing image information.

Moreover, while the photochemical image is visible on a film; the digital image is only a sequence of ones and zeroes and is not directly visible, similar to the video image whose electrical signals need to be translated at each playback. This complicates the visual comparison. Indeed, the image in the two latter cases needs to be visualised on a screen every time. The photochemical image, as well, is generally projected when its quality needs to be visually determined. For instance, when trying to determine the quality of a negative image, an answer print is struck from it and projected for visual control. The subject of all these quality controls are ephemeral images, but the conditions of their appearance are not the same, and the influences of these systems need to be taken into account. On the other hand, image characteristics can be mathematically described, in order to define concepts such as sharpness, graininess, contrast, etc.

[69] I will come back to the question of formats in Chapter Four.

[70] David Walsh, 'Slow Disasters: How Neglect Continues to Destroy Our Film Heritage', *Journal of Film Preservation*, no. 99 (October 2018): 27.

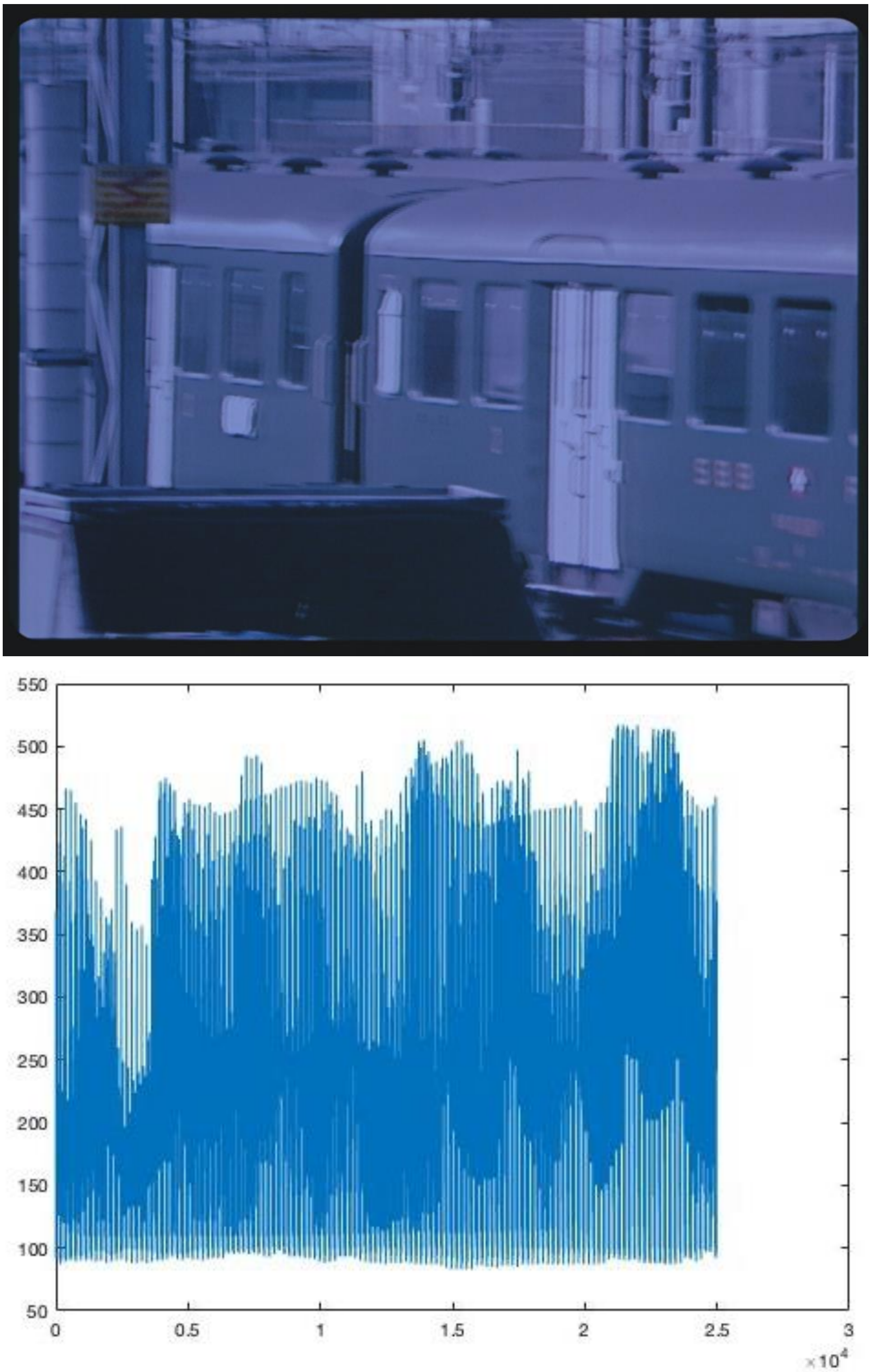


Figure 17 On top, a digitised frame of *Une Lettre à Freddy Buache* (Jean-Luc Godard, Switzerland, 1991). The film was shot on video, and it preserves a specific look of video, particularly as the train is moving and the objects seem to have a sort of shadow. Courtesy of Cinémathèque suisse. On the bottom, there is a portion of the same image, represented as a video signal, where the x-axis is the positions of sampled image points in a linear way and the y-axis their amplitude.

But as the images are inherently different, their mathematical comparison, which describe the same concepts differently, can hardly be done within one same framework.

From what I have described, it becomes clear that every image (re)production is done in a different technological system, with different regimes of mapping, pragmatism and reductions (of course, apart from rare experiments which re-enact the original technologies). The choice of imaging methods and the different layers of approximations involved in any of them make a degree of scientific or visual subjectivity inevitable in any technological framework. My analysis here proposes to keep in mind these differences, when comparing images (whether mathematically or visually), especially when an image goes from one system to another. Historically, image comparison has been done constantly throughout the technical history of cinema, by manufacturers (in a mathematical way) or other actors in the field (mostly visually). Several understandings of quality as well as several measures of superiority have existed, which I will detail later in this chapter.

2 Constant Crisis: Archival Identity Crisis in View of the Uncertain (Digital) Future

In the previous subchapter, I explained how the film industry – and to a lesser extent, film archives – were moving towards an amplified hybridity, integrating newer modes of imaging into their already-diverse technological framework. Different film, video and digital technologies were in co-existence, a phenomenon which was not inherently new in the bigger mediatic context, but by this time it was shifting into the foreground of the cinema scene, especially with mainstream cinema. From the archival perspective, some new technologies were already on the way to becoming integrated into certain practices (such as restoration, as explained in Chapter One) and archives were faced with calls for a so-called transition, albeit not many real digitisation projects had been defined, let alone implemented. Moreover, there seemed to be an understanding within the industry and archives that digital technologies were to replace film technologies entirely in a not-too-far digital future. In this situation, archivists were wondering, what would become of film archives, film collections, and simply film in a digital future?

I will argue that the identity crisis ignited by the digital future appeared to threaten the very existence of archives, as could be observed in the archival discourse network during these times. Archivists would hypothetically illustrate this future, and theoretically address the question of archival identity. This was never a simple question with one unique answer accepted by all archives, as was rightly acknowledged by Robert Daudelin back in 1987 at the FIAF Symposium in Lisbon.[71] Ay my brief historical overview below will suggest, it was indeed a

[71] See: Robert Daudelin, 'Introduction', in *Rediscovering the Role of Film Archives: To Preserve and To Show, Symposium Proceedings, FIAF 1989 Lisbon Congress*, ed. Cinemateca Portugesa (Lisbon: Cinemateca Portuguesa / FIAF, 1990), 11.

recurrent subject of discussion within the archival community, triggered by different situations. Archival turning points and transitions were imagined for several reasons: social, cultural, geo-political and, of course, technological; or a mix of those. Notably in the 1980s, when archives were experiencing a professionalisation,[72] their identity, role and future came under scrutiny. In 1983, Freddy Buache (Cinémathèque suisse) wrote:

> "The cinematheques risk to be only the opposite of what they used to be: no more gushing and hardly-contained springs [of cinephilia], but offices among other offices, subject to the sterile order of the robotic. "[73]

Close in ideology to Henri Langlois (Cinémathèque française), Buache dreaded the professionalisation that was on the way by the 1980s. His vision of what a cinematheque had been and what it should be was of course biased towards a cinephilia-driven understanding of film archiving.[74] But the point is that, at the time, archives were already expressing fear over their future and their role because of the changing times. Then again, around 1995 and on the occasion of cinema's centenary, the discussions on the role and the future of archives were refuelled. This time, the drive was the need to fix an agenda for FIAF's future, given a rise in the number of its member archives due to "the increasing power of animated images nowadays conveyed by television in all the countries of the world as well as the geo-political developments of these last years".[75] At the LA Congress that year, the perspective and agenda of the future was discussed with a focus not only on these political and theoretical challenges, but also with a look to the future of "cinema in the electronic age", considering questions such as the following:

> "How is the cinema culture today, and what is the role of the archive in the present situation of image making and dissemination? Given the rapid evolution of the media environment, how will audiences change? How will their expectations about the cinematic experience evolve? What role will film archives play in developing literacy about the art of cinema?"[76]

---

[72] See Chapter One, 1.3.

[73] Freddy Buache, 'Préface', in *Les Cinémathèques*, by Raymond Borde (Lausanne: L'Âge d'Homme, 1983). My translation.

[74] For a scholarly study of the formation of this cinephilia-based view of archiving in France, see: Stéphanie E. Louis, *La cinémathèque-musée. Une innovation cinéphile au cœur de la patrimonialisation du cinéma en France (1944-1968)* (Paris: AFRHC, 2020).

[75] Michèle Aubert, 'The Future of FIAF/L'Avenir de La FIAF', *Journal of Film Preservation*, no. 51 (November 1995): 2. My translation. See also the three articles following Michelle Aubert's short introduction, as well as: Wolfgang Klaue and Jerzy Toeplitz, 'A Dialogue Between Two Former FIAF Presidents', *Journal of Film Preservation*, no. 48 (April 1994): 2–14.

[76] 'The First Hundred Years... the Next Hundred Years', Symposium, FIAF 1995 Los Angeles Congress, 1995.

Thus, by 1995, the technological mediatic trigger was also present alongside the more geo-political challenges. This point had already been brought up by Robert Rosen (UCLA) in 1987, who claimed that film archives were facing "major turning points", notably because of accelerating demand for "access to mass media" as well as the heterogeneity of the "nature of media" on which moving images are produced and presented.[77] From then, it was to gradually become more of a pressing matter, by increasing availability of electronic digital image technologies. At the 2000 FIAF Symposium in London, entitled "Futurology of Film Archiving", the new identity crisis, as triggered by the changing technologies in the film industry, was discussed:

> "The modern film industry is changing fast. Films now no longer need film materials for post-production. Soon cinema projection will include, or be dominated by, digital video projectors. Even now feature films are being made with digital video cameras. So what does this mean to us? How will it affect the work of film archives in the future?"[78]

Continuing the discussions launched in London, at the open forum of the 2001 FIAF Congress in Rabat, Steven Ricci presented a symposium project dedicated to the future of film archives as "an opportunity to establish the centrality of film preservation and film archives in a world of digital videos". The proposal did not get realised in this form, but as mentioned by Jose Manuel Costa, it became subject to "continuous discussion for the next years".[79] According to Peter Kubelka at the same congress, the digital technologies threatened film, in a matter of "colonisation by progress", where a "technical conquest" tried to wipe out the "Cinema of XX^th^ century".[80] There was a fear that the new media of the 21^st^ century might put archives' *raison d'être* in peril by replacing film altogether. The confusion about the uncertain future was reinforced by the growing digital culture and its rather democratised accessibility, such as the wide adoption of home computers, the internet, online video platforms, etc., which also contributed to amplifying the transition discourses towards a digital future. The fear of digital technologies was clearly formulated in the title of the Second Century Forum at the 2004 FIAF Congress, chaired by Robert Daudelin (formerly at Cinémathèque québécoise), baptised "The Digital Dragon":

---

[77] Robert Rosen, in *Rediscovering the Role of Film Archives: To Preserve and To Show, Symposium Proceedings, FIAF 1989 Lisbon Congress*, ed. Cinemateca Portugesa (Lisbon: Cinemateca Portuguesa / FIAF, 1989), 58–62.

[78] 'The Futurology of Film Archiving', Symposium, FIAF 2000 London Congress, 6 June 2000.

[79] 'The Future of Film Archives', in *FIAF 2001 Rabat Congress Report and Minutes* (Brussels: FIAF, 2001), 30–31.

[80] Peter Kubelka, 'Colonisation by Progress, the future of cinema', in *FIAF 2001 Rabat Congress Report and Minutes* (Brussels: FIAF, 2001), 32.

> "The Digital Dragon is at our door, even within our walls. It is time to look more closely at the Dragon's impact not only on film preservation but also on our role as guardians of the film culture. What will film archives be like in the digital age?"[81]

In reality, the "digital dragon" did not appear out of nowhere at the archives' door, nor did it "invade" cinema and archives,[82] but its presence and impact certainly did increase in an exponential manner, which reiterated and reinforced the feeling of an identity crisis already present within the film archival community, leading to a point where basic archival concepts were to be re-examined. In 2005, FIAF Technical Commission organised a workshop during the FIAF Congress in Ljubljana, entitled "What is Film?":

> "What makes a film a film, and thus a film archive a film archive? There is no doubt that films and cinema are currently in a transitional phase from analogue to digital. Whether this change will alter the content of the film collections on other levels other than the physical storage media remains to be seen."[83]

The "identity issue" was also part of the discussions at the 2006 Second Century Forum, which reconsidered the place of film archives inside a larger "film heritage world", a larger "network" within which archives were supposed to find a solution to exist.[84] The 2006 symposium, entitled "The future of film archives in a digital cinema world: film archives in transition", fit into a dialectical archival landscape where "the replacement of the film by the image digitalization [seemed] to fascinate and to frighten the increasing public of the seventh art".[85]

The so-called transition was taking place within a mixed mediatic context, where film, television and computers were regrouped and the borders between them were blurry, compared to "back in the days when film was film, television was television, and computers were bigger than the desks they now sit on".[86] As it was understood from the FIRST project, and perpetuated by subsequent discourses, the transition seemed to mean digitising everything; a "switch"[87] from analogue to digital. But the digital future was not there yet. Thus, the archives did not

---

[81] Robert Daudelin, 'Second Century Forum: The Digital Dragon', Official Website of FIAF 2004 Hanoi Congress, 2004, https://web.archive.org/web/20040607233506/http://www.fiafcongress.org/SCF.htm, accessed 26 December 2021.

[82] Daudelin, 'Editorial: Spirit of the Times'.

[83] 'What Is Film? FIAF Technical Commission Workshop', Congress Programme, FIAF 2005 Ljubljana Congress, 2005.

[84] 'Second Century Forum: The Role of FIAF', in *62nd FIAF Congress*, Congress Programme (Sao Paolo: Cinemateca brasileira, 2006), 28–29.

[85] *62nd FIAF Congress*, Congress Programme (Sao Paolo: Cinemateca brasileira, 2006), 3.

[86] David Walsh, 'How to Preserve Your Films Forever', *The Moving Image* 8, no. 1 (2008): 38–41.This number of *The Moving Image* was guest-edited by Leo Enticknap and focused precisely on transition of film archives towards a digital future.

[87] FIRST, 'State of the Art Report', 260.

seem to be headed towards a clear goal, and the practices had been considerably less impacted than it would appear from the discourses. The two main questions of "what is film?" and "what are film archives?", which were formulated at these times of confusion over archival future and identity, will be explored in the following subchapters in a cross-analysis with the technical details they instigate.

2.1 "What is Film?" The Dilemma of Grain vs. Pixel

As mentioned in Chapter One, Article 1 of FIAF's Statutes and Rules had given, from the early 1990s, a very broad definition of the term "film", by including any recording of moving images on any carrier.[88] With the popularisation of digital technologies by the mid-2000s, the question of "What is Film?" was formulated again, providing a context for a more in-depth technical questioning of moving image technologies, film or digital.[89] The aim was to draw a comparison between the two, which would determine the superiority of one to another, but also enable the transition. During this period, not only were digital image technologies in constant development, but also new photochemical technologies were developed and presented by manufacturers such as Fuji and Kodak.[90] These discussions focused more on image production, rather than image projection, hence the comparison was conducted between recorded images on photochemical or digital carriers. I will discuss image projection in Chapter Three.

The TC workshop at the 2005 FIAF Congress claimed that films were going "carrier-independent" in transition.[91] Indeed, the detachment of the digital image from its carrier was a widespread perception (to which I will come back in Chapter Four while discussing conservation), and it ignited discussions where the relation between content and carrier were explored:

> "The mission of film archives is not limited to preserving film 'content'. Film archives are also expected to preserve and prolong the life of film as 'carrier', that is, object which consists of various gauges and materials, as well as the 'context' of film including the systems of projection and sound, based on the notion that all three comprise (a set of) cultural assets."[92]

[88] See the citation in Chapter One, 2.2.
[89] Analogue video image was hardly, if ever, taken into account at this time.
[90] Fuji and Sony, 'Technical Debriefing: Two Possibilities of Leading-Edge Technology for Film Archiving' (FIAF 2007 Tokyo Symposium, Tokyo, 2007).
[91] 'What Is Film? FIAF Technical Commission Workshop'.
[92] *FIAF 2007 Tokyo*, Congress Programme (Tokyo: National Film Center, 2007), 6.

In this case, the digitisation of film would create trouble, because it only kept the "content" and parted ways with its "carrier" and technological "context". But how would that relate to the image in a technical sense? The question of "what is film" can be approached from different angles, for instance film as a dispositif (projected film image through mechanical machinery in a cinema hall for spectators), as a material object (the film strip) or as a conceptual artefact ("content"). Here I focus on the recorded image as the incarnation of film's material existence (carrier) and technologies that create it (context), in order to explain the archival concerns of digitisation around this time. The mentioned statement considers the image to be the result of these aspects coming together. Indeed, a change of carrier, with the help of old or new technologies, would change the look of the image. In this way, the question of "what is film" becomes "what is film image", crystallised in the dichotomy of grain vs. pixel. If archives were to undergo digitisation, how would they ensure that the image quality of their film elements would not suffer when digitised? How would analogies be drawn between the characteristics of film and digital images? How could a digital image, comprised of pixels, rival (or reproduce) a film image, characterised by its grain, presenting the same quality?

While comparison between digital and film images was mostly from a subjective and empirical point of view ("pragmatic methods"), some quantifiable (scientific) estimations were also proposed to be carried out.[93] Both of these methods contributed to the establishment of a regime of approximative comparison between film and digital images. The FIRST project, which had addressed the questions of "What is a film image? What resolution? What bit-depth?"[94] at a conference in London in 2004,[95] presented these approaches as follows:

- "Estimates from intrinsic film characteristics": "optimum resolution and bit depth can be calculated from published characteristics of a film stock, and a knowledge of display systems and the human eye".[96] This approach was mostly inspired by technical studies from the broadcast field, as well as some archival and industry initiatives. I will come back to these scientific estimations in the next subchapter.
- "Estimates from pragmatic opinions": "Another view, at the other extreme, holds that film images are complex structures and that it is essential to scan film at the highest resolutions, and bit depths, to ensure that no information is lost and that digitization

[93] FIRST, 'European Film Heritage on the Threshold of the Digital Era. Full Report (Part One).', 38.
[94] FIRST, 35.
[95] The conference was part of a UK initiative on digital cinema, "Digital Test Bed", at the National Film Theater. See: https://web.archive.org/web/20031102175123/http://www.bfi.org.uk/features/dtb/about.html, accessed 5 January 2022.
[96] FIRST, 'European Film Heritage on the Threshold of the Digital Era. Full Report (Part One).', 36.

should not be carried out unless this is possible".[97] Tables were prepared following some pragmatic tests, in order to advise archives on resolutions necessary for each film element (Figure 18).

The characteristics of the photochemical image were more familiar to archives, but they did feel a necessity to understand the digital image better. The "technicalities of digital image technology" were researched and presented notably by Mikko Kuutti at the FIAF Congress in 2006, "starting with the humble pixel, and covering such key concepts as resolution, bit depth, bit rate, compression and defects (or artefacts, as digital technicians prefer to call them)".[98] The term resolution, very commonly used at this time for image quality, only referred to the pixel count, which, as I will explain later, is not precise.

Digitisation was desired to reproduce images as close as possible to their photochemical original, but how was that to be achieved technically? According to David Walsh, "digital technology [could give] us what we have always wanted: the power to extract all the picture and sound information from less-than-ideal film masters".[99] The digitisation output was in fact believed to be "as close as is possible to seeing the quality inherent in the original negatives [or other intermediate elements scanned]",[100] even though the image on the negative was never seen by the audiences as such. This tendency to reproduce more image details did not aim at the reproduction of any original print, but it intended to extract the information from the most original elements of a film under scan (negative, when available, and interpositives, internegatives or prints when not). But, as summed up by Fossati, "how do we assess the data content of images in order to define the resolution needed for digitisation?"[101] How to reproduce all the "fine soft details"[102] of the image? A sort a matching between photochemical and digital image characteristics seemed to be sought.

---

[97] FIRST, 38.

[98] As recounted by: Walsh, 'Technical Symposium - FIAF Congress 2006 São Paulo: Film Archives in Transition', 71.

[99] David Walsh, 'Do We Need Film?', *Journal of Film Preservation*, no. 72 (November 2006): 4–8.

[100] Walsh, 7.

[101] Giovanna Fossati, 'Notes on the 2004 Joint Technical Symposium. Preserving the AudioVisual Heritage – Transition and Access', *Journal of Film Preservation*, no. 68 (December 2004): 28.

[102] Antti Alanen, 'Il Cinema Ritrovato/Le Giornate del Cinema Muto 2009', *Journal of Film Preservation*, no. 82 (October 2010): 81.

RESOLUTION OF SOME FILMS IN "SCANNING" TERMS. PRAGMATIC ESTIMATES FROM DISCUSSIONS, 1997-8

RESOLUTION REQUIREMENTS IN PIXELS

Estimates from discussions

FILM SYSTEM and frame size	RESOLUTION REQUIRED? Height x Width pixels Approximations	total Pixels millions
35mm Eastman Colour Academy frame 1997	2057x3656	7.52
35mm Eastman Colour full frame 1997	2664x3656	9.74
35mm Eastman Colour Vistavision 1997	3456x6144	21.23
35mm Technicolor print Academy frame 19 50	1000x1750	1.75
35mm Black & White nitrate negative Academy 1935	2057x3656	7.52
35mm Black & White nitrate print Academy 1935	2057x3656	7.52
35mm Black & White nitrate negative full frame 1920	1140x2000	2.28
35mm Black & White nitrate negative full frame 1915	1140x2000	2.28
35mm Prussian Blue toned full frame 1925	761x1354	1.03
35mm Cinecolor [2-colour] print Academy 1940	1000x1750	1.75
16mm Eastman Colour frame 1997	900x1575	1.4
16mm Ektachrome EF News film	761x1354	1.03
16mm Eastman Colour print 1960	761x1354	1.03

Figure 18 Correspondance table between film and digital images, prepared by the FIRST research group. As it can be seen, different types of film were attested to correspond to different pixel counts (called resolution here).[103]

The FIRST report emphasised on the reproduction of an image with a "correct resolution" and bit depth, but it did underline that no "consensus of opinion, or adequate research" existed which could indicate clearly what those "correct" values were.[104] The assumption that digital reproduction could extract all image information on the film element, was countered by film manufacturers. Kodak, for instance, claimed that the image on a modern negative contained 5 to 10 times more information than any digital representation,[105] but their estimation remained highly approximative. Of course, Kodak's goal was to prove that film was still a better medium for capture (and else) to benefit their business, and thus was considerably biased. The comparison between the amount of image information on film or digital, whether using mathematical approximations as in the case of Kodak, or done visually, could not provide a definitive, unique answer, as explained before with regards to different technological frameworks. These empirical discourses could not provide exact matchings between digital and photochemical images.

---

[103] FIRST, 'European Film Heritage on the Threshold of the Digital Era. Full Report (Part One).', 38.
[104] FIRST, 24–25.
[105] Kodak, 'Capturing Information on Film', May 2007, https://www.kodak.com/content/products-brochures/Film/Capturing-Information-on-Film.pdf, accessed January 11, 2021. Originally published in: In Camera, April 2007.

What archives supposed at this point was that higher pixel counts would extract more information from original photochemical elements being digitised. Indeed, a sort of linear causality was imagined between them; which is partly true, but more complicated, as the quality of a reproduction does not depend only on pixel count, but also on the performance of different parts of a scanner (lenses, mechanics, lights, etc.), on the type, generation and conditions of the film element being scanned, and also on the "limits of the human eye"[106]. Finally, the reference photochemical image, which was compared to the digital image, was not fixed; it could be the negative or a print, according to the context of production or reproduction. Taking all of this into account, the comparisons between digital and film image remained subjective, approximative and inconclusive from a discursive point of view.

Image quality was a recurrent concept within the discourses at this time, and many terms were used to qualify it, notably resolution (in the sense of pixel count). Archivists (and industry actors) were not aesthetically judging the images as artworks, but trying to establish a framework within which technical image characteristics and details could be defined, calculated and therefore compared. The main question was how a digital image, with its pixel grid, could represent as closely as possible an image recorded on film? The image quality seemed to include several factors, some of which were quantifiable while others remained more perceptual. Historically, the question of image quality has been regularly evoked in the film industry as well as archives, although not always based on scientific methods. In what follows, I will look back to historical scientific studies and the construction of the concept of image quality, in order to critically analyse its understanding within film archives. With this discussion, I argue how the dilemma of grain vs. pixel was technically deep and could be interpreted in different ways, and how the seemingly basic question of "what is film (image)" within film archives could be complex because of the whole socio-cultural history of image technologies.

2.1.1 Defining a Vague Concept: "Image Quality"

Technical image quality has largely been judged from a visual point of view and based on pragmatic approaches within the film industry and film archives.[107] The term, as its use cases show, cannot be simply defined in one unique way, and harbours different meanings. In this part, I will open up the discussion on image quality by claiming its subjective character, whether

[106] As mentioned by Charles Poynton (independent consultant) at the JTS 2004, recounted by Fossati, 'Notes on the 2004 Joint Technical Symposium. Preserving the AudioVisual Heritage – Transition and Access', 28.

[107] On a scholarly level, Benoît Turquety, notably, has expressed doubts about the term and specifically about the comparison between photochemical and digital film. See: Turquety, *Inventing Cinema. Machines, Gestures and Media History*, 15–17.

owing to its scientific modelling, or because of its biological and psychological perceptions, and how that influences the industrial and archival use of the word. Then I will detail its place within the history of image science, as well as its numerous definitions and components, in order to technically lay the ground for a better analysis of archival discourses, and provide explanations for concepts such as resolution and film look.

Within the film industry, image quality refers to the collection of the visual characteristics of an image, such as sharpness, graininess, resolution, latitude, colour range, contrast, etc. These aspects have sometimes been mathematically modelled in different ways, but their technical calculations and definitions have remained mostly limited to the research laboratories of film manufacturers (such as Kodak, RCA, Ilford, etc.) and shared in technical magazines and reunions (such as SMPTE or BKSTS) to the attention of film lab or studio technicians. The scientific study of photochemical image quality predates its use within the film industry, as it had been initiated by the late 19th century. Image science started with physical experiments, before also developing an important mathematical wing. While the former provided performance curves between different characteristics of images (sensitivity, light intensity, grain distribution, etc.), the latter mathematised these concepts: by mathematisation, it is meant that the optical and photochemical characteristics of film images are modelled as mathematical problems, and solved with the aid of mathematical solutions (calculus, statistics, etc). Since the 1940s, in comparison with television (electronic) imaging, a new interest for quality calculations arose that aimed to achieve closer image reproductions. While sometimes called objective because of its mathematisation, it is important here to underline again that image science does include a degree of subjectivity, approximation and estimation precisely because of its mathematical modelling.

The subjective aspect of image quality is reinforced because of its biological perception through the Human Visual System (HVS). The HVS indicates what the human eye can or cannot see, or how the human eye perceives visual phenomena. For instance, if the human eye cannot see a certain detail, it is believed unworthy to be considered in image science (the threshold of "just noticeable difference")[108]. The concept of cinema itself is based on how the human visual system works: when still images roll at a certain speed, the human visual system (the combination of eyes, nerves and brain) perceives movement. To include this aspect within the calculations, the HVS can be modelled as well. Although its mathematical models, similar to

[108] Brian W. Keelan, *Handbook of Image Quality. Characterization and Prediction* (New York and Basel: Marcel Dekker, 2002), Introduction.

any modelling of natural and physical processes, are not free from estimations and omissions, they do provide a limiting framework for image science. This approach gained popularity among researchers with regards to digital formats,[109] but it could in fact apply to any vision apparatus or image technology.

The subjectivity of image quality is also due to a more psychological and aesthetic aspect of visual perception, which has been studied through conducting surveys with the participation of human subjects. It can be modelled if a sufficient amount of human opinion is available: the more, the better. Simply put, it tries to quantify how humans qualify an image as technically good or bad. For instance, if a great number of human subjects qualify an image as having good quality, it could be chosen as a reference for a good image, and other images would be compared with it in order to achieve a so-called good image. This is referred to as "psycho-physical" or "psycho-visual" aspects of image perception. It has been known and applied to (film) photography since the early 20th century, and considered by film manufacturers in producing film stock.[110] In archival applications, this aspect has been noted, whether by its scientific name[111] or through its effect. For instance, when restorers consider that a newly-restored film needs to provide an image quality appealing to new audiences, they are indirectly including the collective psycho-visual perception in their decision-making process. The imprecision of such a statistical approach is that those perceptions which diverge radically from the more common ones are marginalised, and this, in cinema, represents a considerable body of aesthetic and cultural tendencies (for example small-gauge filmmaking) which are not represented in these calculations.

From a scholarly perspective, the mix of these two approaches has been coined as "perceptual technics" by Jonathan Sterne, who defined it as "the application of perceptual research for the purposes of economizing signals".[112] Perceptual technics have been used by film manufacturers in the design and production of film stock, and subsequently, the continuously-evolving film stock technologies (with the different image that they produce) have shaped the collective public perception of technical image quality. The concept of image quality is therefore socio-historically and culturally constructed, through a discursive network that gathers technologists,

[109] I will investigate this further in the next chapter about JPEG-2000, its compression and its adoption.

[110] For a short early history of psychophysical photography and its application by film manufacturers, see: Loyd A. Jones, 'Psychophysics and Photography', *Journal of the Optical Society of America* 34, no. 2 (February 1944): 66–88.

[111] Martin Roux, 'Image numérique et image argentique, quelles différences perceptives ?' (Toute la mémoire du monde, Cinémathèque française, Paris, 2016), https://vimeo.com/160244246.

[112] Jonathan Sterne, *MP3: The Meaning of a Format* (Durham: Duke University Press, 2012), 19.

film manufacturers, professionals and diverse audiences. These two-way processes created a normative understanding of image quality – and its aesthetic measures, which, of course, were not universal nor historically constant. For instance, the physical artefacts (such as scratches, tears or decomposition traces) which a film element would present after extensive use and old age, came to be known as quality degradations gradually within the film industry and archives, while the same damages were put to aesthetic use in later films such as *Decasia*.[113] In the same way, a less grainy, sharper image was promoted as having a better quality, as my examples in Chapter One demonstrate. The history of image science and the concept of image quality that I will investigate in the following parts will show how technological developments went in this direction. This understanding, however, did not always correspond culturally to how image quality was perceived by different people, whether audiences, film professionals or archivists: a grainy image for instance, as I will underline later, could be in fact desired in many cases, despite the more mainstream quest towards a sharper, less grainy image.

In archival practices, the question of image quality was discussed within the framework of reproduction. This means that each reproduced image was supposed to resemble its own reproduction source (whatever that might be, whether a print or a negative or else). In this case, image science presents another term for quality, which is "image fidelity", although historically the two terms have been often used interchangeably. The main difference between them is that image fidelity aspires to recreate the visual characteristics of its reproduction source (often within a new technological system): "image fidelity is the subset of overall image quality that specifically addresses the visual equivalences of two images".[114] The reproduced image could then undergo manipulations that went beyond the immediate fidelity, and aimed the recreation of an imaginary reference (what archives believed the film originally looked like). In many of the technical studies on image reproduction quality, the term fidelity has appeared since at least the late 1920s (in comparison with television) and is characterised by the reduction of a loss or deviation from an ideal reproduction. I will come back to these concepts in Chapter Four.

During the 2000s, the comparison between photochemical and digital image quality, although stemming from the discourses on reproduction, was directed at a more general comparison which would prove the superiority of one to the other. In the following part, I will focus on the term image quality as a polysemic, historical construct within the boundaries of its scientific

[113] *Decasia: The State of Decay* (Bill Morrison, 2002) celebrates the aesthetic effect of decaying nitrate film.

[114] Scott Daly, 'The Visible Differences Predictor: An Algorithm for the Assessment of Image Fidelity', in *Proceedings of Spie 1666. Human Vision, Visual Processing, and Digital Display III*, ed. Bernice E. Rogowitz, vol. 1666 (SPIE, 1992), 2–15.

understanding and calculations in order to clarify how these concepts correlate (or not) with archival discourses and practices.

For a Scientific History of Image Science

The relation of scientific research to image quality has been a complex one, as image science is not a homogenous field: over time, it has included several research questions, which have been addressed with different methodologies. A quick look back at the history of image science will help me argue how the very understanding and mathematical modelling of an image influenced the definition and determination of its quality.

The technologies of early film photography were widely discussed from a chemical perspective, concerning the material and processes "composing the image": "the [invisible] image is […] the property of the chemist, and by him must the scientific foundation of photography be laid".[115] The image that was under scrutiny was strictly the one registered on a film element as a photosensitive material. There was particular attention paid to the subject of "sensitivity" of photographic material which recorded the "impressions" as invisible images. In 1890, two chemical engineers Vero Charles Driffield and Ferdinand Hurter defined the terms opacity, transparency and density of a negative based upon the "laws of absorption of light by the opaque black substances". "Opacity" and "transparency" indicated the amount of light intensity that a substance would absorb or let through, while by "density" was meant "the number of particles of a substance spread over unit area, multiplied by the coefficient of absorption". [116] Hurter and Driffield conducted a series of experiments in order to establish the link between image density and exposure as an attempt to determine the "sensitiveness" of photographic material. The method and the resulting curves were poised to be "a progress both in the preparation of the plates and their application" and could help "plate makers and photographers" ascertain "accurately the sensitiveness of different plates", and "apply this information in practice".[117] Indeed, the chemical properties of the material influenced the image formed on it. This information could guide photographers so that they could create the image that they desired,

[115] Raphael Meldola, 'The Photographic Image', *Nature* 42, no. 1080 (10 July 1890): 246–50. This article retraces the "first half-century" of photography.
[116] Ferdinand Hurter and Vero C. Driffield, 'Photo Chemical Investigation and a New Method of Determination of the Sensitiveness of Photographic Plates', ed. W.B. Fergusen, *The Journal of the Society of Chemical Industry* 9, no. 5 (1920): 76–122, accessed 15 January 2021 [The Journal of the Society of Chemical Industry, Vol. 9, No. 5, May 31, 1890].
[117] Hurter and Driffield, 122.

and help manufacturers to produce a film which they judged more suitable. This scientific approach became known as “sensitometry”:

> “Sensitometry is the exact measure and knowledge, or, to say it better, the precise expression of the luminosity received by a photographic plate. […] All the photometric measures obtained via photography depend on the [chemical] solution of this plate.”[118]

In the beginning of the 20th century, the sensitometry of photographic material was further studied by researchers in different fields where photography was applied, such as astronomy or physics.[119] It was also widely adopted and researched by the research laboratories of Eastman Kodak, which assisted them in film manufacture. A direction that was intrinsically interlaced with sensitometry was the study of the particles in film which absorbed (or not) the light intensity. This study was notably initiated by Perley G. Nutting (Kodak) in 1913:

> “Photographic density depends upon the size and number of the imbedded silver grains and to a slight extent upon their form and distribution as well.”[120]

The interest for grain as the basis for image density is significant in the fact that it linked the photochemical performance to the existence of a great number of particles, of different sizes, shapes and sensitivities, in various distributions. As a result, more mathematical approaches and modelling could be applied, accompanying (and sometimes replacing) the experimental studies: “The mathematical problem of relating density to grain is obviously to be treated by probability theory rather than by infinitesimal analysis.”[121]

The particles of latent and developed images were thus considered as forming specific image units absorbing light, representing unit image densities. By the early 1920s, the theoretical approach expanded to not only concern the characteristics of the photographic material but also to include the light that the material received. The light was studied within a light-quantum theoretical framework where it was “split up into light-quanta or discrete parcels of very concentrated monochromatic light”.[122] The light was, of course, scientifically studied before quantum theory, but the latter decomposed it into discontinuous photons (light-quanta), which,

---

[118] Charles Nordman, ‘Revue scientifique : les cent ans de la photographie, Revue des Deux Mondes (1829-1971’, *Septième période* 28, no. 4 (15 August 1925): 932–42.
[119] See for instance: Robert James Wallace, ‘The Daylight Sensitometry of Photographic Plates, and a Suggestion Standard Dispersion-Piece’, *Astrophysical Journal* 25 (March 1907): 116–50.
[120] Perley G. Nutting, ‘XXXII. On the Absorption of Light in Heterogeneous Media’, *The London, Edinburgh, and Dublin Philosophical Magazine and Journal of Science* 26, no. 153 (1913): 423–26.
For an earlier study of grain from a more experimental point of view, see: ‘The Grain in Photographic Film’, *Nature* 70, no. 1823 (6 October 1904): 571.
[121] Nutting, ‘XXXII. On the Absorption of Light in Heterogeneous Media’.
[122] L. Silberstein, ‘XIX. The Quantum Theory of Photographic Exposure’, *The London, Edinburgh, and Dublin Philosophical Magazine and Journal of Science* 44, no. 259 (1922): 257–73.

in the context of photographic material, could prove useful because, in turn, it could enable a decomposition of the process of photochemical image recording. In this way, the image structure has been considered as a random array of photon-counters ("photoreceptors") that absorb light photons (or "quanta", in terms of quantum physics). The photoreceptors are distinct from the real material silver-halide grains, but are naturally related to them.[123] This discontinuous image structure on film appears continuous to the eye through observation on film (unless magnified considerably), or when projected:

> "When an apparently uniform area is examined under sufficient magnification, at least theoretically, it is found to consist of particles or groups of particles arranged in a regular or a random fashion. The particles or groups are, to use a general term, 'samples' of energy or matter which, according to number, arrangement and size, determine the image quality. The imaging process is fundamentally a sampling process."[124]

This technical visualisation of the structure of an image on film demonstrates that "continuity and uniformity of an area, in strict sense, are illusions",[125] even though they appear continuous to an observer. The shift towards the study of microscopic particles of both film and light could define a greater number of image aspects, rather than only sensitivity, notably thanks to the discontinuous representation that it offered. The discontinuity, an important observation based on the material properties of film, allowed for adequate statistical modelling and subsequent treatments.

These studies were mostly done with the goal of the theorisation of experimental observations rather than the determination of image quality, although, overall, they did contribute to it, especially as they potentially provided more control over image characteristics for manufacturers (and also photographic film users and labs). But, of course, the determination of image quality was also a potential research question, notably since the 1930s.[126] In later decades, the computation of the "resolution" (or "resolving power") of an image, as a characteristic of its quality, gained more momentum. The "resolution" of an image formed on film,[127] which I will address later in more details, concerned not only the inherent characteristics

---

[123] J.C. Dainty and R. Shaw, *Image Science: Principles, Analysis and Evaluation of Photographic-Type Imaging Processes* (London: Academic Press, 1974), Chapter 1.

[124] Schade, 'Image Gradation, Graininess and Sharpness in Television and Motion Picture Systems. Part I: Image Structure and Transfer Characteristics', 139.

[125] Schade, 140.

[126] H. Frieser, 'Uber das Auflösungsvermögen von photographischen Schichten', *Kino-Technik*, no. 17 (1935): 167–72.

[127] The resolution of an image projected on a screen depends not only on the resolution of the image on film, but also on the characteristics of the projector. Within the field of cinema and image science, the resolution

of photographic film, but also (maybe more importantly) it concerned the instrument which redirected the light towards the film: the optical equipment, which was also to be modelled.
The application of the Fourier Transform[128] to the study of optics was another breakthrough introduced to image science in the 1940s. In this perception, the light was considered as a signal thanks to its wave-like performance, which, alongside its particle-like performance, describes how light travels and functions. The conception of light as wave was not new and could be traced back to the 17th century, but by the 1940s, its modelling as a signal would open many doors to the mathematical study of optics. By the 1940s, the Fourier Transform had become very popular, especially in (electronic) signal processing, and this method was integrated largely into the study of television signal (electromagnetic waves). The Fourier Transform transferred a signal's mathematical amplitude-time wave from the time domain into the frequency domain, where the same signal and its operations were defined with relation to their frequencies. But of course, being primarily a mathematical solution, it could also be applied to other types of problems. In 1946, Pierre-Michel Duffieux, a French physicist, published a book where he applied the Fourier Transform to optics. Duffieux's idea was not a direct result of the combination of two preceding research fields of optics and Fourier Transform, but it was developed at a time where the optical characteristics of film machines and Fourier analysis of television signals co-existed in a visible manner. The cultural context of the time, which assimilated film and television as two mediums of recording moving images, might have also favoured this mathematical application. In this way, thanks to the Fourier Transform, the problem of light intensity could be treated as a problem of spatial frequencies for any optical system: whether the optics of cameras, photographic film or even the human eye.
Since the early 1950s, the Fourier methods were regularly applied for determining the resolution of film and television images, as well as cameras, printers, television tubes and other machines.[129] Fourier calculations, however, still remained almost exclusively limited to the technical wing of the film industry: technicians, labs and manufacturers. In film archival milieus, these methods were rarely mentioned as well and image fidelity/quality appreciation

was calculated and discussed for the image on film. Of course, the images on film were mostly projected on a screen for a visual analysis of the quality, but the mathematical modelling was generally done for the image on film, which meant the omission of the effect of projection on resolution.

[128] Invented and developed since the first half of the 19th century, the Fourier Transform considers complex mathematical operations in a parallel domain, where they become easier to calculate.

[129] Schade, 'Image Gradation, Graininess and Sharpness in Television and Motion Picture Systems. Part I: Image Structure and Transfer Characteristics'.
Otto H. Schade, 'A New System of Measuring and Specifying Image Definition', *National Bureau of Standards Circular*, no. 526 (1954): 231–58.

in reproduction remained qualitative. But decades later, in confrontation with digital image technologies, new interest arose for the tools offered by Fourier analysis of images and imaging systems. Fourier methods considered imaging systems as dynamic optical entities whose resulting images were produced by spatial wave-like movements. In the next part of this subchapter, I will go more into technical details of these methods.

In the late 1940s, another tendency in image science appeared which considered image details as information, inspired by the works of Claude Shannon (and others) in communication theory (part of information theory). Shannon's theory concerned primarily the transmission of information, via electrical signals for instance, and discussed how to "transmit" the source information as a signal and how to "receive" it, in a way that no information was lost or distorted.[130] The theory was developed and published almost at the same time as when the concept of cybernetics was coined by Norbert Wiener to represent mathematical theories on control and communication in humans and machines.[131] Both were concerned with information circulating through various channels, and contributed to the formation of a general imaginary which characterised the society of the epoch as an "Information Society".[132] Applying this concept to images would thus quantify the image details as information, enable a more quantitative study of image quality, and favour a reproduction system where information would not get lost:

> "The aspect of information theory that is here important is that it has been found possible to define a mathematical quantity corresponding to amount of information. This quantity agrees with our intuitive ideas in the sense that, whenever the value of the mathematical quantity is changed, it is always possible, despite some paradoxes, to agree that our intuitive measure of information has also changed in the same sense."[133]

As I mentioned above, in archival discourses, the question of "image information" was indeed very recurrent, especially since it could provide an answer to the question of how much loss

[130] Claude Elwood Shannon and Warren Weaver, *The Mathematical Theory of Communication* (Urbana: University of Illinois Press, 1998). Originally published in 1949 as a book, and in 1948 as two articles: Claude Elwood Shannon, 'A Mathematical Theory of Communication', *The Bell System Technical Journal* 27, no. 3 (July 1948): 379–423; Claude Elwood Shannon, 'A Mathematical Theory of Communication', *The Bell System Technical Journal* 27, no. 4 (October 1948): 623–56.

[131] Norbert Wiener, *Cybernetics or Control and Communication in the Animal and the Machine*, 1st ed. (Cambridge, MA: MIT Press, 1948); Norbert Wiener, 'Cybernetics', *Scientific American* 179, no. 5 (November 1948): 14–19.

[132] Richard Gere, *Digital Culture*, Expanded 2nd (London: Reaktion Books, 2002), 51–57.

[133] Peter Fellgett, 'Concerning Photographic Grain, Signal-to-Noise Ratio and Information', *Journal of the Optical Society of America* 43, no. 4 (April 1953): 271–82. See also: P.B. Fellgett and E.H. Linfoot, 'On the Assessment of Optical Images', *Series A. Mathematical and Physical Sciences* 247, no. 931 (17 February 1955): 369–407.

was entailed by an image reproduction process. On the other hand, here, the link to the film's chemical materiality was much less stressed, as was the link to the projected image, viewed and perceived by different observers.

The rich mathematically-diverse history of image science that I have briefly outlined here, demonstrates how images may be studied from different perspectives and how their understanding (and quality appreciation) can be related to that particular perspective. Images, as recorded on a film element, could be chemical materials, photochemical objects, optical systems, or, simply, information. Their comparison could be based on a mathematisation of visual characteristics as observed directly on the film material or while projected; or on a theorisation of their material properties. Going back to the archival re-questioning of the meaning of film, historically and scientifically, no easy answer could be provided from a scientific point of view; and each answer would bring its own ontological consequences.

The Long List of Factors to Determine Image Quality

Throughout the history of image science, several factors have been attached to the concept of image quality. Similarly, in the film industry and archival context different factors have been mentioned and used historically and culturally, which I briefly mentioned in the first part of this chapter. Perhaps the most frequent of those is resolution but others, such as density, definition, sharpness and graininess are also very common.

The early studies of image science, which focused most particularly on the physical and photochemical aspect of the existence of image, explored the link between silver grains (as particles in developed emulsion) or silver-halide grains (in undeveloped emulsion) and the clarity and density of the image: the size, shape and distribution of grains would impact the "photosensitivity", tacitly referring to quality.[134] Furthermore, sensitometry quality assessments based more on the visual aspect of photographic image were also conducted through experimental observations with regards to light exposure. "Resolving power" (or "resolution")[135] was a regular factor in photographic studies, and could be defined generally as the ability of film to represent details. In the photographic context, it was expressed in terms of "lines", according to Kenneth Mees (Kodak, 1909):

[134] For a summary of these early studies, see S.E. Sheppard, A.P.H. Trivelli, and R.P. Loveland, 'Studies in Photographic Sensitivity: VI. The Formation of the Latent Image', *Journal of the Franklin Institute* 200, no. 1 (July 1925): 51–86.
[135] The terms were often used interchangeably.

> "In considering the resolving power of a photographic plate it is, of course, necessary to deal with the linear resolving power, so that we may define the resolving power to be the distance which must separate two lines of light falling upon the plate in order that the developed image may be recognized to be that of two separate lines. This resolving power will then give the distance by which, e.g., the images of two spectral lines must be separated in order that they may be recorded as separate lines, or the images of a double star in order that it may appear double. It is clearly of no use to obtain a higher resolving power in an instrument than the plate used in that instrument will possess."[136]

Resolving power can thus be summarised as the number of (horizontal) lines per mm that a system can resolve: represent, or see. It denotes a pair of lines, one black and one white. As a result, it does not technically depend only on "spectral lines", but also "spectral hues".[137] Simply put, it has two directions: spatial frequency and image density. For the photographic material, the resolving power was studied in relation to the granular materiality of photographic film, which changed the light irradiation and diffraction. Mees concluded:

> "(1) That the resolution of a photographic plate is dependent on the amount of irradiation displayed by that plate.
>
> (2) That irradiation is not directly proportional to the size of grain, but is caused by two different forms of scatter arising from (a) reflection and (b) diffraction."[138]

Beyond the chemical characteristics of the photographic material which, as Mees underlined, affects the material's ability to resolve details (albeit not in a linear way), the resolution of an image also depends upon the resolution of the optical equipment (lenses) which records the light on the film. Therefore, the resolving power of an image recorded on a film is the overall resolution of each of the different parts of an image recording system: the photographic material and the optics (plus the characteristics of the projector for the projected image, which I do not detail here). Up to the 1920s, when talking about the quality of images on film, only the resolution of the photographic material was considered (which depended on its chemical characteristics), but later, with the considerations of light and optics, this view changed. According to Otto H. Schade, who worked in the RCA[139] Laboratories and regularly contributed

---

[136] C.E. Kenneth Mees, 'On the Resolving Power of Photographic Plates', *Proceedings of the Royal Society of London* 83, no. 559 (3 November 1909): 10.

[137] Wallace, 'The Daylight Sensitometry of Photographic Plates, and a Suggestion Standard Dispersion-Piece', 122.

[138] Mees, 'On the Resolving Power of Photographic Plates', 15.

[139] Radio Corporation of America.

to technical film journals such as the *Journal of the SMPE* between the 1950s and 1980s, image quality was controlled by the sampling process:

> "The image quality is controlled basically by the energy levels obtainable in the imaging process. The higher the useful level of energy and the larger the number of samples, the higher can be the image quality obtainable by the process. A given image quality is, therefore, characterized by: (1) the total number of sample aggregates in the image frame; (2) the relative accuracy of sample density and location in the frame with respect to the original; and (3) the size of the sample aggregate with respect to the frame size."[140]

According to Schade, the closer the reproduction to its "original" (whether another image or a real scene recorded by a camera), the better the image. The better or worse image quality is here judged within this particular scientific understanding of sampling, and not as an aesthetical measure. The sampling process depended both upon the chemical characteristics of the film, and the way it was conducted via the optics in use:

> "[An] optical device spreading light samples in two dimensions (over a small area) when point sources of light are imaged, is an 'aperture'. It is well known that the shape and area of the point image made with a pinhole camera are controlled by the size and shape of the pinhole aperture. The point image itself may be identified as the 'sampling aperture' of the imaging device."[141]

Thus, the quality of an image was determined in the process of image recording, where "points of light" would impress "point images". An imaging process inputs varying exposure and outputs varying density. As mentioned above, image science had long lingered on the discontinuous microscopic particles making up the area of an image and the light it received. It had been observed that because of light scattering, the individual grain was not equivalent to the smallest output image area (holding one density), the photoreceptor, or point image, in the words of Schade. According to the scientific vision, the smaller the area of point images, the better the image quality on the film. By calculating the diffraction of light when a point image is exposed to a point light source, it is possible to estimate the unit area. Indeed, this point exposure gives an image density distribution within the area. A point spread function (PSF) determines how well a unit area absorbs light: an ideal PSF would link a point light to a single point on the image (no light would be diffracted and thus no blurring would affect the image). Through the calculation of a PSF, the quality of an imaging system can be determined: how the

[140] Schade, 'Image Gradation, Graininess and Sharpness in Television and Motion Picture Systems. Part I: Image Structure and Transfer Characteristics', 141.
[141] Schade, 140.

system actually performs with regards to how it should ideally perform (ideal as understood in mathematical terms). The PSF depends thus upon the characteristics of a film as well as the exposure light (which are related by the density-exposure curves[142] as sensitometry studies had shown). It is a transform function that relates the source image densities to the reproduced image densities as recorded on film: r(x,y)=PSF(o(x,y)), where o(x,y) is the original image unit density and r(x,y) is the reproduced image unit density.[143]

The Fourier Transform of the PSF is called Optical Transfer Function (OTF): instead of working directly with spatial coordinates and their corresponding image density, the transformed function proposes to work with spatial frequencies and their amplitude (and phase, if necessary). If only the amplitude is considered, the function becomes Modulation Transfer Function (MTF). Spatial frequencies come from the perception that image densities are considered as signals, which, instead of being dependent on time, are dependent on distance. The spatial frequency is the inverse of spatial distances: the higher the spatial frequency, the lower the distance between two resolution line-pairs (one dark and one light) on an image. A spatial frequency of 100 lp/mm, for instance, means that the distance between two line-pairs is 0.01mm; as a result, for a 35mm full frame of 24mm x 36mm, 24/0.01=2400 line-pairs can fit (horizontally), and in total, 2x2400=4800 lines. The MTF curve was widely used and provided by manufactures in the fact sheets of their film stock. An example is shown in Figure 19. The curve means that at high spatial frequencies (closer lines), the film's capacity to record information decreases. According to this graph, a 30% drop is predicted at the spatial frequency of 100, which would reduce the number to 3360 horizontal lines.

The MTF curve, as explained above, describes the potential resolution that a photographic material can provide at a specific light, but the resolution of the actual image formed on it is also dependent on the actual optics of the camera and the printer and the process of development. Thus, the availability of this information for a specific type of film (the number of lines fit in the height of an image), calculated in this way, could not determine the actual resolution of the image recorded on the film. Of course, MTF can be calculated for a specific image on a film as well, according to its visual characteristics: it plots the contrast of the image in function of its spatial frequency. But when the image is already recorded, it is not very easy to access such information without the use of a computer.

[142] In reality these curves show the density of image versus the logarithmic scale of the exposure light (D-logE curves).

[143] For more information, see: Schade, 'A New System of Measuring and Specifying Image Definition'.

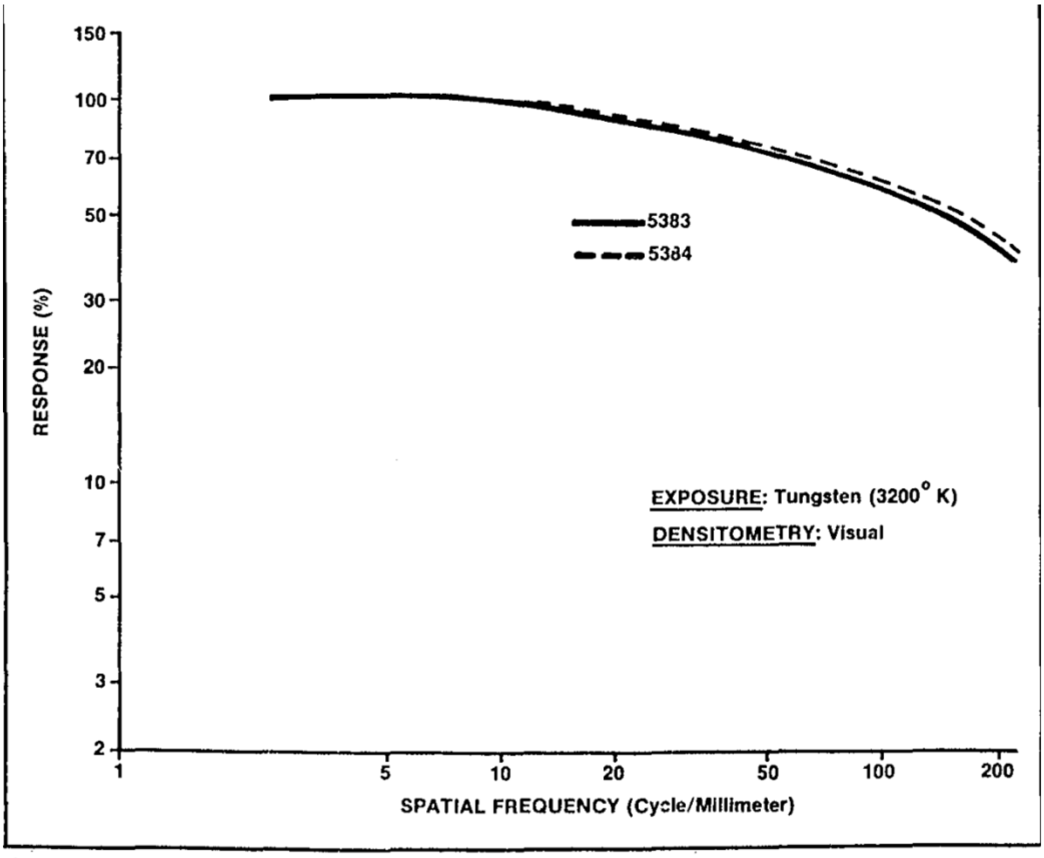


Figure 6. Modulation transfer function (MTF) of Eastman color print films.

Figure 19 the MTF response of Eastman color print 5384, as indicated by Kodak in 1982.[144] As it can be observed, around 100 lp/mm (on the x-axis), the response shows a considerable drop of around 30%.

Moreover, resolution does not depend on the width and height of the image, as it indicates the number of lines per area. It can also be calculated by the number of dots per area. However, when describing digital images (or digital displays), the term resolution has often been applied to the pixel count. It is thus common to hear the terms 2K or 4K resolution regarding digital images. This normative use of the term resolution within industry and archives, as has been repeated in the statements that I have cited in this thesis, does not correspond to the technical meaning of the term. More importantly, it is striking how the perspective changed when talking about the quality of photochemical or digital images: the former is qualified through its resolution, its ability to resolve details per area, while the latter through its pixel count. As a result, when comparing the resolution of photochemical images with the pixel count of digital images, different factors of quality are put on the same line, which is problematic technically. Despite these problems, when archives compared film and digital, they did use MTF as a factor to which an equivalent digital pixel count was associated. This relative adoption of scientific

[144] K. J. Carl et al., 'Eastman Color Print Film 5384', *SMPTE Journal* 91, no. 12 (December 1982): 1161–70.

calculations underlines the multiple ways through which quality was understood and judged within archives. Further down, I will come back to the archival applications of MTF.

Resolution is calculated mostly as a factor that characterises the imaging process, rather than indicating a specific visual detail in an image. But it can also apply to the visual ability of an observer to resolve lines in an image, in which case it includes not only the resolution of the recording system, but also that of HVS. The resolution of an image on film can be calculated through mathematical modelling of the whole system comprised of photographic material, optical systems in use and the HVS. Beyond the biological aspects of HVS, the place of an observer as a person who perceives an image from a psycho-physical aspect needs to be considered as well. The visual quality of an image has been described through different terms within image science, which all carry a certain degree of psycho-physical perception, as Kodak researchers underlined in 1955:

> "Definition in photography […] is the quality aspect of a photograph that is associated with the clarity of detail. This is a subjective concept because it is an impression made on the mind of an observer when he views a photograph. Definition is the composite effect of several subjective factors, such as sharpness, resolving power, graininess, and tone reproduction."[145]

These factors could be modelled and calculated when applied to different types of images, changing the understanding of the word in the process, as I explained with regards to resolution in this part. Similar to resolution, the term definition has also embodied several different understandings historically. While generally it signified the clarity of a photochemically-recorded image on a film, when applied to television images it became associated with the number of horizontal lines which make up a television image. In television image quality assessment, "better definition" would be achieved with "sharp narrow lines", so with a higher number of horizontal scanning lines representing the image.[146] While the number of lines could be quantitively exact, their narrowness was more dependent on the instruments and subsequently, more difficult to be precise. The term was adopted in French to apply to pixel count as well, while in English it persists in some expressions such as High-Definition (HD) for digital images.

---

[145] George C. Higgins and Robert N. Wolfe, 'The Relation of Definition to Sharpness and Resolving Power in a Photographic System', *Journal of the Optical Society of America* 45, no. 2 (February 1955): 121.

[146] Frank Gray, J.W. Horton, and R.C. Mathes, 'The Production and Utilization of Television Signals', *Transactions of the American Institute of Electrical Engineers* 6, no. 4 (June 1927): 918–39.

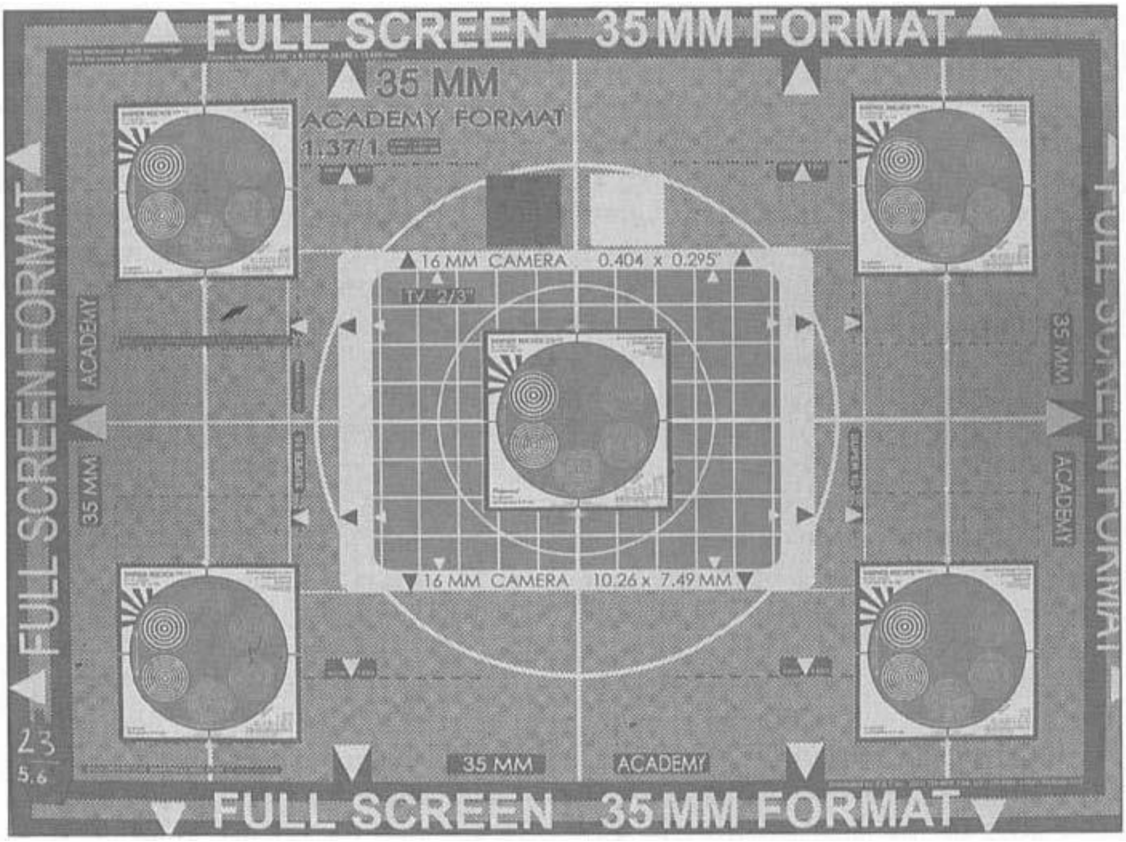


Figure 20 A sharpness Indicator

Another factor, sharpness had been discussed in subjective or physical terms since the 1920s,[147] but in the early 1950s, it was assimilated to a measurable quantity called "acutance" which correlated with "the psychometric evaluation of the sharpness aspect of definition".[148] Acutance is the gradient of density, which means that it is related to the difference between the highest and lowest densities. Sharpness can also be represented by the difference between the edges and the surface they contour.[149] In the film industry, the measure of sharpness was not quantitatively important, but sharpness indicators have been widely in use for image reproduction since the 1960s, as well as in archival practices (Figure 20).[150]

[147] Frank E. Ross, 'Photographic Sharpness and Resolving Power', *The Astrophysical Journal* 52, no. 4 (November 1920): 201–31.
[148] G.C. Higgins and L.A. Jones, 'The Nature and Evaluation of the Sharpness of Photographic Images', *Journal of the SMPTE* 58, no. 4 (April 1952): 277–90.
[149] See for example: C.E. Kenneth Mees, 'The Structure of Photographic Image', *Journal of the Franklin Institute* 191, no. 5 (May 1921): 631–50.
[150] Two indicators were designed during 1960s almost simultaneously, but the first one was used more often. Ivan Putora and Pablo Weinschenk-Tabernero, 'The Sharpness Indicator', *SMPTE Journal* 107, no. 2 (February 1998): 106–12.Originally published in English as: Ivan Putora and Pablo Weinschenk-Tabernero, 'The Sharpness Indicator', *SMPTE Journal* 78, no. 11 (November 1969). This work was based on research that they had conducted since the early 1960s.
Dwin R. Craig, 'Image Sharpness Meter', *Photographic Science and Engineering* 5 (December 1961): 337–42.

If the image is considered as information, other factors may also be added to the ones mentioned which quantify the optical quality, such as “Relative Structural Content” (relation between light intensities – or densities – of the image and its source), “Correlation Quality” (how well the visual pattern of the image and its source correlate) and “Image Fidelity” (how faithful the reproduction is).[151] A “compression” of information needs to be conducted anyhow, related to the characteristics of films, and also the limits of HVS. By considering the image as information, the performance of different technological systems was compared:

> “The photographic material is able to record a much greater information content in a given area than other recording media (such as the magnetic tape) do, [because] its capability in recording fine details of the optical image is better than that of the other media. The maximum information content recorded in a given area of the photographic layer is restricted by the granularity (which is the physical characteristic of the granular pattern in the image), for the granularity veils the low contrast images.”[152]

Thanks to the methods of information theory, noise or loss could be more effectively modelled and calculated. Of course, noise consideration was not unfamiliar to image science before information theory; but the signal-to-noise ratio calculations contributed mathematically to a more quantitative image quality factor in image graininess. I will detail the image graininess in the next part.

All these factors which may help in describing the quality of an image, from a visual or mathematical point of view, as seen by an observer or as produced by the imaging system, have been detailed here as the image science (and within that, the technical wing of the film industry and manufacturers) understood them. As explained, a better technical quality was defined in this context as having better clarity and sharpness. The image science approached the image as it was recorded on a film, and generally, it did not include the effects of projection on diverse image quality factors. Image quality, understood in this way, did not always have the same cultural bearing as when it was discussed within the archival community, although many concepts and methods were borrowed from it.

Grain: A Term with Multiple Definitions

During the early 2000s, the discussions of grain had an exponential growth within the archival community, where it was regularly considered as the photochemical equivalent to pixel. It was

[151] E.H. Linfoot, ‘Transmission Factors and Optical Design’, *Journal of the Optical Society of America* 46, no. 9 (September 1956): 740–52.
[152] Shingo Ooue, ‘VI The Photographic Image’, *Progress in Optics* 7 (1969): 301–2.

the same within the dominant film industry, where film image, thanks to its grain, was considered of higher "resolution" than digital image:

> "The largest piece of film grain is always smaller than the smallest electronic camera pixel. Film's image resolutions are captured with grains far smaller than other resolution limiting factors." [153]

From what I have explained in the previous part, resolution did not depend on grain or pixel directly, although these both affected it. However, as illustrated with this statement by Peter Swinton (Cintel), the structure and resolution of a digital image were thought to be defined by its pixels, while those of a photochemical image were associated with its grains. In this comparison, the image in question is the one recorded on a carrier, but the specific looks attributed to grain and pixel were also visible when images were projected (albeit a little differently). But can grains and pixels be compared in this way? How does grain relate to image quality?

> "The term photographic grain has been used in the jargon of the trade with three separate meanings: it applies sometimes to the grainy pattern visible in a highly enlarged photograph, sometimes to a particle of the developed silver in the image, and other times to the undeveloped silver halide particles of the original film." [154]

As evident in this statement by J. F. Hamilton (Kodak Research Laboratories) in 1972, confusion has reigned around the term grain for a long time. The scientific research from the late 19th century was very interested in grain as the forming matter of film emulsion and experiments demonstrated that the size, shape and distribution of grains in the emulsion did impact image quality as recorded on film, although they were not the image unit. Out of the three possibilities of grain evoked by Hamilton, two (silver grain and silver-halide grain) exist materially. Indeed, if the silver-halide grains, that are scattered in the undeveloped emulsion, receive enough light (passing a certain threshold), they will turn into silver grains and are blackened in development. The silver-halide grain functions thus as a simple on/off photoreceptor, which can be developed (subsequently contributing to the formation of the image) or not. During the 2000s, when different media were thought to be all converging, the silver-halide grains, as on/off photoreceptors, were compared with digital bits, which can be 0 or 1.[155] When the film is developed, a material silver grain structure is formed with variable sizes, shapes and random spatial distribution. The material existence of undeveloped or

[153] Peter Swinton, 'The Film Look. Can It Really Be Defined?', *Image Technology* 87, no. 1 (January 2005): 17–22.
[154] John F. Hamilton, 'The Photographic Grain', *Applied Optics* 11, no. 1 (January 1972): 13–21.
[155] Peter Swinton, 'A Crazy View of Film?', *Image Technology* 85, no. 3 (May 2003): 18–19.

developed grains was microphotographed since the early 20th century, and their sizes were scientifically estimated (for example, between 0.1 to 10 μm in diameter for silver-halide grains as estimated by Kodak Labs in 1921).[156]

On the other hand, the visual impression of "graininess", although related to the material grain structure of the film, is not equivalent to it:

> "The lack of homogeneity [in the visual aspect of an image] is due not to the ultimate grains themselves […] there are three phases in the non-homogeneity of a photographic deposit: (a) graininess due to the existence of the individual particles of silver, (b) graininess due to clumping of these particles, and (c) graininess due to the agglomeration of the clumps."[157]

These three reasons create a visual/perceptual pattern of graininess, which becomes most visible to the unaided eye when the moving image is projected. Graininess does not exist materially, but it is perceived by an observer. In the material grain structure, grains (or their groupings) of variable sizes are distributed randomly in the emulsion. The visual aspect of the grain is in reality due to the "statistical fluctuations in the spatial distribution of the developed grains."[158] This means that the image units (photoreceptors) that are constituted of different numbers of different-size grains (or an agglomeration of grains and clumps), behave slightly differently when they receive the same light exposure. There are thus small density fluctuations between neighbouring image units (spatially and temporally) which create an impression of graininess in the visual aspect of the image. These fluctuations are situated on the Z axis (density), not the XY (spatial plate). Moreover, the visual graininess is also related to the chemical or thermal fog, happening in development, which leaves a part of grains undeveloped: these undeveloped grains have some residual density which increases the fluctuations. The grainy appearance is therefore not only related to emulsion's initial silver-halide grain composition but also to the density of light photons received as well as the chemical development (and even the chemicals used for that). The relation between the silver (or silver-halide) grains with the visual grainy pattern of an image materialises the relation between the image as content and its carrier. They are physically related; the second's material characteristics create the visual perception of the first. This scientific basis goes in line with the definition of film as suggested within the archival community. But graininess, as visible on an image, is not its structural element. In order to avoid confusion, the terms related to each of these concepts have been defined as follows:

---

[156] Mees, 'The Structure of Photographic Image'.

[157] Mees, 645.

[158] Hamilton, 'The Photographic Grain', 14.

"The physical characteristics of the granular pattern are called the granularity and its effect that causes the visual impression of roughness is called graininess."[159]

As explained above, the visual impression is seen mostly in projected moving images, while the granularity is related to the material aspect of the film. Granularity, which creates the aforementioned density fluctuations, has in fact been considered as noise in many scientific studies, and mathematically modelled as such. For instance, the Selwyn coefficient (proposed in 1935) modelled it statistically based on the "variance of a set of measurements of the density";[160] or, it can be considered, similar to electrical fluctuations, as a noise signal (which may have different shapes: random, gaussian, etc.). Similarly, in mainstream cinema, many manufacturers, technicians, operators and even archivists had a tendency towards considering graininess as a visual problem and finer-grain material was dominantly preferred, although others could indeed appreciate graininess as an aesthetic factor. The fine-grain material presents not only more details, but also less density fluctuations, less graininess. In archival reproductions as well, as said in Chapter One, finer-grain material was used so that the graininess would be less visible. Moreover, some scanners and telecines had integrated noise-reduction possibilities. When digital manipulation methods were being adopted and adapted, de-graining was also discussed, developed and implemented in dedicated software.[161]

In confrontation with digital imaging, which did not create any graininess impression, the latter came to embody a more privileged place in archival and industrial discourses, as it was considered as a distinctive visual sign of the film image. By the mid-2000s, archival discourses pushed for a preservation of the original graininess.[162] In this case, as scholar Diego Cavallotti has pointed out, the graininess of the image acquires a sort of an "aura" and "symbolic

[159] Ooue, 'VI The Photographic Image', 309.

[160] Robert Clark Jones, 'New Method of Describing and Measuring the Granularity of Photographic Materials', *Journal of the Optical Society of America* 45, no. 10 (1 October 1955): 802.

[161] As an example of grain reduction systems which identified film graininess as a "disturbance pattern", see: I. McLean and S. Witt, 'Telecine Noise Reduction' (IEE Seminar on Digital Restoration of Film and Video Archives, London, 2001), 2 1-2 6. This seminar, as explained in Chapter One, regrouped archivists and technologists together, notably Sony researchers McLean and Witt.

[162] Algorithms exist that have been implemented in film restoration software that allow the elimination or retouching of grain. In DIAMANT, this function is called "de-grain". It is however strictly avoided by a number of archives to apply it in restorations. "Re-grain" is also another possible function to retouch grain (in restoration or post-production), in order to achieve a specific look. For technical information about these algorithms, see: Peter Schallauer and Roland Mörzinger, 'Rapid and Reliable Detection of Film Grain Noise', in *Proceedings of ICIP International Conference on Image Processing* (Atlanta, USA, 2006); Peter Schallauer and Roland Mörzinger, 'Film Grain Synthesis and Its Application to Re-Graining', in *Proceedings of SPIE 6059. Image Quality and System Performance III*, vol. 6059 (San Jose, USA: SPIE, 2006).

meaning".[163] Therefore, it is not noise, contrary to how it has sometimes been modelled within image science, but it is a part of the image.[164] In 2003, Thomas Christensen determined graininess as an intrinsic part of cinema, whose perception would undergo a change:

> "As a digital process replaces the analogue nature of film, the well-known qualities and deficiencies of cinema [such as graininess] will be replaced by something different, which will be the cinema of the future. It will probably be possible to simulate old films in the new formats; however, the processes will be much less transparent. It is possible to degrain old films, and new films may very well no longer look 'wrong' without grain as spectators get used to the grain-less look that digital is capable of. The grain 'quality' of old analogue films might become an unwanted artefact, which will be removed when restoring old films."[165]

The association of the film look with graininess is an important point that comes back regularly in archival discourses, where its digital retouch has often been discouraged (although it may be conducted in some restorations). However, the act of digitisation (because of the scanner light and optics as well as the pixel structure of the sensor) and that of digital grading (which intervenes precisely on image densities) bring modifications to graininess.

Neither graininess, as a visual impression visible in projection, nor the physical grain could be considered as equivalent to a digital pixel; as none of these is a structural element of images (whose quality depends upon many factors as explained above). None of them, whether grain or pixel, is equivalent to resolution, definition or sharpness either, although they do affect these factors. But as Christensen points out, graininess and pixel structure both contribute to a specific image look within different technological frameworks. The graininess and pixel structure were described by Peter Swinton (Cintel) in 2005:

> "While film's images comprise granular clouds of dye randomly scattered and randomly sized, electronic images are acquired onto regular fixed size and fixed position sensors. Additionally, these sensors tend to have a highly patterned structure and any noise is added onto this structured signal, rather than being part of it. It has been said that film

[163] Diego Cavallotti, 'From Grain to Pixel? Notes on the Technical Dialectics in the Small Gauge Film Archive', *NECSUS. European Journal of Media Studies*, July 2018, https://necsus-ejms.org/from-grain-to-pixel-notes-on-the-technical-dialectics-in-the-small-gauge-film-archive/, accessed 31 January 2021. See also: Eva Hielscher, 'Amateur Film, Benjamin's Aura and the Archive or: The Archive as Amateur Film's Age of Technological Reproducibility', in *The Archive/L'Archivio. Filmforum 2011. Atti Del 18° Convegno Internazionale Di Studi Sul Cinema.*, ed. Alessandro Bordina, Sonia Campanini, and Andrea Mariani (Udine: Forum Edizioni, 2012), 149–61.
[164] Swinton, 'The Film Look. Can It Really Be Defined?'
[165] Thomas Christensen, 'The Historical Film as a Title or as a Collection of Physical Elements', *Journal of Film Preservation*, no. 66 (October 2003): 24.

uses a new sensor every frame. This, combined with grain's randomness within each frame, really does contribute to the film look."[166]

Swinton's further explanation of how graininess is typical of film look underlines the historical and cultural construction of HVS, which, according to him, had been formed by viewing photochemical film to ignore fine random granularity and maybe see even more sharpness.[167] Although it would be difficult (and not envisaged by this thesis) to prove the veracity of this claim, it could be intuitively and discursively attested that, during the 2000s, the grain was considered as a "necessary film artefact intrinsic to its film image", contributing to its look.[168] This fact was noted most often in comparison with digital image technologies (or video image technologies with their specific line-based look).

It is important to underline that the so-called film look was not a unique characteristic shared between all film stock and film technologies, but it was variable according to how the film was manufactured and how the image was registered and developed (and also, how it was projected). Thus, the comparison between grain and pixel could be even more complicated. For a long time from the 1980s, the new photochemical film stock technologies by manufacturers such as Kodak and Fuji had been going towards a less random, more organised, and as always, a finer grain structure. In 1991, Kodak received an Oscar from the Academy of Motion Picture Arts and Sciences (AMPAS) for having developed a new silver-halide grain technology:

> "The faster the film, the larger the grain—which gives the so-called 'grainy' look. Kodak scientists have discovered that if the grain shape is changed to a flatter shape, the crystals intercept more light but the total amount of silver does not increase, allowing for an increase in speed with less noticeable grain. The new emulsions are called T-GRAIN Emulsions because of the flat, tabular shape of the grains."[169]

The T-Grain emulsion was first presented in the mid-1980s by Kodak, although it had already been in development for a number of years.[170] As can be observed in Figure 21, the tabular grains were larger in spatial size, but with less depth. Thanks to their larger size, the grains would receive photons more easily, thus the T-Grain emulsions were more sensitive. Moreover, they were also (mostly) mono-size, contrary to the traditional variable-size cubical silver-halide

[166] Swinton, 'The Film Look. Can It Really Be Defined?'
[167] Peter Swinton, 'The Film Look. Can It Really Be Defined? Part II', *Image Technology* 87, no. 2 (April 2005): 9–12.
[168] FIRST, 'European Film Heritage on the Threshold of the Digital Era. Full Report (Part One).', 25–26.
[169] Kodak, 'Eastman Professional Motion Picture Films: H-1' (Eastman Kodak, 2000), 23–27, https://web.archive.org/web/20030709112201/http://kodak.com/US/en/motion/support/h1/index.shtml..
[170] See: J.T. Kofron and R.E. Booms, 'KODAK T-Grain Emulsions in Color Films', *Journal of Society of Photographic Science and Technology Japan* 49, no. 6 (1986): 499–504.

grains. The uniformity offered by mono-size grains reduced the graininess impression, and it was implemented in films by other manufacturers as well (such as Ilford, for still photos). According to Kodak, T-Grain emulsion offered a sharper, less grainy image, despite the fact that one would logically think that the larger grain size would increase graininess. This shows how the relation of material grain size with image graininess cannot be defined in a linear manner.

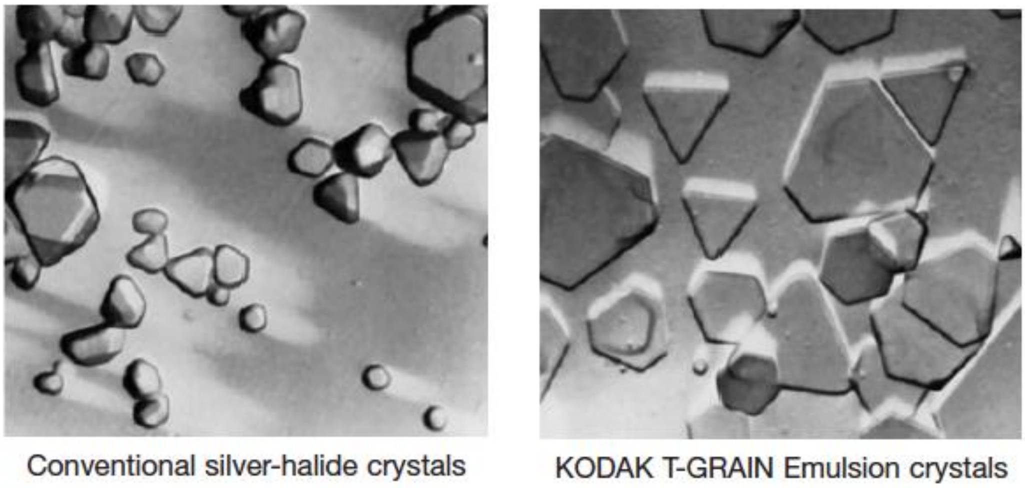


Figure 21 The conventional grain technology, as seen above, presents 3D grains of different shapes and sizes. The Kodak T-Grain emulsion has grains which are flatter and less diverse in their shape and sizes. The photos are taken from a Kodak technical publication.[171]

While the T-Grain technology existed from the 1980s, it was not always implemented by Kodak in all their film stocks. Most films had a mixed conventional and T-Grain structure. There were three layers with three different grain sizes: the smallest grains capturing the highlights, middle-size grains for capturing mid-tones and biggest grains for shadows.[172] In 2006, Kodak introduced "Kodak Vision2 500T/5218 color negative film", with a new advanced version of T-Grain which improved resolution and reduced the visual graininess, offering a film stock for the "digital future", while "keeping in mind that the classic 'look' offered by film system is a standard that most digital systems are currently trying to emulate".[173] Thus, during the 2000s, film technologies developed by Kodak maintained complex relationships with digital technologies: grains were becoming more organised and graininess less visible, while the film look was still to be preserved.

[171] Kodak, 'Eastman Professional Motion Picture Films: H-1'.
[172] Tony Harcourt, 'Exposure Levels and Perception of Grain', *Image Technology* 81, no. 10 (January 1999): 19–20.
[173] David Long, Mike Ryan, and Roger Morton, 'A New Kodak Color Negative Film for the Digital Future', *Image Technology* 88, no. 3 (May 2006): 16–23.

A few years before 5218, in 2001, Fuji had also presented a new negative film stock, Fujicolor F-400, using notably two proprietary technologies: the "Super Uniform Fine Grain (SUFG) technology, which ensures a uniform and fine grain" as well as "DIR technology, which enhances edge-effect for improved sharpness". [174] It was already underlined that, thanks to its new technologies, the film stock would have "excellent telecine characteristics".[175] Then, another Fuji grain technology, called "super nano-structured sigma grain" was used, coupled with DIR technology, to produce ETERNA 500 in 2005, promoted as "Technology gives quality";[176] quality being defined as the overall clarity in an image in this context. It controlled the "microstructure of the silver-halide grain down to nanoscale" and thus made grains smaller, flat and in a hexagonal shape, as well as more sensitive on their surface (Figure 22).

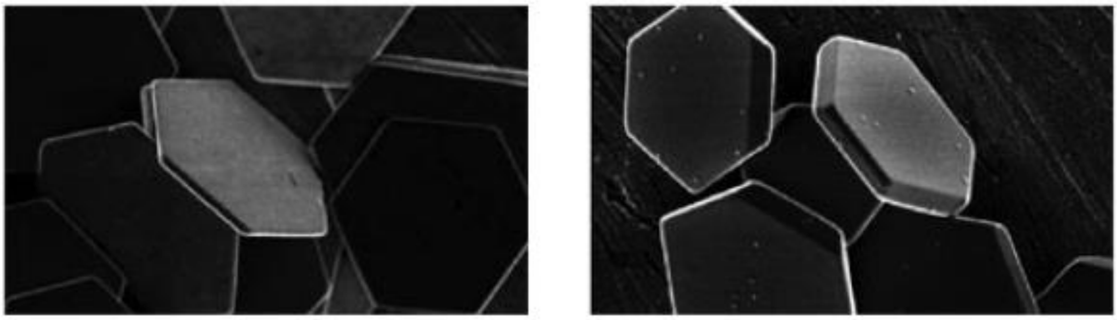


Figure 22 Fuji's grain technology.[177]

In this way, photons were more efficiently concentrated on the grains to form the latent image. ETERNA 500 was also supposed to perform well for digital intermediate. The adaptation to the "digital future" went further in Fuji by the production of ETERNA-RDS, which was specifically designed for archival digital separations. All these film technologies used different grain structures, and offered thus different graininess and film looks. They seemed to move in the direction of digital image technologies by making more uniform grains, but also at the same time, keeping the film look, whatever that could have been.

Towards an Inclusive Understanding of Image Quality; from Grain to Pixel

As explained above, the technical comparison between photochemically and digitally-recorded images did not yield conclusive results and could not scientifically establish the superiority of one to another. Film and digital image technologies seemed to move towards a common ground,

---

[174] Hikari Mirakami, 'Fujicolor F-400', *Image Technology* 83, no. 4 (May 2001): 21–24.
[175] Mirakami.
[176] Jim Slater, 'Something Special from Fuji', *Image Technology* 87, no. 3 (May 2005): 30–32.
[177] https://www.fujifilm.com/products/motion_picture/lineup/eterna_rds/, accessed 19 January 2021.

where film image was to look more digital, while digital image was to look more like film. Image technologies (whether carriers or optical equipment) created different images, and the analogies between different characteristics of photochemical and digital images could not be technically more than educated-guess estimations. Moreover, the comparison remained highly subjective according to different criteria: modelling estimations, viewing conditions, cultural uses, aesthetic decisions, specific sought-after visual characteristics, economic availabilities, etc. That does not, of course, dismiss the efforts to search an estimated correspondence between image qualities, but as I have argued, if these differences are kept in mind, the possibility of a universal solution is ruled out.

When Otto Schade started to present his research on film image quality in the beginning of the 1950s, he underlined the importance of mathematical calculations that would allow for better image reproductions according to him. In this view, "the 'perfect' picture should, in a practical sense, look like a piece of the real world to the unaided eye".[178] Such understanding is one way of perceiving an imaging process, where the recorded image needs to present less and less deviation compared to its source. It is but one way of approaching the complex question of quality and it does not take the aesthetic aspect into consideration, but it has been the dominant vision within the scientific community (also including the technical wing of the film industry). Indeed, a less grainy, sharper image had long been promoted as good quality by manufacturers, and many new technologies (whether digital or photochemical) tried to achieve it. These mainstream discourses were not necessarily endorsed by all film professionals and many alternative practices (such as small-gauge filmmaking or experimental videomaking) continued to exist which defied this understanding.

In 1987, Schade himself conceded that the subjective aspect of image technologies was too important: "nevertheless, viewing conditions remain important parameters. and a picture is far more instructive than a set of numbers or functions describing the image".[179] What Schade remarked was how (subjective) perception remained a crucial factor in judging technical image quality; rather than only mathematical modelling. The viewing conditions, as he underlined, concerned the technical circumstances in which the comparison was conducted, but it should be expanded to also include the observer, their subjective judgement, their cultural surroundings, their aesthetic sensitivity in how they view and perceive images. According to scholars Francesco Casetti and Antonio Somaini, "the question, therefore, becomes that of

---

[178] Otto H. Schade, 'Image Quality. A Comparison of Photographic and Television Systems', *Journal of the SMPTE* 96, no. 6 (June 1987): 571.

[179] Schade, 'Image Quality. A Comparison of Photographic and Television Systems'.

determining where lies such authority, and who has the power to decide what is acceptable and what is unacceptable, what needs to be pixelated and what does not".[180] Therefore, whether an image is of better or worse quality goes far beyond the technical question (which, as I have demonstrated, was not simple either), and encompasses a whole cultural and aesthetic dimension as well.

The technical understanding of image quality might sometimes cross paths with its understanding within the archival community: the discussion of "better image" that I presented in Chapter One is one example of that, and the archival applications of technical concepts, as I will detail in the next part, is another example. But this proximity is definitely not always the case. Indeed, the diversion between the technical and archival visions increased during the 2000s, as the understanding of film itself within the film archival community became more complex, and especially more related to its museological aspects. The discourses on the "original", which were focused on the film's content before, were extended to the image look as well. As I will detail later, the graininess (of old films), with its noise-like random structure, became representative of the photochemical technologies that had created it, and thus needed to be preserved as an original characteristic. Too much sharpness was also criticised in archival discourses, as it might reveal details in a film image which were not visible in the contemporary prints. The quality factors, as defined by image science, might have been useful in some cases within the archival community (or the film industry), but they could not determine all cultural or aesthetic aspects of quality.

Based on what I have detailed in this subchapter, I claim that the quality of digital and photochemical images cannot be scientifically compared in a conclusive manner, and the comparison might give different results under different circumstances and by choosing different factors. Considering the uncertainty of the grain vs. pixel debate, the film vs. digital view also needs to come further under scrutiny. In the meantime, the archives did try to find their way through the scientific comparisons of image quality, and through that, define better the film image.

[180] Casetti and Somaini, 'Resolution: Digital Materialities, Thresholds of Visibility'.

2.1.2 Controlling Image Quality in Film Archival Practices

While technical image quality was quantitatively discussed by film manufacturers,[181] it had been mostly left to subjective, visual judgements within the film archival community. In 2000, Paul Read and Mark-Paul Meyer picked up the same concept of image quality as defined within the scientific discourses and the technical wing of the film industry, while keeping in mind that the new prints needed to look like the old prints. At the time, this constraint concerned mostly the reproduction of contrast and tonal range, rather than the photographic characteristics of sharpness and graininess. To them, the “photographic quality” needed to be controlled “first to ensure that the product is of the highest quality, and secondly to ensure that the quality is maintained consistently”.[182] The “highest quality” tacitly indicated that the reproduction needed to have low graininess and high sharpness as possible (regardless of the characteristics of the original prints). Read and Meyer identified “statistical quality control” (provided by sensitometry) as a means of “monitoring” a system that would enable decision-making and actual control of photographic image quality. They underlined that within the industry, not many tools were provided by manufacturers, and photographic quality control remained empirical and visual in most film labs and by archivists. According to Read and Meyer, the same sensitometry basics developed for film capture could be applied to film reproduction as well:

> “Quality control in the printing and processing of any photographic materials requires similar objectives to those used in the original manufacture of the products. Among these are achievement of correct speed, colour balance, contrast, freedom from physical defects etc.”[183]

Read and Meyer presented a technical overview of film measurements provided by sensitometry, such as density and exposure (as well as their characteristic curves as explained in the previous part), which would help control better the image brightness and contrast range as well as the degree of light scatter in film printer’s optical system. Beyond these technical details, they also provided practical information on how to adjust machines and processes in order to obtain desired results.

---

[181] Kodak, which had been provided workbooks on sensitometry since 1981, published a revised edition in 2006 for a wider public: Kodak, *Kodak Basic Photographic Sensitometry Workbook*, H.-740, 2006, https://www.kodak.com/content/products-brochures/Film/Basic-Photographic-Sensitometry-Workbook.pdf.
[182] Read and Meyer, *Restoration of Motion Picture Film*, 106.
[183] Read and Meyer, 107. For more information, see Read and Meyer, 105–25..

They also tackled the question of resolution, albeit only in comparison with newer technologies (video and digital image), where resolution referred to the pixel count necessary to reproduce images on different film stock. The comparison was presented as "a series of guesses arrived at by discussion with experienced technicians (who probably will disown their estimates!) at the sort of resolution needed to store all the data on various film materials or systems". According to them, "only time will tell if these are relevant – no easy method exists for deriving the resolution needed from an archival film frame".[184] There was therefore a tendency to have a similar feature which could be compared with the pixel count of digital images. As also mentioned before, this correspondence between film and digital was a recurrent subject within archival discourses around the turn of the century. While presenting the TC report at the FIAF Congress in London in 2000, Michael Friend expanded the written project of "research into digital technologies" by including also a proposal to launch a scientific research on the analogies between film and digital images:

> "There is a need for commissioning a research institute to come up with a reliable way to determine the significant characteristics of a motion picture image. On the basis of that kind of analysis, new devices should be developed to extract that information and render it back to film […] without forfeiting its quality."[185]

Michael Friend's idea was thus to develop a methodology to determine the resolution of film image so that the digital intermediate procedure of photochemical image would reproduce it without introducing quality loss. This idea was echoed by Alfonso Del Amo, who proposed to establish the technical characteristics of film images in order to enable better digital reproductions.[186] Despite the fact that several methodologies for image quality (in all its diversity) had been developed in image science, no useful technological solution had been implemented for everyday use in film archives. Up until then, the photochemical reproduction in archival practices was mostly quality-controlled visually in labs, where the use of a sharpness indicator was common practice. But the question of quality correlation between source and destination films was not addressed per se, and it was considered normal to duplicate older films on newer, "better-quality" material; rarely doubts were expressed about it.

A year later, in 2001, FIAF TC launched a project to prepare a "FIAF test film", which was presented at the 2003 FIAF Congress in Stockholm. The necessity of this "objective assessment tool" was announced in conjunction with digital technologies, although it was certainly to be

[184] Read and Meyer, *Restoration of Motion Picture Film*, 221.
[185] Friend's speech has been paraphrased in *FIAF 2000 London Congress Minutes* (Brussels: FIAF, 2000), 15.
[186] See Chapter One, 4.2.

used for photochemical duplication as well. The test film was supposed to offer the archives a tool for "checking and evaluating image quality" especially with regards to "micro image properties, mainly resolution", because "the [capture] of the finest detail is sometimes of utmost importance". The following factors were identified as having an impact on the quality:

- Related to reproduction equipment: vertical and horizontal resolution of the optical systems (in lp/mm), optical flare (undesirable light scattering), steadiness of the equipment, spectral distribution (quality of exposure light).
- Related to film: "spatial resolution" (a "micro-image" characteristic, the potential resolution of a film stock), emulsion contrast (related to densities), flare and halation, film physical properties.[187]

Although these factors do not necessarily coincide with terms used in image science (which already had different definitions), they do represent some of the same concepts. They were described in the FIAF presentation in order to be understood in the same way within the community. The test film was elaborated to fulfil the requirements with regards to these factors, and it provided a reference of how the reproduction should be, although it did not explicitly quantify the measures, nor did it make a direct comparison with digital pixel count.

During the 2000s, more technical studies of correspondence between film and electronic images appeared, which considered the image as information, and focused more specifically on the characteristics of the film stock. In the EBU Tech3289 published in 2001, the "information content of film images" were presented from a study around 10 years earlier by MTF measurements. The Super 35mm (full aperture) negative, having potentially the highest image information, was estimated to need a pixel count of 3.24Kx2.43K in order to be reproduced digitally (Figure 23).[188] It was thus proposed that 4Kx3K was "sufficient to reproduce current film stocks".[189] This study did not include the characteristics of optical systems and the chemical processes in its calculations; considering tacitly that the resolution of the image was determined only by the resolution of the film stock, which is not necessarily the case. For instance, a lens with a resolving power lower than that of the film stock produces images with a resolution lower than the potential resolution offered by the stock.

---

[187] Joao S. de Oliveira, 'Technical Commission 2001-2003', FIAF 2003 Stockholm/Helsinki Congress Report (Brussels: FIAF, May 2003), Appendix 2.1.1.

[188] 'Tech 3289. Preservation and Reuse of Film Material for Television' (European Broadcasting Union (EBU), May 2001), 58.

[189] 'Tech 3289. Preservation and Reuse of Film Material for Television', 59.

Film format	Image area e= exposed p= projectable		Aspect ratio 1:	See note no.	Pixels per frame (N)		Pixels per frame (N/Pr or N/IP/IN/Pr)	
		(mm x mm)			(k x k pixels)	(Mpxl)	(k x k pixels)	(Mpxl)
16mm formats								
Std. 16mm	e:	10.05x7.42	1.35	1	1.31k x 0.96k	1.26		
	p:	9.65x7.26	1.33	2			1.06k x 0.8k	0.85
Super-16mm	e:	12.35x7.42	1.66	1	1.6k x 0.97k	1.55		
	p:	12.20x7.35	1.66	2			1.34k x 0.8k	1.09
35mm formats								
Academy	e:	22.00x16.00	1.37	1	2.86k x 2.08k	5.95		
	p:	20.95x15.29	1.37	2			2.3k x 1.68k	3.87
	p:	20.95x12.62	1.66	3			2.1k x 1.26k	2.64
	p:	20.95x11.78	1.78	2			2.3k x 1.3k	2.99
	p:	20.95x11.33	1.85	3			2.1k x 1.13k	2.37
Cinemascope	p:	20.95x17.53	2.39	3			2.1k x 1.75k	3.67
Super-35mm (Full aperture)	e:	24.92x18.67	1.33	1	3.24k x 2.43k	7.86		
	p:	24.00x18.00	1.33	2			2.64kx1.98k	5.23

Figure 23 Table presented in the EBU Tech 3289 report (2001), from tests conducted in the early 1990s.

Around the same time, a scientific committee of ITU (International Telecommunication Union) also conducted a study on film resolution in view of the upcoming digital projection technologies, which consisted of two series of tests: first by calculating MTF (Figure 24), second by subjective observation. This study compared the image resolutions in projection, contrary to many other tests and comparisons being done at the time that focused on the recorded image. The results determined that a 35mm negative could resolve around 2100 lines per height of the image;[190] so if every line were represented with a line of pixels (and the pixels were square-shaped), the pixel count needed to reproduce it would be around 2.8Kx2.1K for a 35mm full frame. This measure includes the estimation that a negative does not reach its nominal capacity as that proposed by EBU, and loses 10% when exposed and processed. In this case, the study did model the chemical processes, but it still neglected the effect of optical systems on resolution. Of course, that complicates highly any study, as instead of focusing on film stock, the resolution of each film image needs to be calculated separately considering its stock and its production methods (cameras, printers, developers, etc). Many pieces of this type of information are missing for most old films.

[190] Vittorio Baroncini et al., 'Résolution du film 35mm en projection cinématographique', [Abbreviated French version from original: ITU-R 6.149, 35mm Cinema Resolution], 20 September 2001.

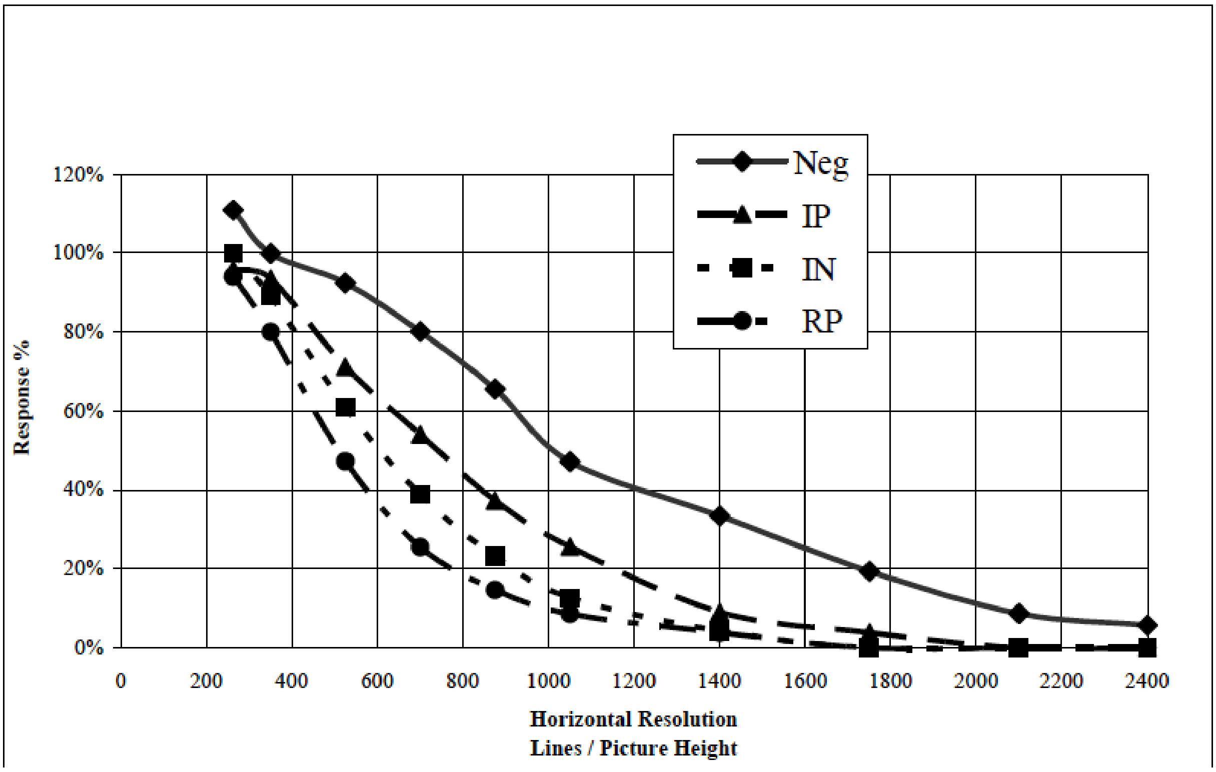


Figure 24 The comparison of MTF response between different elements: negative, duplicate positive, duplicate negative and release print (all 35mm). This result is from the ITU study in 2001.

These estimations found a way to correspond the resolution of film material (regardless of the actual recorded image resolution) with the pixel count of a digital sensor or image, so that it could be reproduced. Despite their inevitable simplifications, both of the aforementioned studies were used and cited by the film archival community. Referring to the results of Tech3289, the FIRST report regretted that the MTF curves did not exist for most old film stock, while underlining that resolution estimation "is a pragmatic one and could not be easily pre-determined".[191] It did not go further in calculating MTF for different types of films (nor equipment such as scanners' cameras). In any case, as stated before, these methods could not calculate the amount of information actually recorded on a film. This was evoked not only by the FIRST reports, but also by film restoration experiments:

> "Imaging specialists have many tools to examine the performance of lenses, film emulsions, cameras, etc., and to predict the cascaded performance of imaging systems. However, these techniques, useful as they are in predicting final image content before the fact, tell us nothing about the information content of the existing image."[192]

---

[191] FIRST, 'European Film Heritage on the Threshold of the Digital Era. Full Report (Part One).', 36–40.

[192] William Glen, John Galt, and James Pearman, 'How Many Pixels in Lawrence of Arabia?' (JTS 2004: Preserving the Audiovisual Heritage – Transition and Access, Toronto, June 2004), https://web.archive.org/web/20070817110721/http://www.jts2004.org/english/proceedings/Galt.html, accessed 16 September 2019.

The scientific methods of image quality were indeed applied for the restoration of *Lawrence of Arabia* (David Lean, United Kingdom, 1962), as presented at JTS 2004. The MTF calculations were conducted to determine the optical resolutions of the material and equipment used. The lack of insight on actual image information on the negative given by MTF was compensated by a study of granularity and Signal-to-Noise (SNR) ratio: for that, the spatial frequencies of noise and image were considered together and "original negative was analysed to see at what resolution the image information became buried in the film grain noise".[193] It was finally decided to scan the 65mm negative of *Lawrence of Arabia* in 6K (horizontal number of pixels) as an uncompressed image, which, despite the calculations, represented a degree of estimation. The technical discussions of image quality also resumed at the JTS 2007, where the idea persisted that a certain pixel count could represent all information of the photochemical source image, but the desired pixel count was perceived differently by experts. Presenting the EDCINE project, Nicola Mazzanti and Paul Read underlined that "historical accuracy and authenticity" in transition from photochemical image to digital image could be ensured by a "sufficient resolution" (depending on the film type) in reproduction.[194] As I have argued, the problem was precisely how to determine the "sufficiency", as a specific film stock could record very different images in terms of sharpness, graininess and resolution according to how they were recorded. These diverse aspects of resolution were hardly included in the search for the right estimations within the archival community (and the film industry).

Another solution was regularly applied within the community which went beyond immediate approximations between film and digital images, by opting for the highest pixel count, so that it would not act as a limiting factor of the overall resolution in reproduction. This method did not look for an exact estimation between film and digital resolution; rather to reproduce the image resolution as was. This view was presented Daniel DeVincent (Cineric laboratory) who explained the advantages of restoring films in the "highest resolution" possible (and sustainable), which was estimated by a 4K pixel count. According to him, a 4K digital image would "maintain as much image sharpness as possible" and reduce "aliasing". And this would apply to any film type of any gauge and any stock:

> "Do older titles have the resolution to justify the extra cost and time? There's no question as to whether it is better to scan at the highest sampling rate. In almost all cases

[193] Glen, Galt, and Pearman.

[194] Nicola Mazzanti and Paul Read, 'Film Archives: Needs and Requirements in the D-Cinema Age' (JTS 2007: Audiovisual Heritage and the Digital Universe, Toronto, 28 June 2007).

we have found that 4k sampling has an advantage over 2k. Even when we did a comparison on new super 16mm negative last year, we found better sharpness at 4k."[195]

The quest for the right pixel count was countered integrally by John Galt (Panavision) at the JTS 2007, who presented there the 24p camera Genesis with its Super35mm sensor and 35mm film lens. According to him, a simple correspondence between film resolution and digital pixel count would not suffice in order to ensure quality, as it omitted the influence of other technological parts (most notably lenses).[196] Speaking at the Reel Thing Conference in 2009, Galt detailed his view further. According to him, beyond the fact that film resolution could only be estimated, the pixel count did not necessarily quantify digital image resolution either. But the system needed to be analysed "as a whole", and digital resolution also depended on the optical characteristics of lenses (which could not be scientifically calculated in pixels) just as did photochemical resolution.[197] This view corresponds to the technical understandings of the terms as I have detailed before. According to Galt:

> "Another problem with a message built on 'marketing pixels' is that it confuses pixels and resolution. They don't have anything to do with each other. What defines the resolution, quite frankly, is the optics more than the sensor. […] The numbers don't mean anything in the context of 100 years of development of film and motion picture technology, optical technology and laboratory practice and cinematographers did wonderful work without understanding anything about the chemistry or photographic emulsion technology."[198]

With this observation, Galt shifted the discourses towards a qualitative appreciation of film and digital image technologies and rightly discarded the possibility of quantitative film or digital correspondence, which, according to him, was not significant enough (just as Otto Schade had conceded in 1987). Indeed, the estimated numbers remained too approximative as they could not include all the factors of the actual quality of a recorded image, unless calculated for every component of the whole system (by considering the film stock, the optics, etc). Pixel count was not an all-inclusive magical factor whose choice would determine the digital image quality

[195] Daniel DeVincent, 'Spatial Resolutions: Restoring Motion Pictures at 4K Resolution' (JTS 2007: Audiovisual Heritage and the Digital Universe, Toronto, 28 June 2007).

[196] John Galt, 'Quality Control in Digital Cinematography' (JTS 2007: Audiovisual Heritage and the Digital Universe, Toronto, 28 June 2007).

[197] Rafael De Luna, 'Relato do The Reel Thing XXII, 2009 (parte 2)', *Preservação audiovisual* (blog), 13 April 2011, http://preservacaoaudiovisual.blogspot.com/2011/04/relato-do-reel-thing-xxii-2009-parte-2.html, accessed 3 January 2021.Original presentation: John Galt, 'Resolution Limitations of Film Scanner: More Pixels Do Not Mean More Resolution' (The Reel Thing XXII, Hollywood, California, 22 August 2009).

[198] John Galt, 'The Truth about 2K, 4K and the Future of Pixels', CreativeCOW.net, 2009.

altogether. Moreover, the proposed numbers and models overlooked cultural and aesthetic aspects. Thus, the comparison between film resolution (as represented by its MTF and other factors) and the digital pixel count did not always yield meaningful results, and visual control needed to preserve its primary place in quality control. In practice, archives continued to use correspondence estimations between film and digital in their restoration projects, but mostly based on pragmatic and empirical solutions rather than scientific calculations.

The discussion on "what is film" within film archives and the film industry, articulated around the constant comparison of grain vs. pixel, seemed to reach the conclusion that film and digital images each had their own unquantifiable characteristics (although technologically they were made to look more and more similar). There was thus a uniqueness attached to film technologies of the past, creating unique-looking images, preserved in film archives. The film was rethought, not only as a carrier for image, but also as an intrinsic part of it. This view introduced the materiality of film, and the production history of its images, into the centre of archival practice. The concept of original did not only concern a film's content, but also the visual aspect related to its materiality and its production history. On the other hand, as mentioned in Chapter One, dissident voices had already risen since the mid-1990s, which were critical, or at least sceptical about digital image technologies.[199] This was intensified by the 2000s, when, as I stated before, there was a threatening presence of an imaginary which pushed towards archival transition into the digital future. Beyond the imminent necessity for digitising everything, this transition implied tacitly that film, as a medium of recording images, might disappear. What were archives to become with all the films that they were holding (and not much technical possibilities or funding to digitise)?

2.2 "What Are Film Archives?" Archives vs. Museums

The disappearance of film was evoked in concurrence with digital technologies from the early 2000s, but it became more of a pressing matter around 2006, when digital projection standards had been set and film projection was thought to be replaced in theatres shortly thereafter.[200] At this point, such a vision of a digital future seemed to become a certainty, although nobody could precisely predict when and how that would exactly happen. Discourses were multiplied on how archives were to function in the potentially-filmless world of the future, corresponding roughly to one of the possibilities depicted by David Francis back at the 2002 Second Century Forum in Seoul:

[199] See Chapter One, 2.2.
[200] I will come back to projection in Chapter Three.

- Firstly, archives could continue to collect only film material and become a "retrospective collection holder". According to Francis, this would create an archival landscape "frozen in time" serving "an ever-decreasing group of aging film enthusiasts".
- Secondly, archives could accept that they "cannot sustain the film experience because technology will eventually force a change". They should thus begin a "transfer" to "provide on-line access to the national cinema heritage".[201]

These two scenarios of the digital future critically summarised the dialectical vision of digital future, popular at the time within the archival community; whereas, according to David Francis, archives needed to find the middle ground in this changing situation. In the following years, strong positions were formed regarding the future role of film archives within the community, which favoured more one or the other approach.

As explained previously, the question of "what are film archives?", which shed light on the identity crisis of archives during the 2000s, was discussed alongside that of "what is film?" at the FIAF TC workshop in Ljubljana in 2005. The workshop, which presented the digital possibilities notably in providing access to film heritage, was perceived by some as leaning towards the digitisation push. As such, it initiated lively reactions from archivists during the congress. Alexander Horwath (Filmmuseum Austria) criticised the digitisation tendencies of some archives, describing them as deviations to what film archives should ideally do. Trying to incite debates and reflections around the subject, Horwath identified a "neo-liberal turn in film archive and film museum politics". According to him, the "Digital vs. Film" question was in fact a question of "The Market vs. The Museum", where "market-style rhetoric" with words such as "content", "user" and "access" had massively entered into the archival language. In this situation, according to him, "consumption" would not only justify any doubtful practice within archives for the sake of "access" to "users", but also relegate the status of films as "artefacts" to "content".[202] What Horwath was severely criticising was that film archives were moving in a direction in which, instead of being active curators and programmers, they would become passive keepers of content:

> "In my book, a museum is a very different kind of place and space, a different kind of social practice. The museum is a critical, ethical, and political tool, which stands in

[201] Francis, 'Challenges of Film Archiving in the 21st Century'.

[202] Alexander Horwath, 'The Market vs. The Museum', *Journal of Film Preservation*, no. 70 (November 2005): 5–9. Originally written and presented at the Open Forum of the General Assembly at the FIAF Congress 2005 in Ljubljana.

direct opposition to whatever social mood or climate or ideology is hegemonic at a given time. The museum does so in many ways. For instance, by simply reminding the visitor of previous and alternative forms of social and cultural organization; and thereby reminding him or her that the current social and cultural climate is not the only one imaginable. That the dominant forms are never 'natural', but historical and man-made."[203]

As described by Horwath, an archive-museum was not only a technical institution going along with the tendencies of its time, but one which exhibited the film's complex socio-technical and cultural history. Film archive-museums had an object/artefact to safeguard and to showcase, which was film – along with its cultural history of more than 100 years. He would rather see a unification of carrier and content in the notion of film as an artefact. I underline that his discourse was mainly theoretical, and most archives at the time, in reality, did not adhere to this idealised view. His political rebellion against "neo-liberal" democratisation introduced by digital technologies, considered the latter as products of "capitalist" society, a characteristic often attributed to digitality in the more general cultural context.[204] I argue that in practice, the analogy of neoliberalism vs. socialism ideologies was hardly applicable to the case of digital vs. film. This viewpoint reduced digital technologies – also different technically, culturally and socially – to a single homogenous category. Most notably, it neglected the fact that, alongside their capitalist (and military) roots, digital technologies had also been shaped by a powerful counter-culture scene since the 1940s.[205] Moreover, film technologies, in the form of 35mm, had been dominantly a sort of "capitalist" format for more than hundred years in cinema theatres. The institutional modifications that archives were going through during the uncertain period of the 2000s could maybe justify a political categorisation as archive-museum or

---

[203] Horwath, 7.

[204] For scholarly references discussing this aspect, see: Vinzenz Hediger, 'Politique Des Archives: European Cinema and the Invention of Tradition in the Digital Age', *Rouge* 12 (2008), http://www.rouge.com.au/12/hediger.html accessed 25 January 2021. Luca Antoniazzi, 'The Sustainability of Film Heritage: Cultural Policy, Digitalisation and Value' (PhD Thesis, University of Leeds, 2017), http://etheses.whiterose.ac.uk/16918/; Luca Antoniazzi, 'Film Heritage and Neoliberalism', *Museum Management and Curatorship* 34, no. 1 (2 January 2019): 79–95.

[205] Some of the earliest digital technological products (computers, internet, etc.) were conceived in the frameworks of the First World War and then the Cold War, with financial and structural support from military institutions in the United States, but of course other products, as well as the underlying scientific aspects, emerged from (sometimes radically) different contexts. Moreover, it has generated a large amount of remediation and re-appropriations. Digital technologies have therefore been historically diverse in a dialectical manner. On the one hand, they have been supported and developed by capitalism, but have also nurtured a counter-culture since the early days of their conception. For more information on the dual origins of digital technologies and their growth, adoption and adaptation in the more general cultural context, see: Gere, *Digital Culture*.

archive-library, but the hybrid technological landscape of the time did not uphold the same categorisation of film vs. digital technologies. Moreover, digitisation was economically believed to cost more than archives could afford (unless structural funding possibilities would be established) and its role as a revenue generator was only speculated.[206] As expected, Horwath's speech did stir some dispute at the Congress:

> "His paper immediately polarized the audience: those who frankly reacted sharply to what some of them called a 'simplistic', 'ideological', 'elitarian' statement; those who felt that Alexander Horwath was talking right from their hearts, and, finally, those who had the impression that there was a confusion between the roles of two different kinds of institutions."[207]

Horwath's view was shared by Paolo Cherchi Usai, who, using the same terminology, presented the role of archives "to present the cinematic experience as a cultural phenomenon, not a capitalist community".[208] On the other hand, Nicola Mazzanti, whose speech at the FIAF TC workshop had instigated these reactions, responded to Horwath in an open-letter in the following *Journal of Film Preservation*. He emphasised the differences between archives and museums, and introduced digital technologies (with their "access on demand" aspect) as an addition to previous archival activities and functions, not as a replacement to them:

> "I think the central issue here is that what we can call 'museology' is still (or just) one of the several functions that complex organizations as film archives have. And the weight of this function against others evidently differs from one archive to another. There are institutions for which this function is at the core of their history and identity (as is the case for the Österreichisches Filmmuseum), but it is correct to say that in most archives this function coexists with others, with which it often has a complex dialectical relation (the never fully resolved chiasm of conservation-exhibition)."[209]

Indeed, as Mazzanti underlined, the dialectical vision of archives did not start with digital technologies, but it had existed since the Langlois-Lindgren debate in archival discussions, where the two archival roles of conservation and presentation were contrasted with each

[206] It could be considered as financially profitable, as the archivists behind the project Images for the Future (2007) had imagined, before going back on their word by 2012. I will go more into the details of this project later in this chapter. Anyhow, in the case of national European film archives, which were mostly state-funded and non-for-profit, the profitability aspect of digitisation was not an important issue within discourses.
[207] *FIAF 2005 Ljubljana Congress Minutes* (Brussels: FIAF, 2005).
[208] Cited by David Francis, 'The Way Ahead', *Journal of Film Preservation*, no. 82 (April 2010): 9–12. In this article, Francis cited Horwath's 2005 intervention and also Paolo Cherchi Usai's statement.
[209] Nicola Mazzanti, 'Response to Alexander Horwath', *Journal of Film Preservation*, no. 70 (November 2005): 11.

other.[210] The digital rush of the 2000s only revived it in a slightly-redefined manner, which associated the visions to types of image technologies, "fascinating" and "frightening" the film world at the same time.[211] The problem had always been that the film archival community searched for one right way to which all archives should adhere, although in practice this was never entirely realised. This view persisted and was even strengthened in the discourses during the 2000s, with some archives adopting a strictly-museological approach, while others opted for an acceptance of new technologies in addition to the traditional ones. This way, the archival landscape was redrawn again as a dialectical battlefield of ideologies and identities.

Defining Museology in View of Film's Possible Disappearance

The renewal of the archival identity crisis, in the form of museum vs. archive discussion,[212] had started a few years earlier, as attested by Robert Daudelin's presentation entitled "is the film archive of the future a museum?" at the Open Forum of the FIAF Congress in 2000. According to him, the structural and organisational changes that many archives were experiencing at the time should bring them to "assume completely the museum mandate", in the sense that the film "material" would be the centre of focus:[213]

> "The museum is a non-profit permanent institution, at the service of community and its development […], [which] acquires material, preserves them, communicates them and exhibits them with the aim of study, education and delight."[214]

In order to prove his point, Daudelin referred to older discussions of the museum mandate, which Peter Kubelka had defined as its curatorial role. Jose Manuel Costa had also "questioned the quality of the activities of [archival] institutions, wondering if [they] do not too often sacrifice quality for quantity, whereas [they] should program with the rigor of a curator of an exhibition". According to Daudelin, "the musealisation of the cinematheques seemed to be a reality now [in 2000]", owing notably to the "progressive disappearance of film support" and the "new practices and deontology".[215] Indeed, the film's future disappearance, which had

[210] See: Leo Enticknap, 'Have Digital Technologies Reopened the Lindgren/Langlois Debate?', *Spectator* 27, no. 1 (2007): 10–20.
[211] *62nd FIAF Congress*, 9.
[212] For a historical study of the museum role of film archives, see: Alison Trope, 'Le Cinéma Pour Le Cinéma – Making a Museum of the Moving Image', *The Moving Image* 1, no. 1 (2001): 29–67.
[213] The International Council of Museums
[214] Definition by ICOM (International Council of Museums). Cited by Robert Daudelin, *FIAF 2000 London Congress Minutes*, 29.
[215] *FIAF 2000 London Congress Minutes*, 29.

haunted the archival imaginary since then, was growing into a more probable hypothesis through the 2000s. At the 2006 FIAF Congress, the subject was extensively discussed:

> "With plans for conversion to digital projection in cinemas the world over, the expectation is that photochemical technology will rapidly become a specialist product, perhaps dropping out of manufacture altogether, and, as Alfonso del Amo said in his opening address, it is likely to become the sole preserve of the archives. This point was highlighted by one of the first speakers (and the main organiser of the symposium), Paul Read, with some apposite quotes from Antonio Perez, the CEO of Eastman Kodak, which quite clearly implied that film may be a useful product for the company in the short-term, but that once distribution becomes digital, the market for the large quantity of film stock currently used in release prints will effectively vanish." [216]

Although by this time, film was still a commodity very much in use and technologically effervescent, it was suspected to disappear in the short-to-medium term. This worried archives from both a theoretical and a technical point of view. Theoretically, the disappearance of film would cast a shadow on the status of film archives: In a world without film, what would film archives become? There seemed to be a generalised fear that the future disappearance of film (and film technologies and knowledge along with it) would entail the erasure of the whole film culture, which had been the focus of film archives up to then. The museological tendency, which privileged material film artefact as the main archival object (what created the projected image experience) went in the direction of countering that. Technically, archives were fearful that the disappearance would prevent them from conducting their tasks. In 2006, David Walsh analysed if film archives' survival were dependent upon film's survival. According to him, while some tasks could continue in the absence of film technologies, others, such as conservation, did not seem plausible to survive:

> "Unhappily, what we can't do *without* film, is find any reliable way of preserving our images. The imminent obsolescence of film is an absolute calamity-in-waiting for the archive of the future."[217]

By this time, archives had but very limited experience and expertise with digital conservation, and did not see a future in it. Digital conservation was rarely discussed (let alone practiced) at this point as a veritable alternative, and was only evoked as a non-convincing possibility. I will come back to the specific discourses and practices of digital conservation in Chapter Four.

[216] Walsh, 'Technical Symposium - FIAF Congress 2006 São Paulo: Film Archives in Transition', 71.
[217] Walsh, 'Do We Need Film?', 8.

During the 2000s, the discussion on conservation seemed to serve only as a counter-argument to a potential filmless future world. The necessity of film for conservation reinforced the museological function of film archives. Indeed, archives were the refuge for film and film technologies: media that had dominated main cinema distribution circuits throughout the 20th century, but by the 21st century it would be exclusively limited to museums. Film technologies' external existence coming to an end, they would only exist as obsolete media in film archives, which would have to undertake efforts to keep them alive.

In its dominant understanding, museology seemed to concern only film and film technologies.[218] With the shadow of a digital future in sight, the "re-foundation gesture" of archives around the concept of film museology was believed to be "as much needed [by this time] as it was in the beginning of the archive movement".[219] While in the 1930s, when FIAF was formed, the object to be conserved was cinema history, in the 2000s it seemed to have become cinema's traditional technologies (which were considered by the time as being on the verge of disappearance altogether). Many archivists focused indeed only on the future safeguarding of film and film technologies. Interest was revived in older film technologies,[220] and some national initiatives were launched, such as the "Conservatoire des techniques" (Cinémathèque française, 2008), which aimed at conserving and presenting older film technologies and machines.[221] What was missing from this approach was that cinema history was not stopping with film, it already included other carriers (analogue or digital) and was visibly going to accept them even more, as I explained in the first part of this chapter. This depicted two possible ways for archives, as it had already been imagined by David Francis in 2002 and reminded of by Dylan Cave (BFI) in 2008:

> "[Archives] are faced with a decision to either remain a safe house of old film or develop their collection to include current digital production."[222]

The museological approach, as it had been constructed within the archival community, tended to neglect the evolving technological status of the cinema of the future, as remarked by Cave. There were, on the other hand, a small number of archivists, such as Mark Paul Meyer, who expanded the understanding of museology to include also digital technologies. According to

---

218 Paul Read et al., 'Museology, the Archive as a Record of Film Technology' (FIAF 2006 Sao Paolo Symposium, Sao Paolo, 2016).

219 Jose Manuel Costa, 'The Role of FIAF: The Major Priorities. RE-FOUNDATION', FIAF 2006 Sao Paolo Congress Report (Brussels: FIAF, 19 April 2006), Appendix 3.1.

220 The FIAF Symposium 2007 in Tokyo was dedicated to short-lived (photochemical) formats and their correct reproduction/presentation.

221 See: https://www.cinematheque.fr/cycle/le-conservatoire-des-techniques-587.html, accessed 8 April 2021.

222 Dylan Cave, 'Born Digital – Raised an Orphan?', *The Moving Image* 8, no. 1 (2008): 6.

Meyer, archives were museums of film culture, in opposition to libraries of moving images, which needed to respect the past, but also look to the future:

> "[Archives should] collect, and present both photochemical films and digital films, and they must deal with 'electronic emulsions' as respectfully as photochemical emulsions. But it is a mistake to replace analog film with its digital duplicate."[223]

In his view, any film on any carrier was considered as a museum object worth conservation in its original form, whether photochemical or digital or else. This approach was indeed much more adapted to cinema's continually-changing technological history, but it was hardly adopted in the majority of film archival discourses of this time. Museology did not need to be limited only to photochemical technologies, and could include any kind of technology. In fact, it indicated a tendency to preserve the cinematographic image as inseparably linked with its materiality (whether film or digital). But since photochemical technologies were considered in danger of disappearance by this time, it was mostly applied to those, and became a resistant force in the rejection of an uncertain digital future.

Film Curatorship: Film and Nothing Else

Practically, many archives had to come to terms with their polysemic role, to accept films on different carriers, while not forgetting film museology as one of their functions. But the museological approach was pushed to the foreground when it was considered as an identity in opposition to that of an archive open to any kind of carrier (including digital). This seemed to be the case in the book *Film Curatorship*.[224] The concepts of "original artefact" and "curatorship" were discussed extensively in this book, born out of several encounters between four archivists: Horwath, Cherchi Usai and Francis and Michael Loebenstein. Their views converged on the fact that cinema should (solely) be regarded from a materialist perspective, considering film and its carrier together. This brought them to redefine the concept of film as a museum object (in all its ramifications, whether as an object, a technology or a moving image experience). The main question was if the concept of film artefact and its cultural existence could "transcend the idea of film as content or art in the Information Age". The archivists discarded digital technologies as these would conceal the technological history of film – which

[223] Mark-Paul Meyer, 'Traditional Film Projection in a Digital Age', *Journal of Film Preservation*, no. 70 (November 2005): 18.
[224] Paolo Cherchi Usai et al., *Film Curatorship: Archives, Museums and the Digital Marketplace* (Vienna: Austrian Film Museum/Synema, 2008).

was to be safeguarded as a museum object. By the end of the book, "film curatorship" was defined as follows:

> "The art of interpreting the aesthetics, history, and technology of cinema through the selective collection, preservation, and documentation of films and their exhibition in archival presentations."[225]

With no mention of cinema's state-of-the-art digital technologies, this definition re-centred the focus of film museums on photochemical film. According to Paolo Cherchi Usai, the focus needed to remain on film; because if museological action were not taken, all photochemical films (and experiences) would disappear and archival institutions would become "equally irrelevant". [226] In 2010, pushing in the same direction, Cherchi Usai presented his "Lindgren Manifesto", in which his idea of film as a museological object and archivist as "The Film Curator of the Future" were articulated by 14 rules, among which some actively rejected digital technologies:

> "Turning silver grains into pixels is not right or wrong per se; the real problem with digital restoration is its false message that moving images have no history, its delusion of eternity."[227]

The discussion of museum vs. archive was therefore, at its core, a discussion of film vs. digital. Film was considered superior, not because of its supposedly higher quality (as understood in scientific discourses or archival discourses close to them), but because of its historical status as a material object which created the experience of moving images, for more than 100 years in cinema history. The image on film, when projected, carried along traces of this rich technological history, whether of film stock, recording equipment, or projection machinery. This constituted an important part of museology, which would be lost with digital technologies when images were reproduced or restored: these traces could have been erased from the moving images, detaching them from their previous material existence. The museological role of archives was thus to embrace and save film as an artefact creating a unique moving image experience, by continuing and reinforcing their diverse practices on film (projection, preservation, conservation). The diverse views on museology and archival identities, in a

[225] Cherchi Usai et al., 231.
[226] Paolo Cherchi Usai, 'Are All (Analog) Films Orphans?', *The Moving Image* 9, no. 1 (2009): 1–18. See also: Paolo Cherchi Usai, 'The Conservation of Moving Images', *Studies in Conservation* 55, no. 4 (2010): 250–57.
[227] Paolo Cherchi Usai, 'The Lindgren Manifesto: The Film Curator of the Future', *Journal of Film Preservation*, no. 84 (April 2011): 4.

context where it was believed that a (destructive) digital transition was to follow, brought archives to elaborate strategies in order to respond to the identity challenge.

2.3 Consolidating Archival Identity: The FIAF Initiatives

In order to clarify the archival identity amid the crisis, the international film archival community started a series of strategic initiatives, either as a united organisation (under the aegis of FIAF or ACE for instance) or on national or local levels (within the specific socio-political framework of each archive). In contrast to the period before, where many publicly-funded projects and initiatives were conducted in Europe, during the mid-2000s, less projects were defined and less funding was accorded to film archives on the European level. The future uncertainty also prevented the development of clear European political projects to counter the identity crisis. But many efforts towards a consolidation of archival identity, through a series of theoretical reflections, were developed and led on a higher international level, that of FIAF. During this time, the weight of FIAF discourse network – populated in majority by European national archives – was felt more strongly within the archival community. In this part, I will detail some of these discourses in order to depict how the polarised archival community of the 2000s reacted theoretically to the possibility of the disappearance of film, before coming back, in the next subchapter, to the more concrete practices, specifically in Europe, focused on digital access and photochemical preservation.

In 2007, a statistical study was prepared by Christian Dimitriu on the status and categories of FIAF film archives as well as the main practices that they conducted, aiming to clarify the archival identity in terms of its functionality: "these averages can help us draw up an *identikit* of specific sorts of archival institutions, and thus contribute to the recognition of our own identity".[228] It was accepted that the diverse frameworks of archives resulted in different missions and practices, while the authority of a higher international-level organisation (FIAF) was underlined:

> "The nature of the information desired could be further identified and studied by and in cooperation with FIAF's specialized commissions, in view of a broader understanding and the best possible management of our archives […] this study should contribute to an increased awareness of the value and uniqueness of the collections kept by each and

[228] Christian Dimitriu, 'The Leviathan and the Identikits – Global Figures for Everyday Use', *Journal of Film Preservation*, no. 73 (April 2007): 7. Emphasis in the original.

every one of our fellow members, as well as consolidate pride in the diversity of the traditions underlying the history of each archive."[229]

Alongside this view, which promoted diversity within the archival community, efforts were also made to find one unique direction to which all FIAF archives would adhere. During the FIAF Congress 2008 in Paris, a Manifesto was presented on the occasion of FIAF's 70th anniversary, which reinforced the importance of film artefact as an archival object:

> "**Never throw film away**, even after you think something better comes along. No matter what technologies emerge for moving images in the future, existing film copies connect us to the achievements and certainties of the past. **FILM PRINTS WILL LAST - DON'T THROW FILM AWAY**."[230]

The manifesto was prepared in reaction to the rise in popularity of digital technologies within cinema and archives. It imagined the future filmless world as one where everything had been transferred onto digital, and the original elements had been disposed of. This dystopic view had appeared despite the fact that no archival, nor political discourse had proposed to throw away films. According to David Walsh, the "copy-and-destroy" mentality of archives, which had persisted for some time in some archives, had already been replaced by more museological approaches recognising the importance of film artefacts.[231] The copy-and-destroy approach was mostly a pre-digital phenomenon, widely discussed regarding film-to-film duplication and almost eradicated by the 2000s. The previously-banished practice had not been re-ignited in the newer discourses dealing with digital technologies, but the Manifesto imagined that the so-called digital transition might revive it; maybe also because it had been observed in some television archives in their digital transition projects. This reaction illustrates how the status of film itself was evolving in the changing technological landscape, acquiring an elevated museological status in view of a possible disappearance. On the basis of the understanding that "film is culturally irreplaceable", the Manifesto placed film in a superior position compared with digital technologies for several reasons:

1. Film is "tangible" and "human-eye readable", and is created under the direct supervision of filmmakers.
2. Film is a "stable" material that can last for centuries (despite its chemically and physically fragility).

[229] Dimitriu, 17.
[230] 'Don't Throw Film Away! The FIAF 70th Anniversary Manifesto', *Journal of Film Preservation*, no. 77–78 (October 2008): 5–6. Emphasis in the original.
[231] Walsh, 'How to Preserve Your Films Forever'.

3. Film is "currently the optimal storage technology".
4. Film elements in the archives are "the original materials" from which all copies are derived.[232]

The focus on the materiality of film as presented in the Manifesto originated from Hisashi Okajima's mission statement for the Executive Committee of FIAF in 2003:

> "Film culture in an original sense encompasses the tactile materiality of film, […] [its] subtle shakes and noises. The beloved film enthusiasts of FIAF are grieved at the decline of film culture in this sense, and react 'romantically' to tiny scratches on the film, even while vigorously researching digital technologies."[233]

The clear distinction between film and digital technologies evoked by Okajima attached to film a uniqueness based on its material existence, which created a unique projected image, bearing witness to its technological history. For instance, the unsteadiness and flicker due to the mechanical nature of film projection, or the scratches as he mentioned, were part of the film experience as it needed to be preserved. The same vision accompanied him throughout the following years, as he drafted the Manifesto, which was later refined by archivists such as Francis, Cherchi Usai, Daudelin and Horwath (whose discursive position was close to museology) but also benefited from input by Read (who had been very active in research on digital technologies).

The Manifesto intended to function as an element of unity in the archival community, which would make them stronger together (as had been proposed by Jose Manuel Costa in 2006), even though not all archivists agreed with its details. When the first version of the Manifesto was discussed at the FIAF Congress in Paris, the then-slogan of "Film can wait" was contested, finally being replaced by "Don't Throw Films Away". Most importantly, the content of the manifesto was criticised by Thomas Christensen (Danish Film Institute) and Martin Koerber (Deutsche Kinemathek), who proposed to embrace both film and digital technologies in order to correspond to "today's realities". According to them, it was necessary to include all cinema technologies in an archival manifesto. But digital technologies continued to garner much resistance from a large number of archivists. Daudelin insisted that the text of the Manifesto should stress that the digital transfer was not always the best solution. Others noted that film was safer as preservation material because its content could be more easily modified with

[232] 'Don't Throw Film Away! The FIAF 70th Anniversary Manifesto'.

[233] Hisashi Okajima, 'Mission Statement by Hisashi Okajima as a Candidate for FIAF's Executive Committee Membership', FIAF 2003 Stockholm/Helsinki Congress Report. (Brussels: FIAF, 2003).

digital, harming its authenticity.[234] Finally, the revised version of the Manifesto recognised that this strategy is "complementary to the development of efficient methods for the preservation of the digital-born heritage", to which Okajima also adhered (and his position had remained clear on that point since his 2003 mission statement cited earlier). Although the Manifesto's slogan and most of its text elevated film to a much higher position than digital technologies, the latter were not explicitly and entirely rejected. The Manifesto was adopted "in principle" by most members, despite the disagreements. The fight for film's survival, started with the Manifesto, was to be continued a few years later, when the perspective of film's disappearance became more real. This will be addressed in the next chapter.

While the FIAF Manifesto was a federating effort within the community to restore film archival identity as a whole, other initiatives provided more concrete solutions, corresponding also to the diversity and multiplicity of archives' identities. At the Second Century Forums of 2009 and 2010 in Buenos Aires and Oslo, this subject was addressed as the "identity of FIAF and its individual member archives". Particularly, it discussed the communications of film archives to the external world, where archival films were to be exposed, most importantly in a digital form. In Buenos Aires, it was discussed how the "museums of the future" were to function in giving access to cinema heritage in its double economic and cultural existence. Indeed, the digital market for content created new challenges for archival identity as it questioned their missions, practices, as well as their place in the digital world.[235] According to Luca Giuliani, by "diminishing [film's] status to the level of 'content'", the cultural experience of film, related to the technological and psychological context of its presentation, would suffer.[236] A solution had to be found for access to cinema heritage, without sacrificing its cultural aspect – while respecting the archives' missions. Following this Forum, FIAF's Programming and Access to Collections Commission (PACC) proposed that archives prepare and publish their "collection policy", as a solution for "strengthening of Archive Identity in an Age of Transition":

> "Each FIAF affiliate should have a written, publicly available Collection Policy, covering acquisition, preservation, and access. […] A Collection Policy should include selection criteria for what kind of elements of what kind of films are collected, priorities made in duplication and restoration, and principles involved in giving access to the

[234] *FIAF 2008 Paris Congress Minutes* (Brussels: FIAF, 2008), 12–14.
[235] 'Second Century Forum', in *FIAF 2010 Oslo Congress Report* (Brussels: FIAF, 2010), 2.
[236] Luca Giuliani, 'Film Heritage as Cultural Patrimony', *Journal of Film Preservation*, no. 82 (April 2010): 7.

collections with regard to both the archive's own presentations and when lending elements for use and presentation by others."[237]

The collection policy would provide answers to what each archive did, but it did not specify how the archival activities were to be carried out. This void was filled by another document, prepared by the FIAF Technical Commission, called "Preservation Best Practice". According to the FIAF TC, "preserving motion pictures is a complex operation, involving both technical and intellectual expertise".[238] Subsequently, the document did not focus on specific technologies, but detailed the ethical and theoretical concepts of practices, shared within the dominant archival imaginary of the time. It included both film and digital elements in its considerations while leaving the technical details to archives, and emphasised how theoretical and technical aspects needed to be intertwined in archival practices. As such, it embraced the museological approach, without however condemning digital technologies altogether, although it did imply that film and digital technologies had different functions. The document tried to avoid a technologically-divided vision, which was prevalent in the imaginary of the time as I will demonstrate in the next subchapter, but it did reproduce it to some extent, by designating certain film technologies as best-practice for long-term conservation and associating digital technologies with restoration and access (temporary practices).

All these initiatives, and the documents produced through them, were efforts trying to clarify the identity of film archives during the so-called digital transition era of the 2000s. Museology and respect of film were defined as the main parts of an overseeing archival vision, shared in principle by everyone, but how and to what degree it was accepted and implemented in everyday archival practices differed considerably according to the diversity of film archives.

3 Establishment of a Two-Tier System: Digital as a Means of Access?

As I have argued, the two discussions of "what is film?" and "what are film archives?", in a general political context of the push for digitisation, established a dialectical vision of film vs. digital within the film archival community. According to this vision, film was considered as superior, not only in its quality (in the sense that image recorded on film was believed to have

[237] Jon Wengström, 'Strengthening Archive Identity in an Age of Transition', *Journal of Film Preservation*, no. 82 (April 2010): 4.

[238] FIAF Technical Commission, 'Preservation Best Practice', *Journal of Film Preservation*, no. 83 (November 2010): 34–36. The document has since been also available with FIAF resources on its website: https://www.fiafnet.org/images/tinyUpload/E-Resources/Commission-And-PIP-Resources/TC_resources/Preservation%20Best%20Practice%20v4%201%201.pdf, accessed 29 March 2021.

more image information compared to any digital reproduction of it), but also as a historical and cultural object and practice. Therefore, archives were expected to assume a museological role with regards to it. At the same time, digitisation and digital technologies could not be entirely dismissed either, particularly for access. The balance to be found between these two roles depended on each archive's missions, priorities and identity. The practical result emanating from this was a generalised dialectical separation of archival practices in relation to film and digital technologies:

> "The preservation policy of the responsible archive of today is probably something of this sort: store the original film masters in appropriate conditions; make duplicate film masters where the originals are unstable; make digital access copies."[239]

This statement by David Walsh summarised the dominant view in the archival community around 2008, which indicated the following two tendencies:

- Film was designated as the preferred archival carrier for high-quality preservation. By film, it was meant either the original carrier itself or, in case of active preservation, a 35mm state-of-the-art photochemical reproduction, or again, a photochemical projection element; and by high-quality, it was referred to the capacity of the carrier to hold more image information. The look of the film, but also the cultural and historical status of its technologies would be lost when transferred to digital, and for that, digitisation was not deemed sufficient for conservation. The perceived fragility of digital conservation, rarely discussed and even more rarely practiced, also played a role in the elaboration of this view (to which I will come back in Chapter Four).
- Digitisation, on the other hand, was appreciated mostly for its access possibilities, where a supposedly low-quality element would suffice. This element was called low-quality as it needed not to represent all the original image information, but only an acceptable portion of it (as decided by the archivists). This tendency reiterated the traditions of 16mm film, Super8 film, and different video formats for the home entertainment market, and was amplified during the 2000s when several alternative digital distribution channels became largely available (for instance on DVD or through the internet). All these formats were prone to considerable reductions and compressions, historically and culturally perceived as a justified compromise.

[239] Walsh, 'How to Preserve Your Films Forever', 39.

The duality of preservation vs. access imaginary, which had preoccupied archives since their early days, was mentioned by Paul Read in 2004 in a mixed terminology, where the word "format" could apply either to film or digital technologies:

> "Archives, in particular film archives, distinguish between preservation formats and access formats. Preservation formats are expected to retain all the image information from the original, and are, or could be, made from the image when the original is at risk from decay or image fading. Film images have far greater image content […]"[240]

According to Read, in order to keep all the image information (which represented the best quality for archives), practically only film was available. On the other hand, for access the quality varied; it could go from the lowest (analogue VHS) to highest (a new restoration film element for cinema display whether through duplication or DI route). Therefore, in the association of high-quality preservation to film material and low-quality access to digital material, the quality was not a binary factor, but a continuous measure. The cinema projection element, although for giving access to viewers, was also believed to require rather high-quality, at least as high as film:

> "[Le Giornate del Cinema Muto] celebrated its 20th anniversary with a discussion over the fate of the cinema experience and the photochemical film in the digital era. David Robinson made the best statement saying that in presentation, if digital can achieve the level of film, there is no problem with digital; the ethical criterion for restoration and reconstruction is: would the film artist thank you; in preservation, forget digital."[241]

Thus, according to some, digital projection, if it provided a quality close to that of photochemically-projected image (in the form of a newly-struck 35mm print), could potentially be accepted within archival practices. However, the argument of quality (as subjective and historically-charged as it was) was not the only important factor in the discourses on theatrical film presentation, and the museological aspect also played a decisive role, as cinema projection remained intrinsically related to film and its materiality:

> "[Cinema] is the dark theatre (that film requires), it's the collective vision of the film, it's even the inscription of time which comes from the materiality of film and includes

[240] Paul Read, 'Archiving Digital Media', in *The EDCF Guide to Digital Cinema Production*, ed. Lasse Svanberg (Burlington/Oxford: Focal Press, 2004), 145.

[241] Antti Alanen, 'Il Cinema Ritrovato, Bologna, 1-8 July 2006', *Antti Alanen: Film Diary* (blog), 2 July 2006, https://anttialanenfilmdiary.blogspot.com/2006/07/il-cinema-ritrovato-bologna-1-8-july.html, accessed 3 January 2021.

traces of its mechanical life; traces that we always hope to see less abundant, but which are part of cinema's impression."[242]

According to Jose Manuel Costa, the projection was thus considered as one aspect of the "film technology" which needed to be maintained, as it was a "key item of [archival] *identity*".[243] This ensured the preservation of the film experience, stemming from the material artefact, as it had been known for a century. At the time, all high-end restorations, whether conducted via the DI route or photochemically, produced a 35mm print. With the generalisation of digital cinema from 2011, this was bound to change, as I will demonstrate in Chapter Three.

Within the archival community, there was a strong agreement on the superiority of long-term photochemical preservation. Of course, this was not merely a discursive posture in promoting museology, but was also related to concrete technical problems that digital conservation presented, as the reports FIRST and *Digital Dilemma* had underlined, and some archives had experienced since the early 2000s. Photochemical preservation implied two different phenomena. Firstly, it rejected digitisation as a possible high-quality preservation practice. PACC claimed in 2010 that "digitization does not equal preservation",[244] and this point was also, somehow indirectly as said above, insinuated by the 2009 FIAF TC Best Preservation Practice, although the latter remained more open to it. Secondly, it favoured the conservation of all film technologies: forgotten and obsolete technologies, as well as dominant ones which could potentially end up obsolete in the digital future.

On the contrary, for many archivists, "digital [meant] a revolution in the *access domains*":[245] Digital access was considered thus as a parallel practice to photochemical archival preservation. The film vs. digital dichotomy signified by this time that film and digital technologies were to each be assigned their own task: high-quality preservation was believed widely to be obtained solely through photochemical carriers, but digital technologies were accepted by archives when they concerned access.

3.1 Digital Access, a Re-Invented Concept

"Granting and guaranteeing access to a collection is thus one of the official duties of a film archive."[246]

---

[242] Jose Manuel Costa and Robert Daudelin, 'De l'avenir des cinémathèques', *Journal of Film Preservation*, no. 71 (July 2006): 15. My translation.

[243] Costa, 'The Role of FIAF: The Major Priorities. RE-FOUNDATION'. Emphasis in the original.

[244] FIAF Programming and Access to Collections Commission, 'PACC Report to the FIAF General Assembly', Appendix 5.2, FIAF 2010 Oslo Congress Report (Brussels: FIAF, 7 May 2010).

[245] Costa, 'The Role of FIAF: The Major Priorities. RE-FOUNDATION'.

[246] Sabine Lenk, 'Manual for Access to the Collections', *Journal of Film Preservation*, no. 55 (1997): 7.

In the archival context, the term access encompasses a variety of practices that aim to make film collections available for audiences, be it through cinema programming or individual viewing.[247] There has been a large amount of scholarly studies on how digital technologies changed access during the 2000s by providing new distribution channels.[248] While not entering into the various aspects and discussions entailed by these studies, in this subchapter I intend to review the digital access technologies in the particular archival context of the 2000s, and argue how the notion of digital access went technically from a low-quality element to a multi-faceted archival practice.

The digital archival access of the 2000s was rooted in an existing polysemic epistemic and technical infrastructure and did not appear suddenly because of technological availability. Firstly, as mentioned by Thomas Christensen at the Archimage conference in 2008, digital access was a continuity to pre-existing access possibilities via 16mm and VHS distribution (or other formats).[249] There had already been projects of mass digitisation into Digibeta, for instance, by the end of the 1990s, such as the Dutch project Digital Film Center, which I mentioned earlier in this chapter. Such access initiatives were common in film archives, but also went beyond the archival borders, joining the wider film industry. Secondly, access was closely related to cataloguing and documentation practices in film archives, which described what was held in archives. The computerisation of cataloguing (digital databases) was realised and promoted within the archival community from the 1980s,[250] and by the 1990s, it could also include sometimes filmographic multimedia CDs with film excerpts accompanying the descriptions. The latter exploited the optical disc technology, available on the consumer market since the late 1970s, first for analogue and then digital video since 1984.[251] Thirdly, a double economic-cultural approach existed towards archival collections, where these were considered not only as cultural objects but also commercial commodities (sources of income); and widening access did bring revenues, however small. Fourthly, the archival community had built

[247] See: Lenk, 'Manual for Access to the Collections'.
[248] See for instance: Giovanna Fossati and Nanna Verhoeff, 'Beyond Distribution: Some Thoughts on the Future of Archival Films', in *Networks of Entertainment. Early Film Distribution 1895-1915*, ed. Frank Kessler and Nanna Verhoeff (Eastleigh: John Libbey Publishing, 2007), 331–39. Dina Iordanova and Stuart Cunningham, eds., *Digital Disruption: Cinema Moves On-Line* (St Andrews: St Andrews Film Studies, 2012). Virginia Crisp and Gabriel Menotti Gonring, eds., *Besides the Screen: Moving Images through Distribution, Promotion and Curation* (Basingstoke: Palgrave Macmillan, 2015).
[249] Thomas Christensen, 'Danish Film Heritage in a Digital Context' (Archimages Conference, INP, Paris, November 2008).
[250] See: Geoffrey Nowell-Smith, 'A European Filmography', *Journal of Film Preservation*, no. 47 (October 1993): 4–10.
[251] See: Peter Konlechner, 'International Film Archive CD-Rom', *Journal of Film Preservation*, no. 49 (October 1994): 15–17.

a vision of cinema history that included not only canonical film history, but also more marginal film history including documentaries, newsreels, amateur films, etc. Considering films as historical documents (a view which dated back to the last years of the 19th century)[252] put film archives on the same level of public access for cultural and research purposes as libraries and other types of archives (such as television archives). Finally, over time, digital moving images were becoming more and more democratised, provided in higher technical qualities (in terms of pixel count, bit depth, etc.), and available to a much larger public. As archives were believed to function within this digitally-effervescent audiovisual culture, their "official duty" of providing access to their films seemed to be amplified:

> "Digital access is expected to favour a significant growth in demands for access to collections, by comparison with the traditional 'programming' or organized access, until now generally provided by film archives."[253]

As explained by Mazzanti, access had been a common archival practice, whose modalities were about to change with digital technologies. But the newly-reinforced museological tendencies of archives discarded digitised access as the role of a library rather than a film archive-museum. This restrictive view would deprive archives of a role they had always secured to different extents and via different methodologies and practices, isolating them from the society in which they functioned. Naturally, it was contested within the community, notably by Nicola Mazzanti:

> "It seems that this would lead to two philosophical principles for film archives in the future. The first model, restricting access to film projection, would be to yet further limit access to their collections, effectively reducing and restricting the role of film archives. The second principle would, in my opinion, be to deny the possibility of duplicating and reproducing film works in other ways than on film, and that is a contradiction of the essence of film, which is based on reproduction."[254]

As Mazzanti noticed, if archives were to continue access practices, they needed to adapt themselves to the new technological channels available at the time. In the archival discourses of the 2000s, the two poles of film museology and digital access could be regarded as mutually-exclusive. However, these two practices were not necessarily contradictory, and co-existed. During this time, archival digital access practices generally went in two main directions: DVD

---

[252] Bolesław Matuszewski, 'A New Source of History [1898]', trans. Laura U. Marks and Diane Koszarski, *Film History* 7, no. 3 (Autumn 1995): 322–24.
[253] Nicola Mazzanti, 'Access Going Digital - Some Technical Issues', *Journal of Film Preservation*, no. 70 (November 2005): 58.
[254] Mazzanti.

and online platforms. Both of these allowed archives to continue their double economic-cultural approach by making a wider range of films available.

DVD: Curated Access of "Good Quality"

DVD, introduced in 1997 in the Unites States and shortly afterwards in other countries, was adopted quickly within the home entertainment market. Celebrated by the film industry as the "sharpest video image ever in home entertainment",[255] it was also adopted by film archives. Archival DVD production and edition gradually became frequent, to the point that in *Journal of Film Preservation*, a column was dedicated to DVD reviews from the early 2000s. DVD uses the compressed format of MPEG-2 (to which I will come back in Chapter Three), but before the image is formatted into the DVD, it can come from a variety of sources and can be prepared in a variety of manners. It could be a simple, unretouched scan of a 35mm vintage print, or it could come from a series of 2K or 4K DPX files out of a digital restoration route. These different practices were often mentioned in archival reviews, offering a sort of genealogy of the DVD image: where it was obtained from, and sometimes, how. The following examples of DVD reviews in archival discourses illustrate this fact:

> "The restoration of Švankmajer's film was made from the original 35mm interpositive kept in Prague at UPP (United Production Partners) studios. The element was digitised in 2K and transferred to HD. Finally, dirt and scratches, as well as some sound interference, were removed using MTI restoration software. The sharpness of the image is impeccable, which does justice to the filmmaker's affection for worn textures and his desire to offer the experience of tactile sensations."[256]

While the trajectory of the DVD image was depicted, these discourses mixed information on source elements with judgments of technical quality (in an absolute sense):

> "Overseen by Jon Wengström, Curator of the Film Collection at the Swedish Film Institute, this set of discs is an exemplary demonstration of archival conservation, preservation and restoration taken to the highest standards of picture quality and integrity."[257]

[255] Bob Auger, 'A Stream Cannot Rise above Its Source', *Image Technology* 80, no. 9 (October 1998): 9–11.
[256] Marco De Blois, 'A Propos d'Alice: Neco z Alenky (Alice) de Jan Švankmajer', *Journal of Film Preservation*, no. 85 (October 2011): 89. My translation.
[257] Clyde Jeavons, 'Svenska Stumfilmsklassiker (Swedish Silent Film Classics)', *Journal of Film Preservation*, no. 81 (November 2009): 81.

The image quality of the DVD was evaluated according to its properties such as sharpness, or, for instance, if it preserved the "grain and picturality" specific to film look, or on the other hand, if the compression was visible.[258] Sometimes, the quality was judged as compromised:

> "The technical quality of the DVDs is very good, given that these films were made under varying conditions and often under strict budget constraints."[259]
>
> "The digital transfers have been done from prints of acceptable qualities, without being subject to integral cleaning."[260]

According to the archival reviews, the image quality of the DVD was closely related to the source element from which it was reproduced. Sometimes, criticism could arise if the source element for the image of the DVD was not a negative, but a print.[261] While retaining the link with the film artefact as the source of reproduction, the reviews hailed better technical qualities which a DVD could offer in making available an archival restoration work. This was also noted by supporters of museology, such as Daudelin:

> "The restoration work, carried out with a blessed seriousness by Ferran Alberich, quickly made us forget the greyness of the bad 16mm prints through which many of us got to know the film."[262]

The DVD offered thus an image believed to be of "good quality", despite its limits in compression, pixel count, sharpness, colour representation, etc. It did not reproduce all the image information on film, and as such, was not supposed to equal the film image quality, nor to replace the film experience, but was added to it as an alternative method of providing access. To achieve that goal, editorial policies were elaborated on by some archives with regards to historical and technical choices in the DVD production activities. Both these technical and curatorial aspects emanated from an archive's identity, as determined by a FIAF survey in 2009:

> "We observe other approaches which are more specific to the identity of the institution : for example, the **Cinémathèque de Bretagne** edits amateur films and documents together, the **Scottish Screen Archive**, National Library of Scotland does not edit but titles with a potential market, the **Danish Film Institute** uses specific funds that they have received for a series of silent films for the target audiences of students and

[258] Eric Le Roy, 'Markens Grøde', *Journal of Film Preservation*, no. 81 (November 2009): 87–88. My translation.
[259] Donald McWilliams, 'Shadows of Progress: Documentary Film in Post-War Britain 1951-1977', *Journal of Film Preservation*, no. 84 (April 2011): 68.
[260] Marco De Blois, 'Lotte Reiniger : The Fairy Tale Films', *Journal of Film Preservation*, no. 79–80 (April 2009): 128–29.
[261] Eric Le Roy, 'La Bataille du rail', *Journal of Film Preservation*, no. 83 (November 2010): 88–90.
[262] Robert Daudelin, 'Un chien andalou', *Journal of Film Preservation*, no. 83 (November 2010): 88.

university researchers, in a similar spirit to the **Norwegian Film Institute** [which edits] the great classics for young people. The **Filmmuseum München** edits forgotten films, the **Narodni filmovy archiv** video-arts and **Austrian Film Museum** only edits films without commercial potential. In an entirely different genre, **Israeli Film Archive – Jerusalem Cinematheque** produces and edits two or three short films made within the framework of a workshop with young pupils."[263]

These different approaches could help archives achieve different goals: to make known archival holdings, specific restorations, expand access to marginalised collections, increase research possibilities, or promote national productions. As a parallel activity, DVD production seemed, in fact, to mobilise a lot of curatorial and editorial efforts within the archives, going far beyond the technological questions. It also helped valorise and shape a new understanding of archival collections and scholarly cinema historiography.[264] According to each restoration and digitisation workflow, the image quality of the DVD could vary, while the digital format remained MPEG-2. This means that the image was in a compressed digital moving image format adapted to television screens, requiring, of course, different technical configurations (such as a reduced colour space).

Online Access

The second digital access possibility largely considered and sometimes implemented by archives was online access. By the early 2000s, the first general online video-sharing websites appeared, such as Dailymotion (2004), Vimeo (2004) and YouTube (2005). These platforms were not designed to curate audiovisual material, but they were a sort of social media where videos from different sources could be shared. Technically, it was possible to integrate (highly-compressed) digital videos to websites before then as well, but the video-sharing platforms created a democratised virtual space dedicated to videos where everybody could share and discover them. Short after, archives such as BFI (2008) and Eye (2010) started using YouTube to give online access to some digitised archival content. Around the same time, the first platforms dedicated to cinema were also developed: Netflix, an online DVD-rental company

---

[263] Eric Le Roy, 'L'édition DVD dans les archives du film', *Journal of Film Preservation*, no. 79–80 (April 2009): 5–6. Emphasis in the original.

[264] For scholarly studies about DVD editions, see: Martin Loiperdinger, ed., *Celluloid Goes Digital. Historical-Critical Editions of Films on DVD and the Internet. Proceedings of the First International Trier Conference on Film and New Media* (Trier: WVT Wissenschaftlicher Verlag, 2002). James Bennett and Tom Brown, eds., *Film and Television After DVD* (London and New York: Routledge, 2008).
In the archival context, Dominique Païni also analyses DVD from an ontological point of view: Dominique Païni, *Le temps exposé, le cinéma de la salle au musée* (Paris: Cahiers du cinéma/essais, 2002), 40.

since 1997, started its streaming service in 2007; and The Auteurs (later renamed Mubi) was also founded in 2007. The two platforms had opposingly different business models: while Netflix strategised on the quantity of films available (as a library of films where each user could find what they wanted), Mubi offered curated programmes in small numbers and also functioned as a social media for cinephiles.[265] By this time, there was not only an increasing amount of moving image content (of every type) becoming available on the internet, but also the very foundation of access, as in the relation between moving images and their consumers, was being redefined. The dilemma of the 2000s for film archives consisted, as stated above, in finding their place in such a digital environment, and the re-definition of access, along with the changing status of audiences/users, meant that archives needed to re-analyse their access policies.

The subject of "film archives in search of their new audiences" was discussed on the three levels of FIAF, European and national frameworks. At the 2003 FIAF Congress in Stockholm, PACC presented a project of "The Digital Film Archive", initiated by the Norwegian Film Archive and supported by national funding. PACC proposed to prepare a report on initiatives of "[placing] archival material on the net" elaborated within the archival community, which would provide a series of answers to the most frequent questions regarding online access: "what kind of material? For whom (a broad public versus academic researchers)? National or international access? Should it be free or on a payment base? [sic] The ethical problems of changing formats. The technical side, how high resolution?" and more.[266] The questions by PACC covered a wide range of subjects, from curatorial choices to technical requirements, also including museological reflections. It demonstrated the large number of possible platforms that archives could establish.

PACC's project to compile a guide for online access projects did not get realised, but the Norwegian Digital Film Archive was indeed launched in November 2004. At the 2005 FIAF Congress, PACC invited Erlen Jonassen from the Norwegian Film Institute to present the project and the service "which [by then held] some 200 films of any kind and genre produced between 1911 to 2004", open to the general public in Norway and specifically intended for

[265] For more information, see: Roderik Smits and E. W. Nikdel, 'Beyond Netflix and Amazon: MUBI and the Curation of on-Demand Film', *Studies in European Cinema* 16, no. 1 (2 January 2019): 22–37.

[266] FIAF Programming and Access to Collections Commission, 'Report to the FIAF Congress 2003 from the Programming and Access to Collections Commission', FIAF 2003 Stockholm/Helsinki Congress Report (Brussels: FIAF, May 2003).

schools, universities and libraries.[267] Conceived as a pilot initiative in 2000, the Norwegian archive digitised a part of its collections, and collaborated with technology providers to develop a streaming website.[268] The Norwegian experience predated general video-sharing platforms such as YouTube, and is still running as of 2021.[269]

In Europe, the Film Heritage Subgroup of the European Commission organised a number of conferences on the subject, where European archives and political institutions interacted and exchanged knowledge; providing a source of encouragement for archives to integrate their content into larger online platforms such as Europeana. Conceived as a "digital library that is a single, direct and multilingual access point to the European cultural heritage",[270] Europeana then joined forces with ACE to launch an online-platform project for film archives, called European Film Gateway (EFG). The project ran from 2008 to 2011, it reunited several European film archives, and by addressing "a number of key issues for access to digital content, namely, technical and semantic interoperability [and] metadata standards", aimed to become "a single access point to the digitised collections of Europe's film archives".[271] EFG's focus was on bringing "the existing digital entities into a format displayed on the [website]" in a unified documented manner, but prior to that, archives needed to make their own digitisations:

> "Since the purpose of the EFG is to provide access to low resolution files for web display, the most relevant route is to give some pointers to medium term digitization at broadcast quality, and how to convert these media to the relevant digital files for medium term use and web purposes. […] The delivery format for EFG is currently foreseen to be Flash video; 640x480, 1000 kbs, approximately. This quality is slightly higher than known from Youtube, but not sufficient for other use than web applications."[272]

The digitisation quality did not need to exceed broadcast material, and the sufficient pixel count was determined in comparison with other video platforms (and of course not in comparison with theatrical film experience). On the curatorial side, each participating archive was free to showcase what it selected, provided that the rights were cleared for free online access, such as

[267] 'FIAF Programming and Access to Collections Commission Workshop', Congress Programme, FIAF 2005 Ljubljana Congress, 2005, 22.
[268] The company Norges Film. See: http://norgesfilm.no/video-on-demand/, accessed 25 January 2021.
[269] https://filmarkivet.no/, accessed 25 January 25 2021.
[270] European Parliament, 27 September 2007, cited by Jon Purday, 'Integrating Europe's Digitsied Memory' (Cinema Expert Group/Film Heritage Subgroup Meeting, Brussels, 9 June 2008).
[271] 'Public Report on Year 1 of the Project', Public Report, European Film Gateway, 2009.
[272] Thomas Christensen and Julia Welter, 'Guidelines for Digitization, Digital Storage and Retrieval', EFG Deliverable 4.3, European Film Gateway, 30 October 2009, 8–11.

"erotic films made in Austria in the early 20th century, advertising films from Norway, newsreels from Lithuania".[273] The EFG portal went online in July 2011, and remains so as of 2022.[274]

The EFG project, which stood out during the 2000s as an important transnational digital access project,[275] was less concerned with the technical quality of films online, as it was with the curatorial and editorial aspects. Once again, it was devised as an alternative access project, which was not supposed to offer the same experience as that of film projection. Its emphasis was on cataloguing in a uniform, interoperable manner; in a way that the content being given access to, was described clearly for its public (researchers or broader public). In this, it was not merely a video-sharing platform such as YouTube, but shared moving images alongside the archival knowledge surrounding them. Indeed, it fulfilled its curatorial role, even though the image quality was compromised because of digital compression (which left out image details). This project shows how archival practices, knowledge and identity, formed through a dynamic discursive and technical network, adapted the technological possibilities to archival needs while trying to fit in the surrounding world.

3.2 Images for the Future: The Practical Paradox of the Film vs. Digital Vision

Up until here, I have argued how a two-fold archival discursive imaginary was shaped during the 2000s, which associated the digital technologies of the time to low-quality access, while the photochemical technologies were synonymous with high-quality preservation work. However, in the technologically-evolutive context of cinema – and therefore film archives – this dialectical vision of film vs. digital seemed to prove somehow insufficient, and this was most felt through practical application. The project Images for the Future (2007-2014), conducted by

---

[273] 'Public Report on the Outcomes of the Project', Public Report, European Film Gateway, 2011.

[274] https://www.europeanfilmgateway.eu/, accessed 7 January 2022. In December 2020, Adobe discontinued Flash Player, and many videos on this website were therefore not available anymore. But the website has been maintained generally: some videos have been moved to YouTube and Vimeo while for some others, visitors are redirected to other platforms where films are available.

[275] Other projects were also designed and lived for some time, but did not persist. Another online platform project, financed at European level by the MEDIA programme and coordinated by Serge Bromberg, called "Europa Film Treasures" was also launched in 2008 and ran until 2013. See: https://web.archive.org/web/20081005040553/http://www.europafilmtreasures.eu/, accessed 25 January 2021. By the end of the decade, many national websites emerged (conceived by archives or universities, for different reasons and functioning differently): filmarkivet.se (Swedish Film Institute, 2011), Memobase.ch (Memoriav, Switzerland, October 2012), Colonialfilm (Nation-wide UK project led by university researchers, 2010). In the UK, another noteworthy example was that of BFI ScreenOnline (2003-2014), which was mostly a filmographic website, but featured also film excerpts. It was only accessible to registered users from schools, universities, libraries, etc.

the Nederlands Filmmuseum (NFM), shows well how practices, which were initially defined through these theoretical reflections, evolved into more complex schemes, revealing in the end the impracticality of this two-level regime.

Incorrectly labelled as a mass digitisation project within the archival community,[276] the Dutch project corresponded in fact to the same dialectical vision of photochemical preservation and digital access. On the one hand, it continued the older national preservation initiatives, and on the other, it was also inspired by the emerging and growing digital culture. In 2005, the Dutch Council for Culture prepared an advisory report called the "Delta Plan for Film Preservation" to the attention of the Ministry of Education, Culture and Science, in which it underlined the need to develop and finance a film heritage preservation project.[277] It followed in the footsteps of the "Delta Plan for Cultural Preservation", "a rescue operation to combat the decline of important parts of Dutch cultural heritage", dating back to 1989.[278] Images for the Future was designed to respond to the rescue operation of film heritage from decay, while also expanding access to the film collections.[279] This dual approach had already been dominant in NFM's vision since 2000, when digitisation for access was evoked in their mission statement alongside the necessity of film preservation (mainly motivated by vinegar syndrome, a highly problematic reason for film decay and very regularly discussed within the archival community).[280]

Images for the Future gathered several Dutch archives, most notably Nederlands Filmmuseum and the Dutch Institute for Sound & Vision (the national television archive), and was granted a funding of around 150 million euros for seven years by the Dutch government. The amount was unheard of within the archival community, and it corresponded politically to a digital infrastructural project; Images for the Future was indeed funded by the Economic Structure Enhancing Fund (Fonds Economische Structuurversterking - FES). But practically, it was not all digital. In fact, for the preservation part, the two possibilities of film and digital preservation were both studied, and it was decided that two different approaches were needed according to the "nature" of film material in question: whether films were culturally and historically important because of their "informative significance" (in the case of Sound & Vision) or

[276] For example in Cherchi Usai, 'Are All (Analog) Films Orphans?'
[277] Raad voor cultuur (Council for Culture) to Dutch Ministry of Education, Culture and Science, 'advies filmconservering Deltaplan voor het Filmbehoud', 1 August 2005.
[278] 'Bedreigd cultuurbezit', Tweede Kamer, 21 965, no. 7, vergaderjaar 1991-1992, 3. My translation.
[279] 'Images for the Future', Project Plan (Eye Filmmuseum, Sound & Vision, National Archives, Kennisland, April 2006).The project was also presented by Giovanna Fossati, 'Images for the Future' (JTS 2007: Audiovisual Heritage and the Digital Universe, Toronto, 28 June 2007).
[280] 'Celluloid and Pixels: Preservation and Collecting in the Filmmuseum', Unpublished Policy Document (Nederlands Filmmuseum, 23 June 2000).

because of "artistic or cinematographic reasons" (in the case of NFM), respectively digital and film.[281] When the project started, NFM, faithful to its museological convictions and high-quality concerns, started to do large-scale film-on-film preservation. Most of the task was done only via photochemical duplication, although for a selected number of films digital intermediate route was privileged (while the end product remained strictly a film element). Sound & Vision, on the other hand, embarked on a large-scale digitisation project for preservation. The second part of Images for the Future, dedicated to access, was to be realised for both institutions via the new digital distribution channels:

> "The world is becoming digitised. In a few years' time, whatever is not available digitally will in fact no longer be accessible."[282]

Indeed, the focus on public access and digitisation seemed to be what secured the funding, although NFM managed to "shape the project in such a way that [they were] also able to preserve and restore the films in an analogue way".[283] The films were thus planned to undergo digitisation as the second priority only after their photochemical preservation, in order to be made accessible through a web portal to a specialised or general public for cultural, historical, educational or creative uses.[284] As a result, a huge part of the project was devoted to documentation and contextualisation as well as knowledge-making and sharing, through a modernisation of cataloguing practices. The questions of copyright and free access to audiovisual material were also discussed within the project, in the sense that film heritage was considered as a "common",[285] intended for everybody, and digital access was the means to achieve it.

The web distribution portal, initially called Filmotech before being renamed as Ximon, was in development from the early stages of the project and finally went online in 2011. It was a customised paid service including both free-access content (public domain films) and pay-per-view films. This business model had been preferred to third-party platforms such as YouTube or entirely free customised services (deemed as not yet viable). It did not host exclusively archival material, but also newly-produced films and series in order to make it profitable.[286] In

[281] Raad voor cultuur (Council for Culture) to Dutch Ministry of Education, Culture and Science, 'advies filmconservering Deltaplan voor het Filmbehoud', 1 August 2005, 8.
[282] 'Images for the Future', 31.
[283] Mark-Paul Meyer, 'As Seen from the Netherlands' (Archimages Conference, INP, Paris, November 2008).
[284] 'Images for the Future', 29–42.
[285] See: 'Economies of the Commons 3. Sustainable Futures of Digital Archives.' (Conference, Images for the Future, Amsterdam, October 2012), https://web.archive.org/web/20130706182500/http://ecommons.eu/.
[286] Marc Jurgens, 'Filmotech' (Cinema Expert Group/Film Heritage Subgroup Meeting, Brussels, 15 October 2010).

the beginning, the project was supposed to generate an income to repay part of the government funding (which was allocated as a loan) through this website; this point was however revised in 2011, leading to a part of the initial funding being cut due to the impossibility of payback. Despite its potential, the platform did not last long and was abandoned after a few years in 2014 due to lack of users.[287]

An important factor in avoiding third-party platforms was the control on image quality,[288] which was changing throughout the project. The digitisation work conducted by the archives indeed underwent modifications during this seven-year run. NFM started digitising material in HD with digibeta, but soon changed to 2K files (first JPEG 2000, then DPX), when it became economically possible for them. At the same time, Sound & Vision also experienced a change in its technical workflows over time; going from SD to HD and finally 2K. While Sound & Vision was satisfied with the broadcast quality (which was also in the midst of HD standardisation at the time), NFM also looked into the possibilities of the digital future, and required a digital quality beyond that of immediate web dissemination (in terms of pixel count, bitrate, bit depth, etc).[289] Towards the end of the project, the digitisation pixel count, which was a significant factor of quality for archives at that time, even reached 4K for some films:

> "These high-quality scans make digital preservation possible: the scans of the original film elements are stored in uncompressed format and for the long term."[290]

For NFM, the important outcome of the project was the photochemical preservation, but the side task of digitisation, which gained more importance as years went by, left the archive with a mass of digitised films that needed to be digitally conserved and also accessed somehow. The boundaries of digital access and photochemical preservation in this project became blurred compared to what was theoretically fixed in the beginning.

Considering this complexity, it becomes clear that this technologically-dialectical schema could not be maintained, by attributing the archival roles of durable preservation and curated access to a group of technologies, film or digital, in a spirit of opposition. I claim that the heterogenous technologies regrouped under film or digital do not necessarily produce the same quality nor the same image. The technical characteristics of digital elements change according to their

[287] In January 2021, Eye Filmmuseum launched a new online platform, Eye Film Player, which functions in a similar manner to Ximon's business model (free and rental films). Here, however, I will not insist on the specificities of later platforms.

[288] Jurgens, 'Filmotech'.

[289] Meyer, 'As Seen from the Netherlands'.

[290] 'Images of the Past. 7 Years of Images for the Future', Project End Report (Eye Filmmuseum, Sound & Vision, National Archives, Kennisland, 2014), 11.

functions: an SD flash video may be suitable for a web application, while it would not provide a good source for a digital cinema element. The European technical project EDCINE (2007-2010) even identified a two-tier system within the digital realm, which preconised different types of digital files provided for preservation or access.[291] The same goes for photochemical elements: some duplications may not be good enough for preservation (for instance 16mm reductions) as they entail considerable loss of image information, but others, such as separation masters, might fit perfectly into an archive's preservation policies. Moreover, the notion of low-quality, which was initially associated with digital access, came gradually to be less attractive as a means of making a film available:

> "The word 'access' in digital age is a problem because some believe that films can be seen instantly and in every format. But which archive wants to show its cinemascope films on a mobile phone?!"[292]

The dialectical vision of the 2000s, which proved to be inadequate in practical applications, was thus to come under further scrutiny later in the film archival community, especially following the digital roll-out, as I will discuss in the next chapters.

4 Chapter Conclusions

In this chapter, I have stated how the changing and hybrid technological landscape of cinema, coupled with the perspective of an uncertain digital future generated existential dilemmas within the archival community between approximately 2004 and 2011. I have argued that the so-called digital future was not a certainty imposed by technological progress on archives, or a pre-defined state as a direct consequence of it. Rather, it was going to be constructed socio-technically and culturally, within historical and political frameworks of archives, based on their own technical understandings, and theoretical approaches to technologies. This chapter works in fact as a buffer between the previous dominantly-photochemical period within archival community (where only restoration was becoming digitised), and the so-called digital era after the digital roll-out (which I will cover in the next chapters).

During the 2000s, several new image technologies were in development and further adopted and adapted within the industry and archives (such as 24p cameras and new scanners). The archives were not directly engaged in the technological developments (apart from some rare

[291] Arne Nowak, Luis Nunes, and Ernesto Santos, 'The EDCINE Project for Archives: A System for Conservation and Access Based on MXF and JPEG 2000' (JTS 2007: Audiovisual Heritage and the Digital Universe, Toronto, 28 June 2007).

[292] Eva Orbanz, 'Report of the President on Behalf of the Executive Committee', in *FIAF 2008 Paris Congress Minutes* (Brussels: FIAF, 2008).

commercial ventures), but their theoretical discourses, inspired by their interactions with diverse technologies, shaped the way they were going to face the digital future and decide on technological adoption, adaptation or rejection. This period is marked by numerous doubts, identity crisis and constant comparisons between different image technologies, creating a dense (and polarised) discourse network which greatly enriched and durably modified the archival episteme, as I will explore in the next chapters, although its practical interaction with the techne remained relatively limited.

The weight of the imagined digital future shook the very axioms of film archives and their community: namely, what was film, and what were film archives. Suddenly, it was recognised that these were not obvious anymore, and the theoretical and ontological discussions surrounding them, mixed with some technical experiments and studies, did not seem to clarify the crisis it generated for archival identity. Indeed, as I have shown, the reactions were divided. Some adhered to a strict understanding of museology, which re-centred archival discourses and practices around the film object (its history and its numerous technologies) as the artefact of interest for archives, rejecting digital technologies categorically. Others acknowledged the responsibility of archives in preservation of all moving image technologies, regardless of whether film or digital. The diversity and discrepancies of archival identities and visions began to show more during this period, and not one specific attitude could be privileged as the only archival way to go forward.

The archival divide of this time could be characterised by the grain vs. pixel debate; literally and metaphorically, which, for images, refers to the much-discussed concept of technical quality. By the 2000s, film archives had already an understanding of how an image should be, which was formed by their cultural habits and subjective control, distantly colliding with the scientific and technical history of the term quality. The historically-available technologies of any type (of film stock, grain, light, etc.), the habits of audiences and archivists at each time, the machines (printers, sensors, etc.), the viewing circumstances and the goals of reproduction (preservation or access) had all influenced the perception of good or bad technical image quality. Through my technical discussion, I have shown how the concept of quality in image recording, and its appreciation, are fragile and charged with a whole history of practices and theories within archives, cinema or science. The various measurements and understandings of image quality have thus created a holy grail around it, depending on the archive experts' perspective. I have also exposed how archives were looking to interpret the photochemical technologies in the same terms as digital technologies; comparing resolution (and to a lesser extent, other image characteristics such as sharpness), and most importantly making analogies between grain and pixel. The technical study shows the impossibility of providing a unique scientific answer to this line of questioning.

Based on this polarised imaginary, a two-tier system was proposed within the archival community, which attributed specific functions to each group of technologies. Supposedly, high-quality preservation was going to be obtained through photochemical technologies, while digital technologies seemed to be associated with low-quality access. However, such theoretical discourse was not sustainable in practice, as the example of Images for the Future suggests. As I have argued, the cinema technologies were diverse, hybrid and multiple, borrowing from each other and subject to remediation and amplification. I claimed that categorising them under a dichotomy of film vs. digital would wipe off the history of their socio-technical and cultural conception. In the following chapters, I will examine how this dialectical view was to change. Indeed, a veritable co-existence of different cinema technologies, whether film or digital, started with projection before being expanded to other image technologies. This mode of hybrid technological adoption within film archives seemed on its way to replacing the film vs. digital vision as established during the 2000s.

Chapter Three. Projected Image: "Cinema *is* Digital. Now."

By 2011, projection was the last remaining pillar of cinema that was still dominantly achieved with photochemical film. Around this time, in most countries worldwide, a digital roll-out was in progress where cinema theatres were equipped with digital projectors. Within a few years, digital projection technologies replaced traditional film projection technologies in most commercial cinemas.[1] While for some years, many films were simultaneously distributed via digital and photochemical means, since 2014 most films have only been distributed digitally, with just a few notable exceptions.[2] In this chapter, I provide a study of the evolution of discourses before and after the standardisation and generalisation of digital projection, in order to identify the patterns of technological adoption and adaptation, based on the collision of archival episteme and techne.

Here, I will therefore focus on projected image, contrary to the two previous chapters where the material image was studied. In Chapter One, I showed how film archives were first interested in digital image manipulation technologies to elevate their film restoration capacities by using technologies that concerned the digital image at an intermediate level, not projected, but visualised on a computer interface and in an uncompressed format such as DPX. Then, in Chapter Two, I investigated technologies primarily in image recording, whether digital or photochemical, and therefore, questioned the material image as recorded on a film element or on a digital carrier. The discussion in Chapter Two explores how other types of digital image technologies came to be in use or in consideration, for access notably, in the archival context with the shadow of a digital future ahead. This digital future seemed to happen finally when cinema projection went digital. The view of how a projected image should be – visible also to spectators in contrast with the material image –, underwent mutations in the archival (and industrial) imaginaries through the standardisation process of digital cinema, while already rich with its own technological and cultural historicity. Of course, the projected image is also

[1] A number of commercial cinemas still conserve their traditional film projection equipment. Some film festivals keep projecting 35mm as well. However, the machines are not always necessarily operational and there is a considerable lack of trained projectionist staff who can project photochemical films.

[2] Among European films, such was the case of *Son of Saul* (László Nemes, Hungary, 2015, winner of Palme d'Or in Cannes Film Festival), *The Other Side of Hope* (Aki Kaurismäki, Finland, 2017) and *Cold War* (Pawel Pawlikowski, Poland, 2018).

perceived materially through light, but it evades a physical existence if not for its projection source; in that it resembles the image visualised by the computer on command.

Digital projection was not a punctual technological innovation, and it had been subject to discussions, developments and implementations within the technical wing of the film industry since at least the late 1990s. As my technical study will show, digitally-projected image technologies were carefully constructed and standardised according to a certain perception of cinema established through a 100-year-old cultural history. Film archives were principally left out of the technical discussions of digital projection technologies and their standardisation by the film industry, and were not significantly engaged in discussions with the scientific community either. During the 2000s, when these technologies and the industrial discourses around them were in progress, archives were mostly concerned about how digital technologies opposed photochemical technologies (the film vs. digital debate, as covered in Chapter Two), and how this opposition would bring about a re-questioning of archival notions, roles and identities. When around 2011 digital projection was on its way to becoming largely prevalent, the archival discourse network, as formed through earlier discussions, seemed to be somehow detached from the actual technological landscape of digital projection. The archival imaginary opposed film and digital against each other, while the industry tried to make them look alike. In this chapter, I aim to bring these two aspects together: on the one hand, the archival discourses on projection technologies before and after the digital roll-out, and on the other, the technical developments and standardisation of digital projection technologies within the film industry. In this way, I intend to analyse how this apparent remoteness at the time contributed in reality to the formation of archival imaginaries, and how bridging this gap between episteme and techne in the archival context can shed a new light on understanding the mutations of the archival discourse network.

Following the digital roll-out, the archival discourses gradually started to let go of the dichotomy of film vs. digital in view of the new technological realities. Film could now be projected in different ways, with (certain) digital technologies becoming the new norm. Archives were left with little choice to accept digital cinema or not, as it was conceived and adopted by the film industry, putting archives in a situation where they were inevitably faced with new projection technologies and their consequences. If archives were looking to stay in the actuality of cinema and not to be relegated purely to the status of museums of obsolete film technologies, they would have to adapt to digital cinema.[3] Only this would enable them to continue to enrich their collection with newly produced films and present their collections on a wider scale, outside of archival premises. In this regard, their position was different from when they could choose if they wanted to use digital manipulation (restoration) technologies or not. As I will explore throughout this chapter, the archival reaction to the changing projection technologies was twofold: on the one hand, digital projection needed to be adopted by archives, and on the other, film projection needed to be maintained. A militancy by archives (and other actors within the film industry – as well as the more general world of art and culture) aimed to save film projection, alongside digital projection, as an option rich with a century-old history and culture, while at the same time, the archival community also produced a considerable body of knowledge on digital projection.

Similar to this two-fold archival reaction, the academic analysis of digital projection also divided scholars into two camps; one claiming a rupture in technological history of cinema, while the other sustaining an idea of continuity. Many scholars believed that, "the DCP replacing a print does not cause a fundamental shift" for an average spectator,[4] while others argued that digital projection did change the look or feel of the images from a psychological point of view.[5] Moreover, there was a second side to this discussion, which examined the source of the projected image instead: either "recorded on a film-film" or "encoded in a film-file",[6] to borrow the terms coined by André Gaudreault and Philippe Marion. This could also be a source of rupture, as was proclaimed by David Rodowick in his 2007 *The Virtual Life of Film*:

---

[3] Although this statement can be more or less generalised in the case of national European film archives, it is not necessarily applicable to specialised, regional and non-European film archives. It also depends considerably on missions of each archive.

[4] Frank Kessler and Sabine Lenk, 'Digital Cinema or What Happens to the Dispositif?', in *Exposing the Film Apparatus. The Film Archive as a Research Laboratory*, ed. Giovanna Fossati and Annie van den Oever (Amsterdam: Amsterdam University Press, 2016), 309. See also: André Gaudreault and Philippe Marion, *The End of Cinema. A Medium in Crisis in the Digital Age*, trans. Timothy Barnard (New York: Columbia University Press, 2015), 6. This view had been also expressed by John Belton in the early 2000s: John Belton, 'Digital Cinema: A False Revolution', *October* 100 (2002): 98–114.

[5] See for example: M.L. Loertscher et al., 'As Film Goes Byte: The Change from Analog to Digital Film Perception', *Psychology of Aesthetics, Creativity, and the Arts* 10, no. 4 (2016): 458–71. This paper resulted from a research program called Analog/Digital: https://www.zhdk.ch/forschungsprojekt/analog--digital-426752, accessed 30 August 2020. Research on this topic views the cinema as a "psycho-social" machine which triggers certain brain functions, as proposed by Ute Holl, *Cinema, Trance and Cybernetics* (Amsterdam: Amsterdam University Press, 2017). Even John Belton, who in 2002 had refuted any perceptible change in the transition from photochemical to digital projection, published a study in 2014 on the subject: John Belton, 'Psychology of the Photographic, Cinematic, Televisual, and Digital Image', *New Review of Film and Television Studies* 12, no. 3 (2014): 234–46.

[6] Gaudreault and Marion, *The End of Cinema. A Medium in Crisis in the Digital Age*, 6.

> "One response to film's virtual life is to cry, 'Film is dead. Long live cinema!' Whether analog or digital, what we have responded to visually and narratively as 'the movies' persists on cinema screens today and will for some time to come."[7]

According to him, while the cinema-going experience as in projected image was to continue (as if nothing had happened), the source of the image – film strip – was "dead". The term "digital film" was marked as an oxymoron by Dan Streible, who insisted that researchers needed to pay more attention to the vocabulary, because "if we forget to specify what photochemical film was, we stand to lose important historical knowledge and awareness".[8] Streible shared the same perspective with David Bordwell, who had written in the year prior: "The film is no longer a 'film'. A movie now usually comes to a theater not on reels but on a matte-finished hard drive the size of a big paperback. […] Films have become files".[9] As archives are precisely concerned with this material source of the projected image, this discussion gains more importance in the archival context – where it may be endorsed or countered. Looking back at film's history, Giovanna Fossati has argued that:

> "[O]n the contrary, […] using the term 'film' today also for 'digital films' is not only legitimate but necessary. It is necessary, to claim the continuity of 120 years of film history. It also serves the objective of stressing the materiality that digital films still share with their analog predecessors, a characteristic of digital film that is too often overlooked."[10]

Fossati's view inscribes digital films within a continuous film history carried by different technologies. In this chapter I follow the same research direction by claiming the multiplicity, hybridity and co-existence of several technological configurations within the context of film industry and archives. By crossing the archival discourses with the technical and mathematical details of digital projection technologies, I endeavour to bring to light the dual epistemic-technic interrelations between film archives and technologies amid the (dis)continuity discussions generated by the digital roll-out. I will demonstrate how archives discussed and perceived the projected image, and how these views communicated (or not) with the film industry regarding the conception, standardisation, adaptation and adoption of new

[7] Rodowick, *The Virtual Life of Film*, 183.
[8] Dan Streible, 'Moving Image History and the F-Word; or, "Digital Film" Is an Oxymoron', *Film History* 25, no. 1–2 (2013): 227–35.
[9] David Bordwell, *Pandora's Digital Box: Films, Files, and the Future of Movies* (Madison, WI: Irvington Way Institute Press, 2012), 7–8. The film *Cinema Futures* (Michael Palm, Austria, 2016), made in collaboration with Austrian Film Museum and which explores the transition to digital cinema from an archival point of view, is presented as "A file by Michael Palm" in its credits.
[10] Fossati, 'Film Heritage Beyond the Digital Turn'.

technologies. I will outline firstly the history of archival projection practices and discourses, which were largely influenced and determined by industry standards. This preamble, going back in time, is necessary as it allows to follow the evolution of archival episteme with regards to the emerging technologies. I will then detail the process of conception and adoption of new projection technologies within the film industry during the 2000s, which clarifies how a certain look was pursued and obtained in digital projection at the time of the roll-out (and how it could correspond to archival imaginaries). Finally, I will investigate the archival reactions to the generalisation of digital cinema through the double approach of launching campaigns to save traditional technologies, as well as developing strategies to adapt new ones to their own context.

1 Projection Discourses and Practices in Film Archives

Technically speaking, cinema projection can be defined as showing images made of light, from pre-recorded images inscribed on a material carrier. It is produced by a complex machinery including several parts and pieces of equipment, using a mix of diverse technologies – mainly mechanical, optical and electrical. Projection technologies concern, on the one hand, the machinery used to project the film, and on the other, the carrier on which the film is recorded. Both the machinery and the carrier have been diverse throughout film history, and varied according to different circuits in which films were projected. However, the carrier had long been rigidly standardised in the form of a 35mm print in mainstream and commercial venues.[11] While industrial discourses around projection machinery and carrier have been abundant,[12] the subject is brought up less frequently within the archival community, since, strictly speaking, it is considered less of an (exclusively) archival practice compared to other activities such as conservation or restoration. Projection is certainly an activity which is shared between the film industry and film archives.[13] In this subchapter, I will first draw a historical overview of projection discourses within film archives that demonstrates how technical studies of projection were gradually integrated into the more theoretical and practical discussion about film

[11] For a history of cinema projection from a technical point of view, see Enticknap, *Moving Image Technology: From Zoetrope to Digital*, 132–57. For a study of its practices, see: Gabriel Menotti and Virginia Crisp, eds., *Practices of Projection* (Oxford: Oxford University Press, 2020).
[12] For instance, many discussions in technical journals such as the *Journal of the SMPE* or *Image Technology* were dedicated to projectors. There were also journals about projection such as the *Projection Engineering* (1929-1933), which then merged into the *International Projectionist* (1931-1965). These journals are available online at: https://mediahistoryproject.org/technical/index.html, accessed 3 January 2022.
[13] Archival sources have regularly referred to more general industry sources in what concerns the technical information on projection. For example, in FIAF's publication *This Film is Dangerous* a section in the bibliography was dedicated to sources dealing with projection in the larger context of cinema: Smither and Surowiec, *This Film is Dangerous: A Celebration of Nitrate Film*.

exhibition. I will then detail which technical aspects of projection were mostly commented upon within archives, and, finally, I will depict how the perspective of digital cinema started to shake existing archival imaginaries on projected image technologies.

1.1 From Exhibition to Projection: Towards More Technical Discourses

Projection is, in fact, the technical axis of cinema exhibition (or programming). The latter, for film archives, has always been one of the most frequent activities. The long-lasting question of "Preservation or exhibition",[14] dating back to the famous Langlois-Lindgren debate,[15] has impregnated archival discourses with two possible approaches to film archiving: whether the archives' role was first to show films or preserve them. In his 1983 book *Les Cinémathèques,* Raymond Borde (Cinémathèque de Toulouse) cited Henri Langlois who considered exhibition as "the only way to have a façade" for the archives (in 1946).[16] Borde, however, criticised already the gap established between these two archival activities, which, according to him, would best be conducted jointly in a more harmonious manner, tacitly indicating a closer relationship between preserved film and projected film.

Based on a survey conducted by FIAF in 1982, and as underlined by Raymond Borde, exhibition practices within archives had grown to become quite diverse by that time.[17] They could include in-house or external screening, participation in other events, and englobed a wide variety of programming choices.[18] Archival exhibition could take place not only in archives' own cinemas, but also at other venues. This remains true as of yet in the current landscape of film heritage screening.[19] Most European national archives have either one or several cinema theatres with regular programming. They may also prepare films for screening in commercial cinemas or other circuits, such as Ciné-clubs or art cinemas, and collaborate in the organisation of events such as festivals, through retrospectives, for instance. Inevitably, these diverse exhibition venues sometimes required technical adjustments for vintage or newly restored prints in order to accommodate the strict in-place technical standards.

[14] Borde, *Les Cinémathèques*, 98–99. The term projection in French can designate exhibition as well as its more technical axis of projecting image (as understood in English).

[15] For a concise historical review of this affair, see: Christophe Dupin, 'Je t'aime ... Moi Non plus: Ernst Lindgren and Henri Langlois, Pioneers of the Film Archive Movement', in *The British Film Institute, the Government, and Film Culture, 1933-2000*, ed. Geoffrey Nowell-Smith and Christophe Dupin (Manchester & New York: Manchester University Press, 2012), 46–68.

[16] Borde, *Les Cinémathèques*, 98–99.

[17] Results of this FIAF survey can be found in: *FIAF 1982 Oaxtepec Congress Minutes* (Brussels: FIAF, 1982), Appendix 8.

[18] Borde, *Les Cinémathèques*, 191–93.

[19] The AFF (Archives françaises du film) of CNC, for instance, have no cinema theatre and project the films from their collections in other venues.

Exhibition and programming activities were recognised more formally as archival practices thanks to the 1989 FIAF Symposium in Lisbon entitled "Rediscovering the role of film archives: to preserve and to show". Speaking at the symposium, Peter von Bagh hailed the moment as historic, because, according to him, "programming people" in archives had remained mostly "outsiders" in the discourses prior to that.[20] This view corroborates what I have claimed here, that although exhibition was a frequent practice by archives, it was less regularly discussed, and certainly not from a technical point of view. But, historically, archival programming has been quite different from commercial cinemas in that archives screen mainly patrimonial films:[21] silent films, vintage prints, restored versions, etc. It depends not only on curatorial decisions and print availability, but also on technical aspects. The latter had long been overshadowed by the former two in archival discourses. However, as underlined by Eileen Bowser and John Kuiper in 1991, these were closely related:

> "The archive shows all kinds of films from different periods of history, and must be able to project silent films at varying speeds and to provide musical accompaniment. The film archive should always strive for the best possible projection, and to show films as nearly as possible in the way they were originally intended to be shown. Special safety construction in the projection booth and equipment is necessary if the archive wants to show nitrate film copies. The sound equipment, the sight lines, the distance from projectors to screen, the type of screen and matting, all are important factors worth serious study, and beyond the scope of this basic manual to describe in detail."[22]

The technical details of projection were thoroughly studied (and often standardised) by the film industry: different periods, different standards. Bowser and Kuiper called for a respect of projection specifications with regards to the film screened, and incited archives to study the technical context in which the films had been released originally. Similarly, at the 1989 Lisbon Symposium, Elaine Burrows had identified the technical limits of projection, and the archival responsibility to present films in "good quality" and close to their "original format":

> "We have spoken, several times, of the need of 'good quality' or 'definitive' prints. It is simply not good enough to try to promote the cinema that we care for by using

[20] Peter von Bagh, in *Rediscovering the Role of Film Archives: To Preserve and To Show, Symposium Proceedings, FIAF 1989 Lisbon Congress*, ed. Cinemateca Portugesa (Lisbon: Cinemateca Portuguesa / FIAF, 1990), 13.
[21] This depends on the missions and possibilities of each archive. Eye Filmmuseum, for example, proposes a mixed programme of old films and new releases in its own cinemas. Cinémathèque suisse, on the other hand, does not generally exhibit new releases, apart from premiere events.
[22] Bowser and Kuiper, *A Handbook for Film Archives*, 112.

> inadequate materials. It should go without saying that, as far as possible, films should be screened in their original format. […] We should not show prints which do not adequately represent the original artistic achievement. Screening a faded, scratched, dirty, chopped-about archive print, does nothing to uphold exhibition standards […]"[23]

The question of projection "standards" within archives did not directly refer to the actual industry standards, but to archival requirements to ensure a "good" projection (in a technical sense). Burrows's statement underlines what was generally regarded within archives as good or bad projection quality: the wear and tear traces were not appreciated, nor were faded colours. There was also a tendency towards reviving the "original formats"; for example, the correct aspect ratio or frame rate. Therefore, in judging good or bad projection quality, there was a (somehow subjective) degree of fidelity with regards to what archives imagined as the original projection, which justified as well the removal of historical traces embedded throughout the film element's existence on it. Similarly, according to Jean-Pierre Verscheure (professor at INSAS in Belgium)[24] at the same Symposium, the archival standards needed to englobe two aspects: firstly, the multiplicity of original projection systems, formats and technologies which needed to be respected; and secondly, the "wearing down of copies" which affected the projection quality, and could potentially be compensated partly through the use of some special equipment on projectors.[25] Verscheure's intervention underlined the malleability of projectors and evoked the possibility of improving the projection quality of a worn print by modifying the projectors.[26]

While it was recognised that film archives needed to accomplish the "task of preserving and showing in a historical perspective",[27] they were generally equipped with state-of-the-art projectors which could offer good projection quality (in the technical understanding of clean, sharp image). The projection of films was thus done on constantly changing machinery because of these new technological means, but it was important for the new projection to mimic the historical characteristics of old processes and systems in terms of projection speed, projection

---

[23] Elaine Burrows, in *Rediscovering the Role of Film Archives: To Preserve and To Show, Symposium Proceedings, FIAF 1989 Lisbon Congress*, ed. Cinemateca Portugesa (Lisbon: Cinemateca Portuguesa / FIAF, 1990), 88–89.

[24] Verscheure was not affiliated to any archive, but was a specialist of cinema's technological history and active in archival

[25] Cinemateca Portugesa, ed., *Rediscovering the Role of Film Archives: To Preserve and To Show, Symposium Proceedings, FIAF 1989 Lisbon Congress* (Lisbon: Cinemateca Portuguesa / FIAF, 1990), 90–91.

[26] This type of quality judgements was not absolute, and what was regarded as bad quality in the archival context of this time, could have been appreciated in other cultural contexts.

[27] The title of the first session of the Symposium. See: Cinemateca Portugesa, *Rediscovering the Role of Film Archives: To Preserve and To Show, Symposium Proceedings, FIAF 1989 Lisbon Congress*, 13.

aspect ratio, etc. State-of-the-art technologies could even remedy the shortcomings of old prints in order to present a closer projection to the original. An example of the adaptation of projectors to get a closer historical correspondence was to add a frequency converter for different frame rates which "[fed] the projector motor with the desired frequency and thus [controlled] the running speed".[28] Therefore, from the early 1990s, there was already a tendency to recreate the original viewing experience of films, albeit through new technologies. The aspiration to present "the best possible projection",[29] shared theoretically with the film industry and its standardisation processes, was to be critical in the conception of new projection technologies as I will demonstrate later in this chapter.

At the 1989 Lisbon Congress, it was also proposed that a Programming Commission[30] should be created, a suggestion that was fulfilled during the 1990 Congress in Havana. The main role of the new commission was to provide insight and formalise practices in order to widen access to archival films. Additionally, it was also supposed to focus on the technical questions related to projection:

> "The Commission, in close collaboration with the Preservation Commission, is also concerned with questions relating to technical standards, notably of:
> - projection standards (luminosity, choice of aperture, types of screen, etc.)
> - projection speeds
> - quality of prints (printing, length, sound, colour, etc.)"[31]

The first task of the new commission was to prepare a "reference manual which will allow the establishment of technical standards for projection and presentation of films",[32] although this was not completed as expected in 1993, nor any time before 2006 when the *FIAF Advanced Projection Manual* was published.[33] Film archives were, in reality, followers of the standards fixed by the film industry, while they could adapt these standards to their own needs, and introduce their own requirements for the presentation of old films. The Commission's role was directed more towards the study and the proposal of recommendations and best practices, aligned with industrial standards and their evolution, and considering the films' needs for historical recreations and mimicry. Such discussions were to continue and intensify throughout

[28] Torkell Saetervadet, *The Advanced Projection Manual* (Oslo: Norwegian Film Institute and FIAF, 2006), 35.
[29] The term was notably used by Saetervadet, *The Advanced Projection Manual*.
[30] Renamed Programming and Access to Collections Commission (PACC) later.
[31] 'Report from the Programming Subcommittee', FIAF 1990 Havana Congress Report, 1990, Appendix 19.
[32] Joâo Bernard Da Costa, 'Activités de la Commission de Programmation', *Bulletin FIAF*, no. 44 (March 1992): 14. My translation.
[33] Saetervadet, *The Advanced Projection Manual*. I will come back to this book in the next section.

the coming years; for instance, through panels such as the "Technical standards for the screening and the presentation of moving images" by Clyde Jeavons, with the participation of Peter Konlechner, Henning Schou and Jean-Pierre Verscheure at the 1992 FIAF Montevideo Symposium.[34]

Although archives adhered predominantly to the existing industrial standards, they also gradually conceived and promoted a more niche approach of recognising, reproducing and simulating the diversity of older projection methods and systems, not least for experimental cinema. This culminated many years later, when digital projection had become a reality, notably at the 2007 FIAF symposium dedicated to short-lived formats (gauges and materials, but also systems of projection), organised by Jean-Pierre Verscheure and with a focus on the correct presentation of the "cinematographic spectacle".[35] Technically, while it is true that standard 35mm had been dominant in archival projection practices, other formats (such as 16mm) and systems (such as different aspect ratios) were not categorically discarded either (although they might have been neglected for several years). Archives might keep and use also older equipment, for example projectors for silent films,[36] nitrate films, sub-standard gauges,[37] etc; or they might modify state-of-the-art projectors slightly to achieve a more original historical projection; or recreate projection prints, which carried their original historical specificities, enabling their projection on any commercial cinema projector. Archives were expected, by their own peers, to become places where an "authentic projection" was guaranteed, similar to a museum;[38] and that could be achieved in many different ways.

1.2 Technical Do's and Don'ts and *The Advanced Projection Manual*

In archival discourses, some projection aspects were more discussed than others. These had to do with the close recreation of the historical characteristics via new technologies. In *Restoration of Motion Picture Film*, the seminal book by Read and Meyer, projection shutter[39], frame rates,[40] and projector aperture[41] were detailed as information useful to know while doing a

[34] *FIAF 1992 Montevideo Congress Minutes* (Brussels: FIAF, 1992), Appendix 14.
[35] Jean-Pierre Verscheure, 'The Conservation of the Heritage of the Film Spectacle', in *FIAF 2007 Tokyo*, Congress Programme (Tokyo: National Film Center, 2007), 8.
[36] In order to respect not only projection speeds, but also aspect ratios.
[37] Lichtspiel Kinemathek Bern, a FIAF associate member archive in Switzerland, organises regularly projections of this type of material in their screening venue. Filmmuseum Austria, specialised in experimental cinema, is also actively promoting this practice.
[38] Robert Daudelin, 'Learning from the History of FIAF', *Journal of Film Preservation*, no. 51 (November 1995): 25.
[39] Read and Meyer, *Restoration of Motion Picture Film*, 24.
[40] Read and Meyer, 24–26.
[41] Read and Meyer, 30–33.

restoration. Projection frame rate has probably been the most discussed subject, and it proved to be one of the major concerns of film archives when digital projection standards were fixed.[42] Other details, such as light source, mechanical route of film in the projector, or the position of platters, which were more difficult to reproduce or to simulate, were evoked less regularly.

In 2004, François Auger (Cinémathèque québécoise) published a projectionist guide in the *Journal of Film Preservation*. This text, originally prepared in 1982 and amended regularly up to 2002 "in view of the upheavals appearing on the horizon (disappearance of film as a carrier, new value of prints, etc.)", detailed the job of an "archive projectionist" in a very factual, manual-type manner. According to Auger, apart from tasks regarding the handling and preparation of prints for projection, the projectionist was also responsible for the correct projection of the film on the screen with regards to its characteristics, such as aspect ratio and frame rate.[43] This document was advised to accompany the *Advanced Projection Manual*, which was in progress at the time and some parts of it were already available to FIAF members. In 2006, in the midst of the development and standardisation of digital cinema, FIAF published the *Advanced Projection Manual*, in collaboration with Norwegian Film Institute, by Torkell Saetervadet. Formerly the technical manager of Norwegian Film Institute cinema, Saetervadet is a cinema design and technology expert, who masters both the photochemical and digital projection technologies. He also served for a period in the FIAF Technical Commission, preparing several documents on projection. The 2006 *Manual* offers a comprehensive view of film projection, with a focus on "best practices".[44] It is a "technical guide to projection of classic and contemporary films with modern projectors".[45] Its "raison d'être" was to "enable films to be presented in exactly the way they were originally intended to be presented, without any compromises with regards to picture, sound and appearance",[46] through state-of-the-art technologies. It recognised the multiplicity of cinema technologies, and aimed to clarify the projection errors, which could have been numerous, because, as explained by David Walsh, "motion picture technology has always been a jumble of conflicting systems and standards, a

[42] See for example: Giovanna Fossati, 'Multiple Originals: The (Digital) Restoration and Exhibition of Early Films', in *A Companion to Early Cinema*, ed. André Gaudreault, Nicolas Dulac, and Santiago Hidalgo (Malden: Wiley-Blackwell, 2012), 563–65. The topic will be discussed more later in this chapter.

[43] François Auger, 'Projectionniste dans une cinémathèque (la Cinémathèque québécoise)', *Journal of Film Preservation*, no. 67 (June 2004): 10–14. My translation.

[44] Saetervadet, *The Advanced Projection Manual*.

[45] Saetervadet, 7.

[46] Saetervadet, 9.

situation which has led to that favourite trap for the projectionist, where it is possible for two entirely different screen formats to appear identical on the film".[47]

The *Manual* stressed the characteristics of the historical film, but by focusing primarily on 35mm. However, it did include a chapter on 70mm projection and another chapter on small-gauge films. For the latter, the book stated: "Narrow gauge film presentation in professional cinemas is in itself a contradiction in term since virtually all gauges less than 35mm in width were initially introduced and designed for domestic use".[48] While this is technically true, it is certain that they were not historically and culturally limited in practice to the domestic context. Although the *Manual* discussed other gauges, it directly judged them as inferior to 35mm. This is a revealing point within the film archival community (similar to the dominant film industry's position), which would later be mobilised in the face of 35mm's disappearance in a way it had never been mobilised for any other film technology on a large scale.[49]

The *Manual* intended to offer a series of recommendations and best practices with regards to the (imagined) original projection of a film, while it was less concerned with the historical projection machinery. It did detail many technical aspects of projection technologies; from screening room characteristics to the pieces of the projector itself (lamp, lenses, film path, film gate, etc.), but for an ideal state-of-the-art projector that would also handle archive material. It did not promote an authentic recreation of the cinematographic spectacle with the original equipment and machinery, but a simulation of it on modern projectors (without qualifying it as such). The point was supposedly to get the "best possible" projected image from a film print. This quality judgment followed the subjective industrial tendency within the mainstream circuit, where a clearer, brighter, more detailed projected image was considered superior. The projected image created by a state-of-the-art projector did not look like an image out of the original projection machinery, but it was embraced by the *Manual*. In this regard, the *Manual* demonstrated a dominant tendency at the time in the film archival community based on material

---

[47] David Walsh, 'The Advanced Projection Manual by Torkell Saetervadet', *Journal of Film Preservation*, no. 72 (November 2006): 90.

[48] Saetervadet, *The Advanced Projection Manual*, 199.

[49] By 2006, 16mm had already been greatly side-lined by the film industry as a format used in alternative production and projection practices. Having suffered more from quality comparison with video, it had been used less and less, and by then most of the labs had already stopped their 16mm activities. See for example: Heather Hendershot, 'In Focus: The Death of 16mm?', *Cinema Journal* 45, no. 3 (2006): 109–12. However, not everybody agreed with the death of 16mm, and, according to Jan Christopher Horak in the same edition of *Cinema Journal*, 16mm film would still remain available. See: Horak, 'Archiving, Preserving, Screening 16mm'. In 2006, British artist Tacita Dean, who was to be an instrumental figure in the fight for 35mm film's survival in collaboration with film archives, had made a film about the closure of a Kodak 16-mm film stock factory in France (*Kodak*, Tacita Dean, 2006). The possible obsolescence of 16mm was thus discussed by some, but it did not generate as much discussion as the disappearance of 35mm, at least in film archives.

film as a historical object, and applauded the state-of-the-art projection technologies which could produce the "best" image out of a film carrier while respecting its historical characteristics. This was based on an image perception, which had historically and culturally been constructed within the archival community to determine what a good image was, quite close to the industrial understanding of a good projected image. Then, while the industrial network was to apply its vision in its conception of digital cinema, the archival network (and scholarly studies) would find a new interest later for the historical machinery (and the image they created).[50] In the second part of this chapter, I will describe how industry and archives undertook these two different directions on the road to technological adoption and adaptation.

1.3 Archives Faced with the Perspective of a Future Digital Cinema

An entire section of around 50 pages in the *Manual* was dedicated to electronic and digital projection technologies. According to it, the video technologies could be of interest by then when it came to projection, as the image quality required for cinema would be ensured with digital electronic projection. This part was less concerned with best practices and recommendations, and was more of an informative nature, it detailed many varieties of video and digital projection technologies, as well as the D-Cinema specifications as defined by DCI (I will come back to these in the next subchapter). When the book was published in 2006, the inclusion of electronic and digital projection technologies was appreciated by archivists such as David Walsh who noted that "this rapidly expanding area is one where most of us feel at least a degree of inadequacy".[51] As remarked by Walsh, digital projection technologies were viewed mostly as a black box, with an image projection process radically different compared to that of film image projection.

Around the time that new digital projection technologies were in development during the 2000s, archives – largely left out of the industry discussions – were faced with future perspective of this change: they needed to reflect upon how they were going to project their own collections (vintage or new prints), in their premises or outside. Digital cinema was regarded mostly as a fatality coming from the industry from the early 2000s, when David Francis predicted that the industry would certainly replace film projection with digital when its technological and economic requirements were fulfilled:

[50] See for example: Giovanna Fossati and Annie van den Oever, eds., *Exposing the Film Apparatus: The Film Archives as a Research Laboratory* (Amsterdam: Amsterdam University Press, 2016).
[51] Walsh, 'The Advanced Projection Manual by Torkell Saetervadet', 90.

> "As soon as the industry feels confident that digital moving images beamed via satellite are as reliable as those originating from celluloid and that the cost of equipment to receive those digital images is competitive, they will make such a change."[52]

Although digital cinema did not end up in the way it was imagined by Francis during the early 2000s, there was no doubt in the archival imaginary at the time that it was coming. Archives were conscious that this would have repercussions on their work, because, as underlined before, they were dependent on industry projection methods, equipment and standards, especially for films they screened elsewhere.

In order to counter the black box views of digital cinema, archives began closer exchanges with actors from the film industry so that they would not fall behind the moving world and its new standards. In many archival conferences organised from the mid-2000s on, representatives from film industry would take part to inform the archivists of the on-going research and novelties in the field of digital projection. During the 2006 FIAF Symposium in Sao Paolo, two presentations were done by industry professionals: the first, "D- and e-cinema in Europe" by John Graham (European Digital Cinema Forum), and the second, "The Barco DP100 2K Projector" by Rod Wheeler (Barco). At the same symposium, Torkell Saetervadet also relayed more industry information on "digital projection and world standards".[53] The presence of industry actors at the archival conferences also continued at the 2010 FIAF Congress in Oslo, when Jorgen Stensland (consultant at Film & Kino) presented the Norwegian digital roll-out,[54] and the 2011 conference *Et si le cinéma perdait la mémoire?* at the Cinémathèque française, where Alain Besse (CST) retraced the history of digital projection principally in France.[55] These presentations covered a vast range of information regarding digital projection and its machines, while they also addressed the specific characteristics of the source image. They reported back on the industrial and scientific collaborations, to which the archival participation remained limited, but their discourses and consequences did echo within the archival community.

What was striking in the collision of archival and industrial epistemes, was how they started at a convergent point, but moved gradually apart. The film industry approached digital projection from the point of view of the spectators (the image projected on the screen), as I will detail

---

[52] Francis, 'Challenges of Film Archiving in the 21st Century', 20.

[53] *62nd FIAF Congress*.

[54] Jorgen Stensland, 'Norway – on the Brink of a Digital Roll-Out' (JTS 2010: Digital Challenges and Digital Opportunities in Audiovisual Archiving, Oslo, 3 May 2010).

[55] Alain Besse, 'La Normalisation du numérique' (Révolution numérique: et si le cinéma perdait la mémoire?, Cinémathèque française, Paris, October 2011), https://www.canal-u.tv/video/cinematheque_francaise/la_normalisation_du_numerique_intervention_d_alain_besse.7755.

technically in the next subchapter. It was even considered financially beneficial to get rid of the material film, whose high costs of fabrication and transport could be reduced by digital projection elements. For archives, it was more complicated, as both the projected and the material image mattered in archival perception. As explained in the previous chapter, archives considered that film's "tradition of quality" would make it superior to digital in projection, but with new digital projection technologies, this position was jeopardised: at the 2006 FIAF Congress, a series of film and digital projection tests were organised which, according to David Walsh, made the archival community realise that digital technologies could project an image whose technical quality was considered good enough:[56]

> "It is no longer possible to dismiss digital projection as being of inadequate quality, and in this particular venue, the digital projection easily outclassed the film, with few people claiming to have noticed any digital defects."[57]

The comparison between the images projected out of film or digital carriers was done in an empirical and subjective manner, and based on what was seen on a screen. It generated diverse reactions on which one was better, but the hegemony of film's superiority in projection seemed to be lost, as digitally-projected image could meet the archival understanding of good-quality image, similar to the same vision as within the mainstream film industry (clear, bright, sharp, and with no wear and tear traces). But, in the film archival imaginary, the projected image was not separated from its material source, thanks to the museological tendencies which favoured a more object-based point of view. The quality of projected image was thus considered together with its material source image as an ensemble that would create a specific visual aspect on the screen. That is why the archival reaction deplored the loss of the "look and feel" of old films when projected digitally.[58] This "look and feel" was described in a certain way by Antti Alanen:

> "Film has an affinity with life, digital an affinity with death. Film has a special ability to catch the flow of life, the vibration, the warmth, the radiation, the thousands of small things that create a full, vibrant image of life, and this is lost in the current 2K norms of digital moving images."[59]

In Alanen's view, the photochemical look was related to a sort of "life" (which presumably referred to the random grainy structure of the photochemical image compared to the digital's

[56] Walsh, 'Technical Symposium - FIAF Congress 2006 São Paulo: Film Archives in Transition', 72.
[57] Walsh, 76.
[58] Meyer, 'Traditional Film Projection in a Digital Age'.
[59] Antti Alanen, 'A Programming and Access Viewpoint', in Paul Read, ed., 'FIAF Technical Commission Workshop. 'What Is Film?' 61st FIAF Congress', *Journal of Film Preservation*, no. 70 (8 June 2005): 61.

computable grid). However, even if the projected image (more or less) corresponded, digital projection was anyhow considered as a "simulation", as claimed by Nicola Mazzanti:

> "Archives should definitely ascertain (by carrying out research and tests) to which extent, in which occasions, and by using which technologies and techniques, digital projection can be considered 'an acceptable simulation of a film projection'."[60]

In terms of the projected image, digital could be considered by some as an "acceptable" simulation, if some technological aspects were adapted to archival requirements. However, archives were conscious that when a material image on film goes mechanically through a projector, a specific visual aspect is created in the projected image, which is not necessarily reproduced by digital projection technologies, at least not in the same manner. Based on this argument, film projection would still remain untouchable in archival views, while digital projection could potentially be satisfactory under certain circumstances. I argue that such distinctions between film and digital projection could be countered by another view of the situation. In fact, film projection did not have one single technology, and it was constantly changing: for instance, the light source (carbon arc or xenon), the mechanical route of film transport, the lenses, the orientation of feed and take up platters (horizontal or vertical), etc. The sought-after "authentic" projection could hardly be achieved unless the exact same technologies were used to produce the projected image, and that, in exact same conditions. A simulated projection strives to produce a projected image similar to how archives believed it was originally projected, but through different technologies. Thus, just as digital projection was considered a simulation, the projection of old films on new state-of-the-art film projectors would also be so; although it had never been addressed as such within the archival discourses. By this time, before the roll-out, whether in industrial or archival discourses, digital and photochemical projection were separated into two different paradigms, oversimplifying the technological diversity of projection systems, in correspondence to the on-going dialectical categorisation and quality comparison between film and digital at the time.[61]

For both the archival community and the film industry, the projected image needed to have a certain look; but what was this look, and how was it related to the 100-year historical and cultural existence of photochemical film? How, technically, was it constructed in projection? How was the archival imaginary modified when faced with this carefully-constructed digital image after the digital roll-out, and how did it react to the missing link between the projected

[60] Mazzanti, 'Response to Alexander Horwath', 11.
[61] See Chapter Two.

image and its material source? A detour by the standardisation process of digital cinema, and its underlying mathematical concepts, shows how the digitally-projected image was conceived with a photochemical model in mind within the industry, while radically modifying its material source. The next subchapter goes further than what was discussed within the archival community, and offers a complete overview of the intertwined theoretical and technical questions of projected image technologies. This analysis reveals the hidden, potentially unconscious roots of what was discussed more openly by archives, and underlines the interrelations of cinema technologies within their socio-cultural context. In this way, I will seek to uncover technological patterns in the conception and standardisation of digitally-projected image, which go beyond the film vs. digital opposition.

2 Projection Goes Digital

The generalisation of digital cinema did not happen overnight. The first demonstrations go back to the late 1990s,[62] while the basis of scientific discoveries that were then used in different technologies of digital cinema were considerably older. Since the mid-2000s, following the standardisation of D-Cinema, there was a call for the installation of digital projection equipment in European cinemas,[63] and by 2010-2012, many national governments and the EU got involved in funding the acquisition of digital cinema equipment for cinema theatres via different schemes.[64] The so-called digital roll-out was an acceleration of the theatre digitisation process,[65] and it was technically based on a series of standards and recommended practices fixed by the mainstream film industry.

---

[62] Some early demonstrations were presented at Cannes Film Festival and Karlovy Vary Film Festival in 1999.
[63] For example: The European Film Agency Directors, 'Common Declaration in Support of Digital Cinema', October 2006. This declaration was signed by many national film centres in Europe (CNC, Czech Film Chamber, Nederlands Fonds v.d. Film, UK Film Council, etc.)
[64] Reports and statistics of installation of digital cinema equipment are prepared by various entities: national ministries of culture, European Audiovisual Observatory, Media Salles, etc.
[65] For more information, see the following studies on digital roll-out:
Charlotte Crofts, 'Cinema Distribution in the Age of Digital Projection', *Post Script: Essays in Film and the Humanities* 30, no. 2 (July 2011): 82–98; Nicolas Wittwer, 'Revolution numérique? Analyse de l'instauration et de la réception des recommandations et normes techniques du cinéma numérique dans les secteurs de la distribution et de l'exploitation (2004-2012)' (Master Thesis, University of Lausanne, 2012); David Mabillot, 'The Pandora's Box of Dcinema', March 2011, https://www.youscribe.com/BookReader/Index/546578/?documentId=517698; Elisabetta Brunella and Martin Kanzler, 'The European Digital Cinema Report. Understanding Digital Cinema' (Strasbourg: European Audiovisual Observatory, 2011), https://rm.coe.int/the-european-digital-cinema-december-2011/168078b728; Susanne Nikoltchev, ed., *IRIS plus 2010-2: Digital Cinema* (Strasbourg: European Audiovisual Observatory, 2010).
For an early economic study of digital projection, see:
Gilles Le Blanc, 'Innovations numériques, distribution et différenciation : le cas de la projection numérique dans le cinéma', *Entreprises et Histoire*, no. 43 (June 2006): 82–92.

Indeed, projection has always been the most rigidly-standardised (formalised) part of mainstream cinema. Up to the early 2010s, 35mm projection – whose technical details were meticulously standardised – remained dominant in most countries. However, other circuits such as festivals, events, school and community projections as well as some non-Western practices[66] did not necessarily follow the 35mm standard model. Since the end of the 1990s, video and digital technologies were added to the already-diverse alternative projection practices, and by the early 2000s, these practices could be considered as a rival for mainstream cinema. Thus, the dominant Western film industry – led by Hollywood studios – called for a universal D-Cinema standard to be conceived and imposed:

> "It is vital that the result of this change [migration to digital cinema] is a technical infrastructure every bit as standardized as 35mm film."[67]

The D-Cinema standard, which started as a set of Hollywood specifications, was subsequently formalised by the SMPTE and finally certified by ISO (and other normalisation organisations on national and international levels). It imposed digital formats and file structures controlled by strict rules and criteria; just as it had imposed at one time the 35mm format with 4 perforations on each side of the image, and a frame rate of 24 fps for sound cinema.

Digitisation of projection meant three things: firstly, digitisation of the print (the pre-recorded source image), secondly the digitisation of the equipment (a digital server instead of mechanical routes guiding film through towards the light source, plus a digital projector), and finally the digitisation of the light (quantified, discrete luminosity). In this subchapter, I explore first the digitisation of the print, as defined by Hollywood-led coalitions of D-Cinema standards. This will show how it embodied the imaginary of the time of how a projected image should appear from an industrial point of view, and how that coincides with the archival vision. Secondly, in line with archival concerns, I will question the validity of an approach based uniquely on the projected image detached from its materiality, by offering an overview of the diversity of the digital equipment.

2.1 Digital Projection "Prints":[68] Standardising the Compression

Originally, the D-Cinema standard for the digital image was fixed with regards to the characteristics of the photochemically-projected image. Whether within film industry or film

[66] By non-Western practices I'm referring to those prevalent in Africa, Asia or South America. See for example: Benoît Turquety, *The Displacements of Film: Medium, Format, Configuration* (Lüneburg: Meson Press, 2019).
[67] Julian Pinn, 'International Standards – LA Plenary Report', *Image Technology* 89, no. 1 (January 2007): 9.
[68] Here, by digital print I am referring to the digital image inscribed on a carrier. The term "digital print", which sounds like an oxymoron, was indeed used by some industry actors, such as Charles Swartz, *Understanding Digital Cinema* (Burlington and Oxford: Focal Press, Elsevier, 2005).

archives, the discourses opposing film and digital, during the 2000s, stressed heavily on the rather ambiguous concepts of image quality and look, which were never entirely defined. However, on the way to shape the details of D-Cinema, these concepts conveyed the perception of industry actors at the time of how a projected image needed to look and how the digital image projection technologies could achieve it. In what follows, I will draw an analogy between the imaginary of the film industry (and archives), and the technical realities, thanks to a study of the mathematical basis at the heart of digital projection technologies.

In a digital projection workflow, the moving image is encoded into a digital format and provided as such to a server, which decodes it and passes it on to a projector, where the zeros and ones representing the luminosity (and colour information) of pixels are transformed into (quantified) light and projected on a screen. The first step is therefore to prepare an encoded digital image. Remembering the matrixial presentation of an image from Chapter One (Figure 12), an uncompressed digital image is like a grid of pixels which hold values of a particular bit depth (the same for all pixels). This means that each pixel in an uncompressed image is described independently of the others, always occupying the same number of bits. Thus, the size of an uncompressed image file depends upon its pixel count and bit depth and can be high for cinema images. Working with image files of large sizes is complicated, particularly for playback and transfer. Simply put, the larger the file, the higher the amount of digital information (held by pixels) that needs to be transferred or accessed for playback. Encoding, or compression, which can be lossless or lossy, is a series of image processing operations (similar to what I explained in Chapter One), which describes the same image information in a different way, and consequently reduces the file size. While a lossless compression aims to preserve all image information,[69] a lossy compression selects the most relevant pieces of image information (according to its algorithm) to keep and discards what it judges as unnecessary or redundant.

While technically feasible to work with large-size uncompressed images, it was deemed "wildly impractical"[70] within the film industry, as it would require more and more powerful computers to read the higher amount of information at the desired speed. A certain technology of compression needed to be designed and applied, such that it did not interfere with the quality of the projection:

[69] Lossless compression algorithms identify redundancies in the data (in different ways), and code the data based on that. The information can be integrally reconstructed upon decompression, but the code streams of uncompressed and compressed image are not the same.

[70] Peter Symes, 'Compression for Digital Cinema', in *Understanding Digital Cinema*, ed. Charles Swartz (Burlington/Oxford: Focal Press/Elsevier, 2005), 123.

> "Used appropriately, compression has little—ideally nothing—to do with the quality of the final cinematic experience; it is just one of the technologies used in taking the image to the projector."[71]

The desired characteristics of compression, as well as its different possible technological implementations, were extensively debated within the industry and its connected scientific community. If digital cinema were to be widely adoptable, a degree of compression had to be accepted, and this compression needed to fulfil a condition required by the industry:

> "Even though a compression system for digital cinema cannot be totally lossless, it is required that the output be indistinguishable from the input under real theatrical viewing conditions."[72]

Lossless compression did not reduce the file size in a practical way. Paul Read, on behalf of the EDCF, reported in 2004 that an uncompressed 90-minute film at 2950 pixels per horizontal line, amounting to 5.5 Terabytes, could be reduced to 3.5 Terabytes by a lossless compression;[73] which required still too much computer power to be read and decoded.[74] A lossy compression seemed to be necessary, in a way that it would be imperceptible by the human eye. The concept of "visually lossless" was regularly used in professional and scientific discourses working on digital cinema, and was defined with regards to the Human Visual System (HVS), and in the theatrical environment:

> "Visually lossless is understood to mean that the reconstructed moving pictures after decompression shall not be distinguishable from the original by a human observer when exposed to typical viewing conditions in a theatre set-up. This applies to different kinds of material such as live action and computer generated. These conditions include assessment by experienced viewers and projection on a large screen in a typical theatrical environment."[75]

A "typical" theatrical environment is not always defined in the same way, despite the definition of some standards for theatres. Similarly, the "human observer" or "experienced viewers" cannot be perfectly and inclusively modelled by any mathematical formula either. As explained in Chapter Two, there have of course been scientific efforts to model the observer in order to

---

[71] Symes, 121.
[72] Brian McKernan, *Digital Cinema: The Revolution in Cinematography, Post-Production, and Distribution* (New York: McGraw-Hill, 2005), 54.
[73] Read, 'Archiving Digital Media', 150.
[74] This means that if the computer needs to read this data in real-time, it should process around 650 Megabytes of data each second: 3.5 Terabytes/90x60seconds = 648 Megabytes per second (Mbps). In comparison, a 4K YouTube video is normally encoded with a bit rate of around 50Mbps.
[75] Symes, 'Compression for Digital Cinema', 126.

include the influence of the HVS in calculations.[76] A complex (partly unknown) system, the HVS is generally modelled based on empirical suppositions, for example the fact that it is more sensitive to a certain frequency band, or certain colours, or objects against a certain background; but not every aspect of the HVS could be modelled.[77] Without going into the details of HVS, I only underline its diversity and complexity, which indicates how difficult it would be to define one unique "human observer".

In the process of designing a compression algorithm, apart from physical modelling of the HVS, there is also the psychovisual aspect which cannot be neglected, as I mentioned in Chapter Two. The inclusion of psychovisual factors enables a sort of "perceptual coding" in algorithm developments, to pick up the term used by scholar Jonathan Sterne.[78] This means that the compression was to be defined on the basis of a certain psychovisual understanding of human subjects, and the perception that they probably had of a cinematographic image (and at the same time, it was going to form or modify the same perceptions). It should be noted that the human observer of newly-produced films was not necessarily the same as that of archival prints (archives' audiences), although archival discourses did theoretically search for the best possible projected image as well just as did the industry, as explained in the first part of this chapter. The modelling of HVS and perceptual coding are the underlying factors of the concept of visually lossless compression, as desired by film professionals during the 2000s.

The mathematical concepts of lossless and lossy, as evoked in this part, are valid in a continuous mathematical state. When the images are represented and compressed via a digital computer, there is always a degree of approximation even in lossless compression, which practically prevents the perfect recreation of the initial image. A visually lossless compression, which is mathematically not lossless, is even more approximative – but it was desired by film professionals as a necessary compromise. For archives, which looked for a simulation of the original, this compromise towards a sort of an acceptable loss (although claimed visually imperceptible) and its surrounding discourse network seemed to be an early trigger towards a rejection of the new projection technologies. An overview of the standardisation process of digital cinema's compression will show how qualitative impressions, technological approximations and discursive power created what was believed to be a visually lossless

[76] A study of HVS, as well as a bibliography on the subject, can be found in: Kadayam Thyagarajan, *Digital Image Processing with Application to Digital Cinema* (Oxford: Focal Press/Elsevier, 2006), 47–72.
[77] Thyagarajan, *Digital Image Processing with Application to Digital Cinema*.
[78] Sterne, *MP3: The Meaning of a Format*, 17.

projected image, and how that image corresponded (or not) to the archival imaginaries of the time.

Towards a Format Standardisation: DCI Specifications

In its D-Cinema specifications in 2005, the Hollywood-led coalition of the Digital Cinema Initiatives (DCI) defined a specific workflow for mastering and packaging a digital film print which contained different steps from uncompressed master to image on the screen (Figure 25).

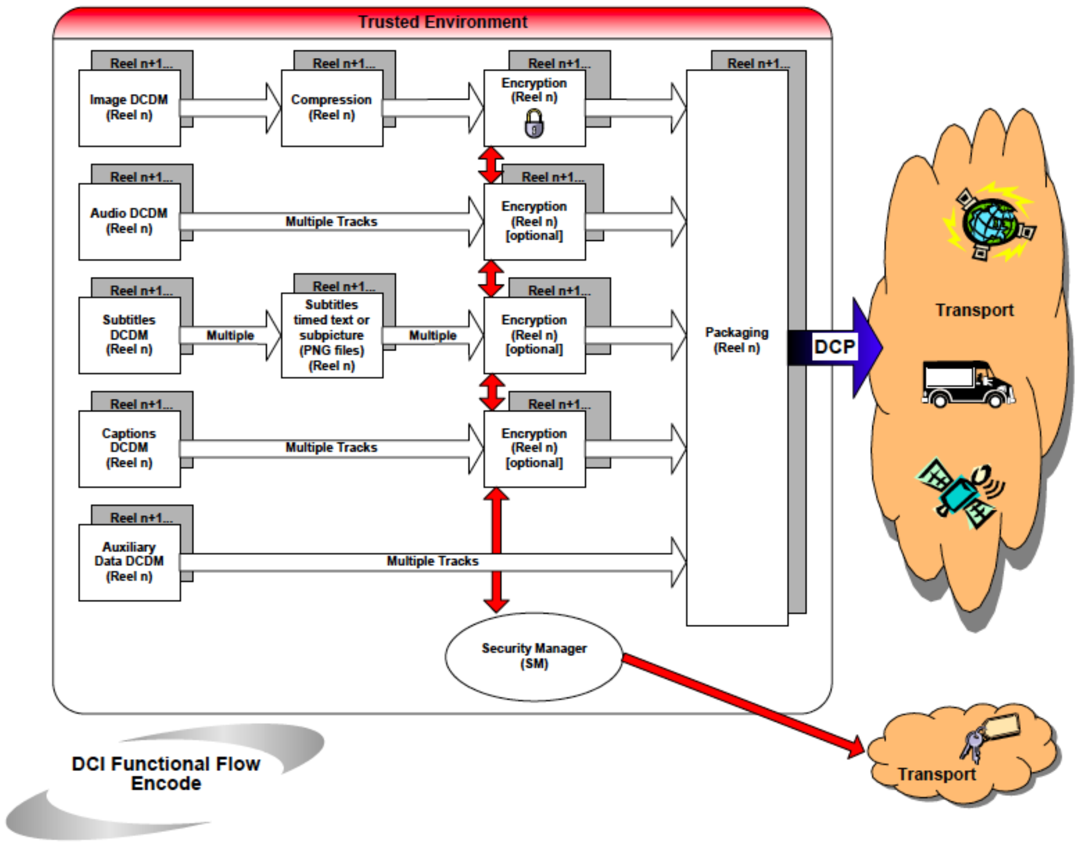


Figure 25 This photo shows how the DCI recommendations brought together and standardised different files needed for a cinema projection: image, sound, subtitles and other types of information. These are all packaged together at the end as the DCP, which is then sent to cinemas.[79]

The workflow could be described with the simple diagram below:

DSM → DCDM → **DCP** → DCDM*[80] → Projected Image and Sound on the screen

Or if only the "image essence"[81] is considered at each of these steps:

Image (any format) → TIFF → JPEG 2000 → TIFF* → Projected Image on the screen

At the first step, the post-produced image, DSM (Digital Source Master), which could be in any format and any compression, is transcoded into DCDM (Digital Cinema Distribution Master)

[79] Digital Cinema Initiatives, LLC, 'Digital Cinema System Specification', V1.0, 20 July 2005, 6.
[80] The * here designates a non-identical reproduction.
[81] A term used in the DCI documents for image content.

alongside audio and subtitle files. The DCDM is basically a folder holding the image, audio and subtitles files, and is not restrictively packaged. In the 2005 document, the image in the DCDM was specified only to be an "MXF-conformant file".[82] MXF being a container, it could wrap several formats in it. In the later revisions of the document, from 2007 onwards, the image format for DCDM was changed to TIFF.[83] But effectively, the DCDM remained not only unrestrictive in its packaging, but also flexible in practice regarding its choice of image format. At the DCDM step, the uncompressed TIFF images go through compression to form the DCP (Digital Cinema Package), the equivalent to a photochemical print, which is distributed to screening venues. In 2005, it was declared by DCI that "the compression standard shall be JPEG 2000".[84] The TIFF images are thus first compressed into JPEG 2000, then packaged in the DCP according to very specific rules and restrictions.[85] When at the venue, the DCP is ingested into the server, where it is unpackaged and decoded, i.e. the JPEG 2000 images are transcoded again back into TIFF. The JPEG 2000 encoding can be lossy or lossless. As the DCI document picked a lossy encoding, the resulting uncompressed TIFF* are not identical to the initial TIFF, but they are claimed to be "visually indistinguishable", as promoted by DCI.[86] Finally, the TIFF* are transformed by the projector into (quantified) light and projected on a screen.

From this brief overview of the DCI specifications, it is clear that the only restrictive part for images in the DCI document is the DCP with its JPEG 2000 compression (as it had been the case with 35mm print before). Of course, this format rigidity, which was supposed to maintain the Hollywood hegemony on the cinema market, was not universally endorsed as it side-lined other practices and technologies of digital projection. This was notably underlined in 2006 by Daniel Goudineau, in a report he prepared for CST and CNC, in which he pleaded for a format polyvalence in order to avoid a monopolisation of the market. He recommended to CNC not to succumb to the temptation of a single standardised format: "in funding schemes, no one compression format should be exclusively preferred, and the polyvalence of servers should be

[82] Digital Cinema Initiatives, LLC, 'Digital Cinema System Specification', 20 July 2005, 12.
[83] It should be noted that TIFF format may also be lossy compressed, but the TIFF version defined in the DCI specifications is indeed the uncompressed "nominal" TIFF with RGB channels. See: Digital Cinema Initiatives, LLC, 'Digital Cinema System Specification', V1.1, 12 April 2007, 14–15.
[84] Digital Cinema Initiatives, LLC, 'Digital Cinema System Specification', 20 July 2005, 23.
[85] This was already the case in the 2005 document, later amendments and standardisation only changed details of this package. For example, the aspect ratio in the beginning was only 2048x1080 (1:1.90) and the frame rate only 24 or 48 fps. These were expanded in the later version to include more possibilities. I am not going into the details of the packaging here, as the packing does not influence the image itself and my discussion here concerns the changes (compressions) the image goes through.
[86] Some differences can in fact be detected between TIFF and TIFF* if they are compared together. But when the TIFF* is projected on a screen (with no points of reference to the original TIFF), it might be more difficult to see the differences.

encouraged".[87] According to him, this hegemony would limit the possibilities that digital technologies could offer in terms of content presentation in cinema theatres. However, he did recognise that such a position would require a larger study of the interoperability of formats and servers.

Important questions can be raised here: despite the voices of discord, how was the use of JPEG 2000 as the compression method for digital prints technically justified by DCI and fervent defenders of a standardised D-Cinema? What goal was to be achieved by this compression? How was the concept of visually lossless compression implemented into the standardised digital cinema? To answer these questions, I will explore the discursive network of the time in order to identify the goal that digital cinema was trying to achieve.

The Sought-After Digital Cinema

Before the standardisation phase, there was a lot of talk about how the digital cinema should and could be. Many possibilities were technically available, just as had been the case for video before. Indeed, analogue video formats were numerous and very often incompatible. This seemed to scare the film industry, as it would lose its market hegemony. On the other hand, the 35mm print was still considered superior technically compared to other image technologies, and it was believed that digital cinema, if it were to be adopted, would have to look sufficiently good, at least as good as the photochemical image. It seemed in fact that the former needed somehow to resemble the latter, or, to be more precise, to a perception of it as constructed within industrial (and archival) imaginary. Indeed, through its past cultural practices, scientific research and technological quests, the film industry had developed an idea of a good projected image which was close to that imagined by archives, formed upon the characteristics of an image projected out of a photochemical 35mm fine-grain print. I will explain here how this projected image was characterised.

From the late 1990s, on many occasions, comparative photochemical and digital projections were organised that explored the new technological possibilities. In 1997, the magazine *Image Technology* (published by BKSTS) reported on a digital projection demonstration with "cinema potential", even if the "quality [didn't] compare" yet; hoping for a "video projector that could give the same quality and brightness of 35mm".[88] Visibly, the quality of the projected image

[87] Daniel Goudineau, 'Adieu à la pellicule ? Les enjeux de la projection numérique' (Paris: CNC, August 2006), 35. My translation.

[88] Jim Slater, 'Digital Projection Comes to the Hippodrome', *Image Technology* 79, no. 8 (September 1997): 26–28.

here was understood in its scientific, technical meaning, based on its clarity and sharpness (and did not refer to the cultural and aesthetic aspects of the term). The same was expected in further demonstrations, such as the DLP technology by Texas Instruments (TI) in 2001, where it was stated that TI was collaborating with filmmakers and cinemas to ensure film-like colours, high contrast, high brightness and perfect sharpness.[89] Moreover, in the early days, the 35mm print was often compared with a digital video image, such as DVD. The first demonstrations of digital projection had coincided with the start of the generalisation of DVD as a home video medium. The DVD videos were encoded in a standardised format called MPEG-2, whose compression could make the image look pixelated, and the movements discontinuous. Therefore, there was a worrying concern among the film professionals that a digital print may create projected images looking like DVD (MPEG-2 or other similar digital video formats). This point was also shared by archivists, such as Robert Daudelin and Jose Manuel Costa, who expressed their dissatisfaction with the look provided by DVD, in that it was far from the photochemical image, "in terms of light, transparency, contrast, even if the distinction seems imperceptible, even if we do not yet know how to describe it completely".[90] I will come back to the technical details of MPEG-2 further down.

The sought-after characteristics of digital cinema were formulated as follows by Steven Morley (Qualcomm) in 1998:

> "This system needs to project the image with adequate brightness, resolution, contrast, colorimetry calibration and range, and sharpness or it is not worth considering. A tremendous debate exists about what is 'good enough'. Certainly if you take pristine film stock and perform laboratory measurements for densities and resolutions you can generate some pretty great specifications. However, let's determine the goal of our proposed Digital Cinema system to be 'to provide the image quality of a first run motion picture on 35 mm film stock projected on opening night at a premier theatre'."[91]

The reference for image quality that digital cinema needed to achieve was desired to be the image projected from a "pristine" (sharp, clear and fine-grain) and undamaged 35mm print. Morley suggested that the "good enough" digital image could be obtained with a scientific comparison with such a film image, as had also been proposed by Paul Read for restorations in 1996. As explained in Chapter Two, this idea was pursued but concretely, quality comparison

[89] Jim Slater, 'DLP Back Projection from TI', *Image Technology* 83, no. 3 (April 2001): 13–16.
[90] See the discussion on DVD between Costa and Daudelin, 'De l'avenir des cinémathèques', 14. My translation.
[91] Steven A. Morley, 'Making Digital Cinema Actually Happen – What It Takes and Who's Going to Do It' (140th SMPTE Technical Conference and Exhibit, Pasadena, CA, 28 October 1998).

between film and digital did not yield concluding results, whether for the image on film or the projected image. In any case, it was believed within the industrial and archival networks that whether projected from film stock or digitally, the image look needed to remain constant and look similarly clear, sharp and bright. At IBC 2002, demonstrations of digital cinema reiterated the desire that the digitally-projected image should look more like a projected film image in terms of brightness, contrast, sharpness, resolution[92] and the "filmic look".[93] The latter indicated probably characteristics such as graininess but also maybe the slight unsteadiness and flicker, which were believed by some archivists to be part of the mechanical process of image projection from film.[94] A criticism was pointed out that the digital black was not black enough as of then.[95] In 2005, Brian McKernan (specialist journalist for Screen Digest in London) noted that for recreating black, film remained "king of the hill", thus:

> "Our ideal digital cinema imager, then, must be able to reproduce as many shades of gray as possible, and do it while not compressing any part of the projected grayscale. That means that 'black' is black, not a low gray. It also means that we should be able to clearly see the nuances between several shades of 'near' white, not a washed-out bright area without detail."[96]

This statement appreciates nuances and details in different colour shades of an image, which might disappear if the colours were (too) compressed: a possible digital artefact if the compression was not visually lossless. The recreation of black was already problematic through photochemical means for archives, which had noticed that nitrate blacks could not be as "deep" and "saturated" when reproduced on modern film stock.[97] It seemed that the vision of how black should be in a projected image had already been modified within the industry to a lighter black, compared to what archives would have hoped for, which corresponded to nitrate film stock. It is certain that black was differently reproduced and projected through different technologies (whether film or digital) in cinema history, and when looking to recreate the desired look of a

---

[92] See: Vittorio Baroncini, Henry Mahler, and Matthieu Sintas, 'The Image Resolution of 35mm Cinema Film in Theatrical Presentation', *SMPTE Motion Imaging*, February 2004, 60–66.
[93] Jim Slater, 'IBC D-Cinema Day', *Image Technology* 85, no. 1 (February 2003): 29.
[94] For example, Paolo Cherchi Usai calls the unsteadiness the "breathing effect", and considers it as normal for film projection: 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 (Chichester: John Wiley & Sons, Ltd, 2012), 536. See also: Paolo Cherchi Usai, *Silent Cinema: A Guide to Study, Research and Curatorship* (Bloomsbury Publishing, 2019), 66.
[95] Jim Slater, 'Digital Cinema: A Major Theme at IBC 2002', *Image Technology* 9, no. 84 (November 2002): 24.
[96] McKernan, *Digital Cinema: The Revolution in Cinematography, Post-Production, and Distribution*, 162–63..
[97] Lameris, *Film Museum Practice and Film Historiography. The Case of the Nederlands Filmmuseum (1946-2000*, 92.

projected image, these nuances were considered important by industry and archives; and that, in different ways.

In 2004, an editorial piece of *Image Technology* described the D-Cinema standards as a way to ensure the highest quality possible for cinema in the future, like 35mm print.[98] EDCF also expressed the need to achieve at least a 35mm quality via digital projection:

> "Better quality than 35 mm has been a common request from exhibitors, and this has led to several attempts to technically define what this means. It is certain that digital cinema systems of today can yield a quality at least as good as a commercially available release print."[99]

This point was raised by Torkell Saetervadet at the FIAF Congress 2006, where he presented the D-Cinema standards in progress, and stressed the fact that industry was pushing for "better-than-film" projection standards at 4K.[100] This quest for supposedly higher projection quality, again in the scientific understanding of higher sharpness and clarity, was an important drive in DCI's work on D-Cinema specifications: "Among the unanswered questions is whether standards set for digital projection will be able to match or exceed the best possibilities of film".[101] DCI specifications clearly relied on the quality comparison with photochemical film projection, judging that digital technologies in 2005 had achieved a level that could produce similar projected images compared to those from 35mm:

> "A number of significant technology developments have occurred in the past few years that have enabled the digital playback and display of feature films at a level of quality commensurate with that of 35mm film release prints."[102]

Further in the document, DCI declared that a fundamental requirement of a digital cinema system is that it "shall have the capability to present a theatrical experience that is better than what one could achieve now with a traditional 35mm Answer Print"[103]. An answer print was struck directly from a film negative. Being only one generation removed from the negative, it had a superior technical quality compared to most release prints. The latter were often three generations removed from the original negative and at each generation, they had lost some details and sharpness because of the process of photochemical duplication. What DCI hoped to

---

[98] Jim Slater, 'Standards - Making Sure That WYSIWYG', *Image Technology* 86, no. 6 (November 2004): 4.
[99] Svanberg, *The EDCF Guide to Digital Cinema Production*, 140.
[100] As recounted by Walsh, 'Technical Symposium - FIAF Congress 2006 São Paulo: Film Archives in Transition', 72.
[101] Bob Fisher, 'Tomorrow's Technology – the ASC and DCI Join Forces to Set Standards for Digital Projection', *American Cinematographer* 85, no. 1 (January 2004): 121–22.
[102] Digital Cinema Initiatives, LLC, 'Digital Cinema System Specification', 20 July 2005, 1.
[103] Digital Cinema Initiatives, LLC, 3.

achieve was a digital print whose projected image would present a significantly superior technical quality in comparison with 35mm prints. But the document did not develop further how these specifications would achieve such a goal, nor included a scientific comparison to prove its point. The question can be raised if the quality of a digitally-projected image could be equal to that of a projected photochemical image (or superior to it)? In fact, from the arguments I have presented in this work, it becomes clear that the two, despite the efforts to make them look similar, do present differences which are related to their different technological frameworks (of production and projection). They can thus be hardly compared in a definitive manner, let alone look exactly alike. The comparison was rooted greatly in a subjectivity related to the perception of projected images, and the industry tried to provide digital images which would be perceived in a similar way by most audiences as the 35mm projected images, the standard of cinema up to then.

Another important point coming back in the discourses was the fact that digital images could always maintain their "first-run" quality. In his 2006 report for CNC, Daniel Goudineau downplayed the supposed ability of digital projection to offer a noticeable quality gain – in the eyes of spectators – compared to photochemical film projection, although that was, as mentioned above, among the demands by professionals. But he appreciated enthusiastically the fact that the digitally-projected image could not get damaged. Indeed, after several runs, even the best photochemical prints showed signs of wear and tear, a problem that would be solved thanks to digital projection. Goudineau wrote:

> "Not only the risk of scratched prints disappears definitively, but also we are certain of having the same spectacle during the whole exhibition of film."[104]

The more a photochemical print is shown, the more it is degraded because of the scratches, dirt or other types of damages appearing on the image. A digitally-projected image, however, would always look the same.[105] This way, all cinemas, projections and audiences would benefit from a constant "first-run" quality.[106] The wear and tear traces, which did not appear on a digital-born image, became gradually a distinctive sign of films shot on film, although film archives had always underlined the film's historically scratch-less image in the beginning of its run. In fact, archives, thanks to their restoration activities, had often tried to remove the signs of wear and tear on the images, or reduce their visibility, as explained in Chapter One. Engraved in the

---

[104] Goudineau, 'Adieu à la pellicule ? Les enjeux de la projection numérique', 8. My translation.

[105] Of course, this discourse does not consider the problem of digital damages which can happen due to several reasons: bit rot, file corruption, etc. I will come back to this point in Chapter Four.

[106] Slater, 'DLP Back Projection from TI', 14.

material and leaving traces on the visual aspect, these signs revealed the film's materiality, but had long been designated as unwanted effects by most archives. Despite the voices of discord from the archival community, the association between film and wear and tear traces was reinforced over time up to a point that it became an artistic effect in some productions.[107] This is what scholar André Habib has ironically described as "effet-pellicule" (film effect).[108] However, in opposition with digital projection, such discourses somehow took a U-Turn at times within the archival community, as explained playfully by David Walsh:

> "So are we perhaps in love with all those comforting spots and scratches which tell us that the image derives from some flawed, but somehow natural, process?"[109]

Of course, this view did not altogether replace the general view that, firstly, film – especially new, well-conserved or restored film – did not show signs of wear and tear; and secondly, it was often desired that the signs of wear and tear be removed in industrial or archival interventions (through restoration). But it demonstrates how these signs could be understood and appreciated differently, as visual traces of the film's history. A digitally-projected image would not accumulate any historical sign as these, and that, for archivists such as Cherchi Usai, indicated a loss of historicity which was embedded into the photochemical film projection system, but lacked in a digital one.[110]

In sum, the industry was aiming for an ideal projected image, having the model of a perfect (imaginary) first-run 35mm photochemical print in mind. It was thus believed that the digital image should be made to look acceptable/preferable for cinema projection. Departing from these qualitative characteristics, how did the film industry settle on a specific technical standard for projected images? How does the JPEG2000 format embody these claimed ideals?

---

[107] For example, in David Fincher's *Mank* (2020, Netflix): "Fincher made 'Mank' using digital cameras, but the director and his creative team took pains to make it appear as though it was shot on celluloid by digitally scratching up the images so that they looked like film grade.": Brent Lang, 'Magnificent Obsession: David Fincher on His Three-Decade Quest to Bring "Mank" to Life', Variety, 2020, https://variety.com/2020/film/news/david-fincher-mank-netflix-citizen-kane-1234834134/ accessed 20 November 2020.

[108] André Habib, 'Rayures, poussière, grain. "L'effet-pellicule" au temps du numérique, ou la survivance simulée de l'involontaire (un essai de reconnaissance)', in *La haute et la basse définition des images. Photographie, cinéma, art contemporain, culture visuelle*, ed. Franceso Casetti and Antonio Somaini, Images, médiums (Sesto S. Giovanni: Mimesis, 2021), 125–42.

[109] Walsh, 'Do We Need Film?'

[110] See for example: Cherchi Usai et al., *Film Curatorship: Archives, Museums and the Digital Marketplace*.

JPEG 2000, the Saviour of Cinema?

JPEG 2000, an image format developed by the Joint Photographic Experts Group[111] from 1997, was standardised in 2000. Succeeding the already existing JPEG format (standardised in 1992), JPEG 2000 was not only aiming to supersede its predecessor in compression quality,[112] but also offer scalability and accessibility:[113]

> "It is motivated primarily by the need for compressed image representations which offer features increasingly demanded by modern applications, while also offering superior compression performance."[114]

It should be noted that an image compression standard is generally not developed in order to replace the previous standards. Different standards may and do co-exist. The standardisation of JPEG 2000 – which was achieved in a general scientific context unrelated to cinema – did not drive out JPEG (or any other previous image format), nor did it aim to do so. Each image standard may have its own specific use cases, as explained by JPEG 2000 developers:

> "In some cases, particularly those in which scalability and accessibility are not sought-after features, the use of JPEG2000 in preference to JPEG or JPEG-LS may be likened to using a sledge hammer to swat a fly."[115]

During the early 2000s, JPEG 2000 was clearly not the only contender for digital cinema compression. Its main competitor was a digital video format of MPEG family, either MPEG-2 (standardised in 1997, and since then successfully implemented in DVDs) or MPEG-4 (in development around the same time as JPEG 2000 and by many of the same experts[116], see Figure 26).

---

[111] JPEG is the joint working group between ISO, IEC and ITU, which are all standardization bodies. More information on the group's activities can be found on their website: https://jpeg.org/index.html, accessed 2 August 2020.
[112] To reduce the loss generated by compression.
[113] David Taubman and M. Marcellin, *JPEG2000 Image Compression Fundamentals, Standards and Practice* (New York: Springer Science+Business Media, 2002), 21.
[114] Taubman and Marcellin, preface, xvii.
[115] Taubman and Marcellin, preface, xviii.
[116] For example, Touradj Ebrahimi (EPFL) who has been the chair of JPEG 2000 standardisation group, also participated in the standardisation process of MPEG-4.

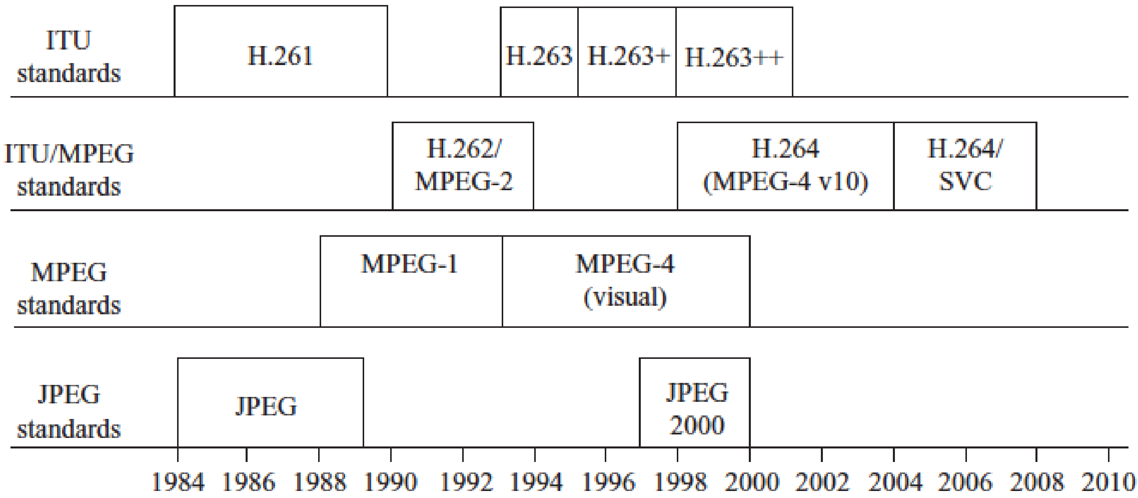


Figure 26 Timeline of some format standardisations for still and moving images.[117]

Another possibility was Motion-JPEG, which compressed every single image in JPEG and wrapped them all together. In addition to these open standards, proprietary alternatives were also in development by companies such as Qualcomm (ABSDCT format[118]), QuVis (QPE format) and Dalsa (L^3 [119] format), but which pursued a different financial goal, that of winning a share in the new market of digital cinema equipment. The standardisation, however, intended "to find an 'open' higher-end compression algorithm for digital cinema".[120] Non-proprietary formats seemed to be preferred, countering the format multiplicity and favouring open standardisation. The diverse formats were thus compared for their openness, but also, specifically, their compression algorithm: which format could provide a projected image more similar to the model that the industry had in mind, while increasing compression efficiency (and reducing the file size as needed)?

In fact, up to 2004, MPEG-2 seemed to be the frontrunner in the race to become Digital Cinema's compression standard. The popularity of MPEG-2 came from two different research directions:

---

117 Mohammad Ghanbari, *Standard Codecs. Image Compression to Advanced Video Coding*, 3rd ed., IET Telecommunications Series 54 (London: The Institution of Engineering and Technology, 2011), 5.

118 Ann C. Irvine and Kadayam Thyagajaran, Hybrid Lossy and Lossless Compression Method and Apparatus, US Patent 2003/0012431 A1, issued 16 January 2003. It should be noted that the ABSDCT compression method was one part of a complete digital cinema system that was devised by Qualcomm (including distribution and projection). A description of the whole system is given by the following paper: J. Hose et al., 'Data Transport and Processing in a Digital Cinema Theater', *SMPTE Motion Imaging Journal* 111, no. 12 (December 2002): 600–608.

119 DALSA's compression scheme, L^3 was a proprietary lossless compression scheme originated with its digital camera, DALSA Origin.

120 Patrick von Sychowski, 'The Digital Future of Cinema – So Close, and Yet so Far Away', in *The EDCF Guide to Digital Cinema Production*, ed. Lasse Svanberg (Burlington/Oxford: Focal Press, 2004), 134.

- Firstly, the research for video coding and standardisation for use in television, notably for HDTV.[121] HDTV, which did exist in analogue form as well, gained more momentum with the digital compression methods and most notably thanks to the development of Discrete Cosine Transform (DCT) by Nasir Ahmed (et al.) in 1974.
- Secondly, the research for complete electronic production workflows, most notably for cinema post-production. The MetaVision project by Snell & Wilcox was an example of research in this direction, where compression schemes were explored which could be suitable for the whole chain from production to distribution. This project proposed a modified MPEG-2.[122]

MPEG-2 (and subsequently MPEG-4)[123] were pointed out as a possibility for D-Cinema by SMPTE DC28 group and MPEG ad-hoc group on digital cinema,[124] the latter carrying out tests and comparisons of compression algorithms presented by the former. In the European context, the MPEG-2 compression also had supporters to become D-Cinema standard. Some studies on "Electronic Cinema" around the turn of the century were indeed focused on MPEG compression.[125] At an IEE Conference in 2003, co-organised by Snell & Wilcox in London, called "Projecting the Digital Future of Cinema", MPEG-2 was championed by Peter Wilson (EDCF/Snell & Wilcox) as an "open-standard", "proven & understood" and available easily.[126] Despite this advocacy, the MPEG formats did not seem to convince everyone. At the IEE conference, it was stated that "some [perceived] D-Cinema as HDTV (big TV in a theatre); not film-like presentation".[127] There had also been some criticism to MPEG-2 prior to that, both

[121] There are numerous studies which discuss the use of MPEG-2 compression for television from the mid-1990s. See for example: Barry G. Haskell, Atul Puri, and Arun N. Netravali, *Digital Video: An Introduction to MPEG-2* (New York: Springer, 1996).
[122] See: S. Andriani et al., 'Comparison of Lossy to Lossless Compression Techniques for Digital Cinema' (2004 International Conference on Image Processing, 2004. ICIP '04., Singapore, 2004), 512–16. Note that in this paper the term Digital Cinema is not restricted to digitally-projected images but includes an all-digital capture-to-distribution workflow.
[123] See: Thomas Wiegand et al., 'Overview of the H.264/AVC Video Coding Standard', *IEEE Transactions on Circuits and Systems For Video Technology* 13, no. 7 (July 2003): 560–76.
[124] Jianfen Zeng and Liang Fan, 'Video Coding Techniques for Digital Cinema' (2004 IEEE International Conference on Multimedia and Expo (ICME), Taipei, 2004), 415–18.
[125] For example, the CyberCinema project in 1998, proposed the use of MPEG-2 HDTV signals for electronic cinema projection. See: Wolfgang Ruppel et al., 'A DVB-Compliant Electronic Cinema Solution', in *140th SMPTE Technical Conference* (Los Angeles, CA, 1998).
[126] Peter Wilson, 'Compression Mastering for Digital Cinema' (IEE Conference: Projecting the Digital Future of Cinema, London, 18 November 2003).
[127] Man Nang Chong, 'Safeguarding the Investment in D-Cinema' (IEE Conference: Projecting the Digital Future of Cinema Conference, London, 18 November 2003). In 2003, the term D-Cinema was not referring yet to the standardised DCI-led digital cinema, but to the in-use formats at the time, such as MPEG-2.

indirectly (by focusing on the differences between film image and DVD image in projection) and directly:

> "MPEG-2 is an established worldwide standard that supports 4:2:2 video formats all the way up to HDTV. The standard is very flexible, well understood by legions of engineers around the world, and supported by a large number of relatively inexpensive chipsets, software, and other off-the-shelf technology. There is also a worldwide organization that supports and maintains the standard. There is some resistance to the use of MPEG-2 due to certain dynamic range, resolution, and colorimetry limitations; MPEG-2 may also be too closely linked with the idea of 'television' to be accepted as a standard for true 'cinema-quality' applications."[128]

What seemed to bother the film professionals most, was the fact that MPEG-2 compression gave a television-like look to the image which – given the long-term rivalry of cinema and television and its economic implications – did not appear ideally suited. The television-like image, in this context, englobed not only broadcast television, but also the new home entertainment (DVD) and other digital video applications visualised via a computer (i.e., not projected). This was also mentioned by archivists; for example, Robert Daudeling, in discussion with Jose Manuel Costa, claimed that even an "excellent DVD projection" is not "cinema".[129] I will underline here some of the MPEG-2 characteristics which create visual and conceptual differences with film. Firstly, it is important to underline that MPEG-2 is a "generic" format, allowing for several profiles with different settings (for instance bitrate, colour encoding, etc),[130] which all have limitations. For instance, the format encodes the RGB colour information (the densities of each red-green-blue colour channels) into YUV (luminance and chrominance components),[131] and it performs subsampling on the chrominance (UV). In decompression of the video signals in playback, this could make colour nuances disappear, which, as noted above, were considered quite important in the desired look of the projected image. Secondly, as noted before, the MPEG-2 compression,[132] based on DCT, operates on blocks of images, creating a

---

[128] Hugh R. Heinsohn, 'Revelations on the Coming of Digital Cinema', *SMPTE Journal* 109, no. 10 (October 2000): 802.
[129] Costa and Daudelin, 'De l'avenir des cinémathèques', 14.
[130] P. N. Tudor, 'MPEG-2 Video Compression', *Elctronics & Communication Engineering Journal*, December 1995, https://web.archive.org/web/20110831043337/http://www.bbc.co.uk/rd/pubs/papers/paper_14/paper_14.shtml.
[131] Chrominance denotes the colour information of the video, while the luminance indicates its brightness.
[132] For more information on the MPEG-2 compression, see: Dragos Ruiu, 'An Overview of MPEG-2', 1997, https://literature.cdn.keysight.com/litweb/pdf/5966-1031E.pdf, accessed 7 August 2020.

visual impression of pixelisation, which did not correspond to the impression of 35mm projected image as the industry had in mind (with its own random grainy structure, defining its look). Thirdly, MPEG-2 compressed the images not only spatially, but also temporally. Therefore, the principle of temporally-discrete images that existed on a film strip could not exist for MPEG-2 compression. This characteristic was in fact deemed as an advantage by some early technical discourses,[133] but the industry, as explained in Chapter Two regarding 24p cameras, seemed to appreciate the temporally discrete images as a distinct characteristic of cinema. By temporally compressing the images, access to each frame is prevented, and that goes against the principles of editing in cinema as had been established since very early.

While SMPTE DC28 and MPEG group were working on standardisation of MPEG formats, they also launched a "Call for proposals for Digital Cinema" in March 2001. Many subsequent papers responded to this call. Several compression algorithms were proposed, generally in two main categories of DCT-based (such as Motion-JPEG, MPEG, ABSDCT) or wavelet-based (JPEG 2000, MC-EZBC,[134] QPE).[135] Every compression algorithm created its own digital image look, whether projected or visualised on a computer screen. As I will underline further down, this look could be closer or further to what the reigning imaginary of the time considered as an ideal projected image look. Looking for open standards, the industry did not widely embrace proprietary formats such as ABSDCT and QPE in its considerations. The DCT-based methods were generally met with mixed reactions as explained above with regards to MPEG-2 because of their specific pixelated look and other disadvantages. Moreover, as noted above, there was also a tendency to keep the frames temporally intact. Fulfilling these characteristics, JPEG 2000 seemed to be the most viable open image compression at the time. It compressed the digital frames individually, did not do chroma subsampling; and, thanks to its wavelet compression scheme, it could also remedy the shortcomings of DCT-based methods in spatial compression. In order to explain how JPEG 2000 technically achieved the ideal of digital cinema as imagined at the time, I will detail how DCT and wavelet compressions function, in

[133] Wilson, 'Compression Mastering for Digital Cinema'.
[134] The MC-EZBC was a wavelet-based video compression algorithm, but it also made temporal compression in order to reduce temporal redundancies. In this sense, it resembled MPEG algorithm by coding all images together and not individually. See: Peisong Chen and John W. Woods, 'Video Coding for Digital Cinema', in *Proceedings of the 2002 International Conference on Image Processing* (ICIP 2002, Rochester: IEEE, 2002), 749–52.
[135] A good summary of these methods can be found in the following paper: Zeng and Fan, 'Video Coding Techniques for Digital Cinema'. The paper itself proposes also a novel algorithm, AVS, which was developed and standardised in China in 2002-2004.

an attempt to provide one possible scientific definition of the qualitative much-debated look of the digitally-projected image.

Discrete Cosine Transform (DCT), developed by N. Ahmed with the collaboration of T. Natarajan and K. R. Rao, was introduced in 1974 in the field of image processing, as a specific form of Digital Fourier Transform (DFT) which was easier to compute.[136] Roughly speaking, DFT decomposes a signal into its frequency components by expressing the data as the sum of a series of cosine and sine functions oscillating at different frequencies and with varying magnitudes. The DCT expresses the data only as the sum of a series of cosine functions. When applied to images (in the form of a matrix), the image pixels are described by their spatial frequencies and magnitudes instead of their positions. The compression is based on the fact that image pixels visually resemble their neighbouring pixels: mathematically this means that the values of neighbouring pixels are correlated with each other. For instance, in the uncompressed image of Figure 27, most of the pixels which constitute the pavement have almost the same white-ish light grey colour, with tiny differences. When compressed with DCT, instead of having a matrixial representation where each pixel holds its own value, the image is represented as a distribution of densities (mathematically uncorrelated). That is to say; instead of saying that pixel no. 1 holds the value X (white-ish light grey), pixel no. 2 holds the value X, pixel no. 3 holds the value X, etc; it is said that the value X corresponds to pixels no. 1, 2, 3, etc. The compression gathers very close densities together and assigns one value to them all. Depending on the number of cosine functions with varying phase and magnitude that are used, the compression can become more precise. Figure 28, which has gone through a DCT-based JPEG compression, shows what this compression yields visually. As it can be noticed, the pavement has now become pixelated. In fact, the pixels constituting the pavement which had almost the same grey level (density), have been assigned the exact same value, and the slight variations have disappeared entirely because of the compression. That is why pixel blocks of the same grey levels have been formed.

[136] Nasir U. Ahmed, T. Natarajan, and K.R. Rao, 'Discrete Cosine Transform', *IEEE Transactions on Computers* C–23, no. 1 (January 1974): 90–93.

Figure 27 A digitised frame from the film *Charles mort ou vif* (Alain Tanner, Switzerland, 1969). The original DPX image has been transcoded to TIFF in order to be visualised in the thesis. Lossless image. Courtesy of Cinémathèque suisse.

Figure 28 The same digital frame of *Charles mort ou vif* as a DPX, has been transcoded here into a lossy JPEG format, which uses DCT compression. See how the image has become pixelated. The compression has been pushed too far in order to show better the pixelisation artefact (example created with XnView software).

In order to apply DCT to an image, the image is partitioned into non-overlapping blocks, whose size, for standard DCT, is 8x8 (thus 64 pixels). The DCT matrix (Figure 29), an 8x8 matrix of cosine waves with different frequencies and magnitudes (which are called DCT basis functions), is applied to each block separately, and this way, the source block is encoded into a linear combination of the DCT matrix. Each pixel block of the image is thus described by the sum of 64 cosine waves. In some modifications of DCT, the blocks can be varying in size according to the visual information in the image (adaptive block-size DCT).[137] In the DCT compression method, the image is thus thought of as a collection of pixel blocks. The pixel, as the constructing element of the digital image structure, occupies an important place in the conception of these algorithms. The whole compression scheme is based on how neighbouring pixels correlate, and on partitioning the image into small blocks of pixels to the number of DCT coefficients (cosine waves). The idea behind such a compression is that the image is a grid structure, reducible to its constructing elements, and manipulable at that level.

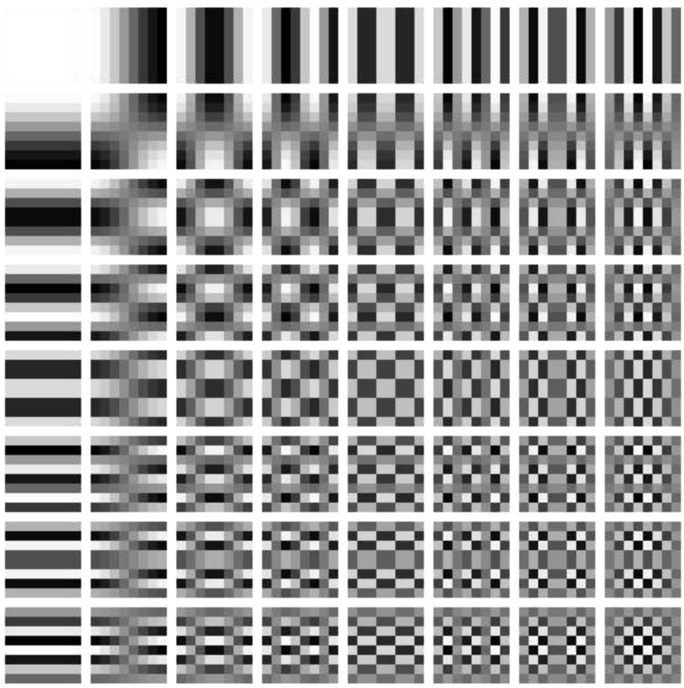


Figure 29 The DCT Matrix. Each of these pixels correspond to one Cosine function with a specific phase and amplitude.

From the early 1980s onwards, digital image processing proposed a different vision of image compression which considered the image as a whole, rather than a pixel grid structure. This vision proposed the image as a function of its resolution and scale and imagined a vertical "deep structure" for the image, including several "projections" of the image at different resolutions.

[137] Javier Bracamonte, Michael Ansorge, and Fausto Pellandini, 'Adaptive Block-Size Transform Coding for Image Compression', in *1997 IEEE International Conference on Acoustics, Speech, and Signal Processing* (Munich, 1997), 2721–24.

Resolution here is understood only as pixel count in a digital image; and I am using the term as it was used in these studies. These derived images at different levels of resolution are all related to one “original” (primal) image, differing only in one parameter (resolution), as shown by Figure 30. The family of images forms a pyramid, where on the bottom there is the original image, and at each upper level, a subsampled and blurred image.[138] The pyramid structure is conceptually at the basis of wavelet transforms.

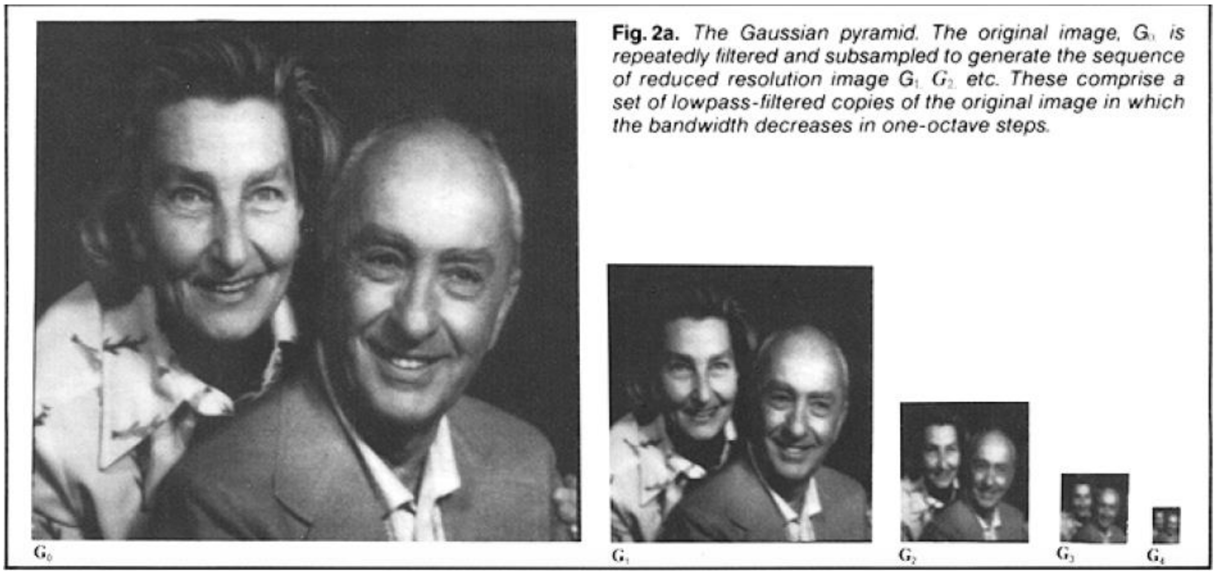


Figure 30 Pyramid images. The whole image is conserved and treated together in this case, but at each level the definition is lower.[139]

The development of wavelet transforms followed the work of Nasir Ahmed on DCT as a data-compression algorithm, where the block-based DCT was replaced with wavelets. In this method, the signal representation was based on small finite wave-like oscillations instead of cosine waves. There are different types of wavelet transforms and Discrete Wavelet Transforms (DWT). The first wavelet transform, albeit not bearing this name initially, had been described in 1909 by Alfred Haar and was called the Haar Transform.[140] Then, continuous wavelet transforms were developed in the 1970s (for sound signals) and later, in the 1980s, the name wavelet was coined by French geophysical engineer Jean Morlet. The field was then expanded

[138] See notably: E.H. Adelson et al., ‘Pyramid Methods in Image Processing’, *RCA Engineer* 29, no. 6 (November 1984): 33–41; Edward H. Adelson and Peter J. Burt, ‘Image Data Compression with the Laplacian Pyramid’, in *Proceedings of the Pattern Recognition and Information Processing Conference* (Dallas, Texas, 1981), 218–23; Peter J. Burt and Edward H. Adelson, ‘The Laplacian Pyramid as a Compact Image Code’, *IEEE Transactions on Communications* 31, no. 4 (April 1983): 532–40; Jan J. Koenderink, ‘The Structure of Images’, *Biological Cybernetics*, no. 50 (1984): 360–70.
[139] Adelson et al., ‘Pyramid Methods in Image Processing’, 34.
[140] Alfred Haar, ‘Zur Theorie der orthogonalen Funktionensysteme’, *Mathematische Annalen* 69 (1910): 331–71.

by researchers Stéphane Mallat,[141] Yves Meyer,[142] and Ingrid Daubechies.[143] The latter developed the 9/7 DWT which was some years later selected by the JPEG Committee as the standard for lossy compression of JPEG 2000. She credited the image pyramid concepts as the inspiration for wavelets and multiresolution analysis:

> "In fact, ideas related to multiresolution analysis (a hierarchy of averages, and the study of their differences) were already present in an older algorithm for image analysis and reconstruction, namely the Laplacian pyramid scheme of P. Burt and E. Adelson."[144]

It should be noted that the wavelets in the beginning were not necessarily developed for images, but as more of their characteristics were discovered, they became interesting for application in image processing:[145]

> "Wavelets allow complex information such as music, speech, images, patterns, etc. to be decomposed into elementary form, called building blocks (wavelets). The information is subsequently reconstructed with high precision."[146]

The wavelets interested the JPEG group in the late 1990s for image compression and the JPEG 2000 standard was born out of this in 2000. The early published papers on JPEG 2000, such as the work of two pioneers of the format, David S. Taubman and Michael W. Marcellin, did not mention digital cinema at all, but they listed the advantages of the format, notably "scalability", "improved compression efficiency", and "the ability to work with truly enormous images without breaking them into independently compressed tiles". [147] In the Summer of 2004, DCI selected JPEG 2000 Daubechies 9/7 wavelet transform, with the whole image as one tile, as the compression standard for D-Cinema. According to Marcellin and Ali Bilgin:

> "DCI wanted a compression algorithm that was an open standard, so that multiple hardware manufactures would be able to build digital cinema systems. The compression

[141] S. G. Mallat, 'A Theory for Multiresolution Signal Decomposition: The Wavelet Representation', *IEEE Transactions on Pattern Analysis and Machine Intelligence* 11, no. 7 (July 1989): 674–93.
[142] Yves Meyer, 'Orthonormal Wavelets', in *Wavelets*, ed. Jean-Michel Combes, Alexander Grossmann, and Philippe Tchamitchian, Inverse Problems and Theoretical Imaging (Berlin, Heidelberg: Springer, 1989), 21–37; Yves Meyer, *Wavelets and Operators: Volume 1* (Cambridge: Cambridge University Press, 1992).
[143] Ingrid Daubechies, *Ten Lectures on Wavelets* (Philadelphia and Pennsylvania: Society for Industrial and Applied Mathematics, 1992); Ingrid Daubechies, 'Orthonormal bases of compactly supported wavelets', *Communications on Pure and Applied Mathematics* 41, no. 7 (1988): 909–96.
[144] Daubechies, 'Orthonormal bases of compactly supported wavelets', 5.
[145] For history of wavelets, see:
Lokenath Debnath, 'Brief Historical Introduction to Wavelet Transforms', *International Journal of Mathematical Education in Science and Technology* 29, no. 5 (1998): 677–88.
[146] Debnath, 686.
[147] David S. Taubman and Michael Marcellin, 'JPEG 2000: Standard for Interactive Imaging', *Proceedings of the IEEE* 90, no. 8 (August 2002): 1336–57.

algorithm needed to support high bit depth (e.g., 12 bits per color component). It also needed to support the X'Y'Z' color space without chroma subsampling. Significantly, the compression algorithm needed to support both 2K and 4K resolution projectors from the same file. JPEG2000 satisfies these requirements and more."[148]

By a look at the main part of the JPEG 2000 compression, its wavelet-based transforms,[149] I aim to propose an explanation of how the requirements of the DCI were achieved with this standard, compared to the previous DCT-based standards. Unlike DCT, which decomposes the image signal into its frequency components, the DWT decomposes the image signal into its frequency and location components (Figure 31).

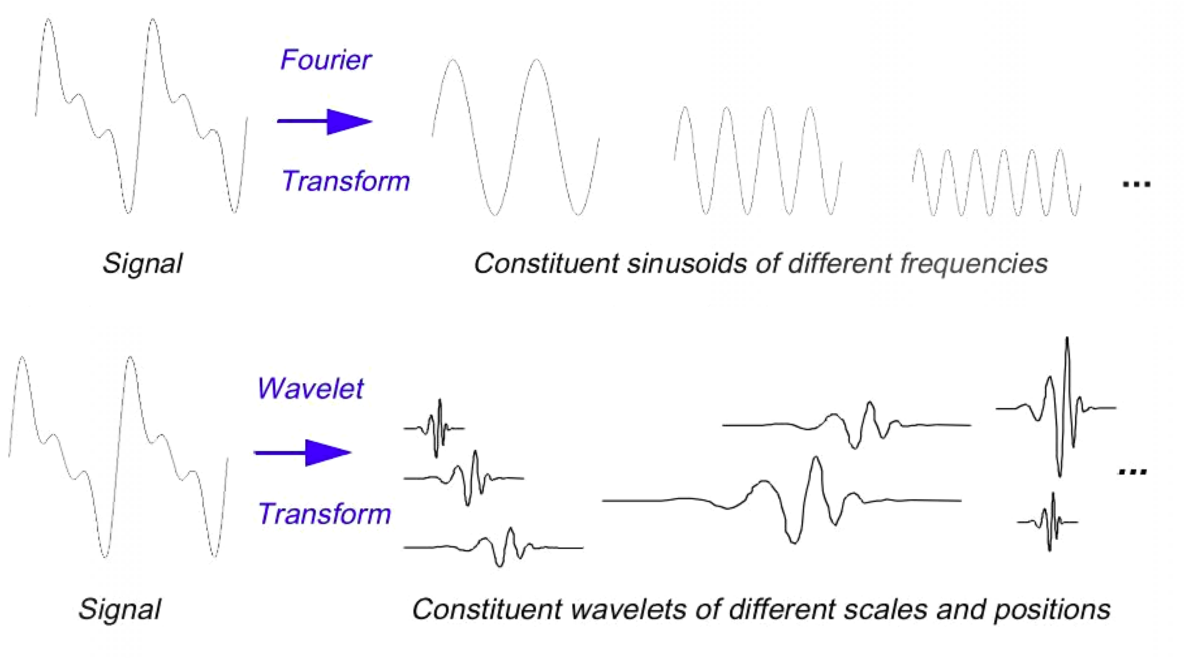


Figure 31 While the Fourier transform, and its derivative transform DCT, were based on sinusoids, wavelet transform manipulated the original signal through their convolution with wavelets at different scales and positions.[150]

This means that when DCT is applied to an image, it does not hold onto the location of pixels, so the compression transform cannot be applied to the whole image at the same time and needs to be applied only to neighbourhoods. On the other hand, the wavelet transform keeps in mind the position of each pixel. When the signal is broken down, it is described by a series of wavelets

[148] Michael W. Marcellin and Ali Bilgin, 'JPEG 2000 for Digital Cinema', in *VidTrans and SMPTE Advanced Motion Imaging 2005* (Atlanta, Georgia, 2005).
[149] A compression scheme, in total, is comprised of three parts: the transform, the quantizer (an A-to-D convertor) and the entropy coder. What particularly changes the look of the image is the transform part. This is why in this thesis I focus only on the comparison of DCT-based vs. wavelet-based transforms. For more information on the entropy coding of JPEG 2000, refer to: David S. Taubman, 'Embedded Block Coding with Optimized Truncation', 17 August 2004.
[150] https://www.yumpu.com/en/document/view/5679137/wavelet-toolbox-users-guide-mit, accessed 18 April 2021.

with different frequencies and magnitudes but also different locations, which preserves the relation between pixel location and its value, and thus the transform can directly be applied to the whole image. In mathematical terms, the Discrete Wavelet Transform dilates the signal (by interfering in its frequencies) and translates it (moves it along x or y axis).

Practically, a 2D-DWT, such as the one used for lossy JPEG 2000 compression, functions based on low-band and high-band frequency filters and down-sampling. The original image is passed through a high-band filter and a low band filter (and down-sampled at one axis at each time) to yield two smaller size images, one which contains all the low-frequency information (the softened image) and the other which contains only the high frequencies (only the differences in intensities that are missing in the softened image). Each of these images go again through the same process of frequency filtering and down-sampling. This iteration yields thus four images: one softened and 2x2 times downscaled image, and three images which represent brightness intensity differences (Figure 32, Figure 33).

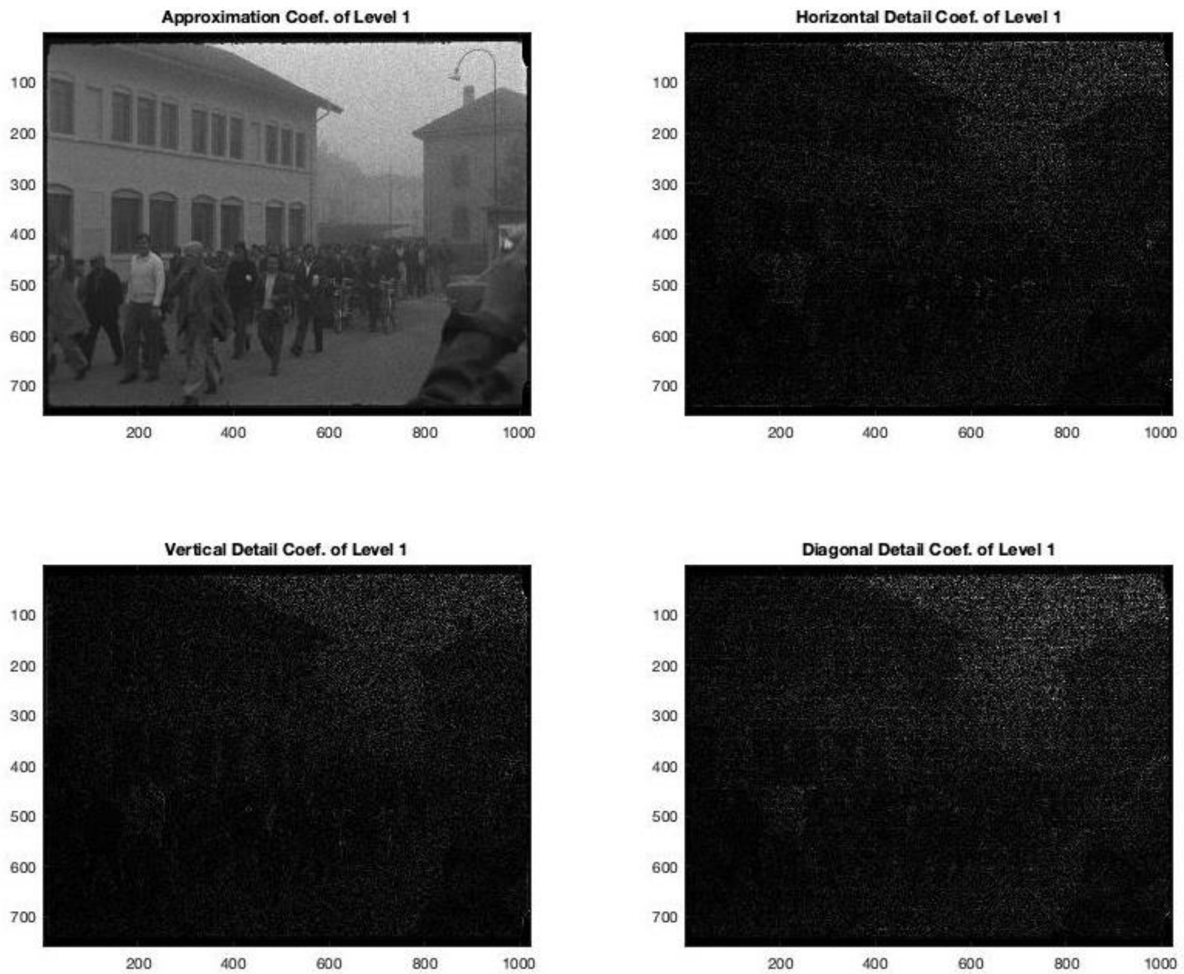


Figure 32 Wavelet coefficients of a digitised frame of *Eléments de grèves* (Frédéric Godet, Switzerland, 1976, 16mm negative original digitised in 2K). Original image courtesy of Cinémathèque suisse. Created by MATLAB coding.

Figure 33 Wavelet coefficients for a digitised image of *Romeo und Julia auf dem Dorfe* (Hans Trommer, Valérien Schmidely, Switzerland, 1941, digitised in 4K). Original image courtesy of Cinémathèque suisse. Created by MATLAB coding.

When decompressing, the inverse operations are done to recover the original image. If the image of Figure 27 of *Charles mort ou vif* is compressed into JPEG 2000 with a wavelet transform (Figure 34), the resulting image is visually different from a DCT-based compressed image (Figure 35) when decompressed.[151]

[151] The wavelet transform does not alter the chroma of colours. It only changes the luma which is the brightness. There is no chroma subsampling. Chroma remains the same in the small downsized image reference of wavelets, but brightness gets extracted into the other wavelets. Moreover, if the original image is 4K, but the server is 2K, the decompression stops at the 2K level. This is obtained thanks to the scalability of JPEG 2000 compression. It can decompress 4K images at 2K (slightly blurred), but again this happens with no pixelisation.

Figure 34 The original image of Charles mort ou vif in Figure 27, compressed into wavelet-based JPEG 2000, in two different resolutions (lower in the top image, higher in the bottom image). The bottom image contains visibly less loss than the top image, but neither of them have become pixelised, they are only more or less blurred.

Figure 35 Clockwise from top left: Close-up shots of the *Charles mort ou vif* frame. A) Original image as lossless TIFF. B) Image compressed as JPEG with DCT compression. C) Image compressed as JPEG 2000 with wavelet compression, higher quality. D) Image compressed as JPEG 2000 with wavelet compression, lower quality, where the too high compression rate has extensively blurred it.

In the case of D-Cinema, the original image to be packaged into DCP was defined by DCI to be in TIFF format, as I explained before. When fabricating a DCP, the TIFF images undergo a compression process which includes a transform by wavelets. According to DCI specifications, the image should only be one tile; therefore, there is no partitioning of the image at any point and the whole image is always considered together. The wavelet-compressed JPEG 2000 images are then wrapped into MXF and packaged into the DCP. Then, when the DCP is unpackaged by the projection server, the MXP is unwrapped and the JPEG 2000 images are inverse-transformed back into their (approximately) original TIFF. The approximation in the reconstruction of TIFF images, due to lossy compression, appears as a slight difference in the luminosity and entails no pixelisation whatsoever. This difference can only be detected in comparison with the original TIFF images. In the example shown in Figure 36, a comparison of the matrices of these two images suggests that an average error rate of 1.1724% exists between the pixel values. Of course, this small difference can hardly be detected when a DCP is projected, as the original TIFF files are not directly available as a reference.

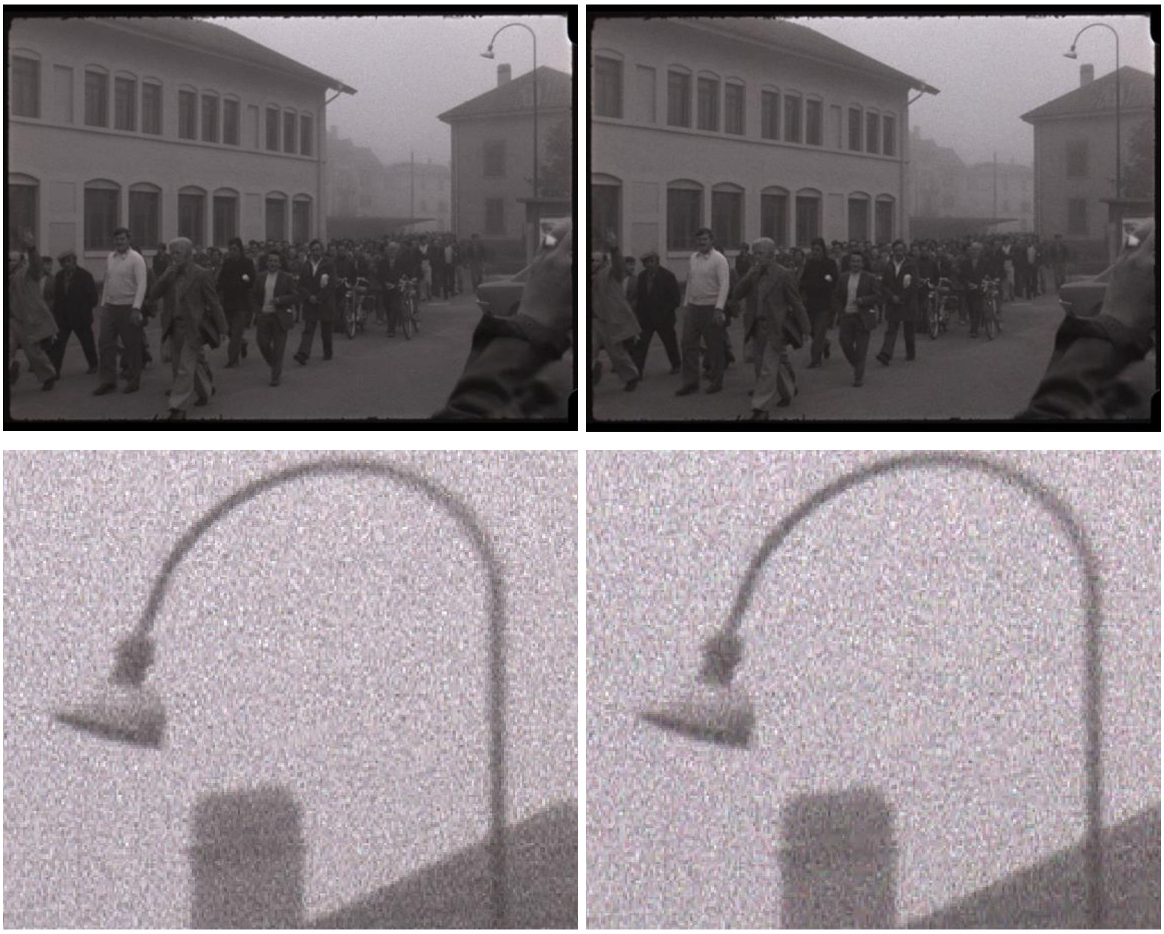


Figure 36 At the top left an original digitised frame of *Elements de grèves* (Frédéric Godet, CH, 1976) as an uncompressed 2K TIFF (2048x1504), and at the top right the same frame once compressed in JPEG 2000 and decompressed as 2K TIFF*. The two images on top seem identical, but when a part of them (their right corner) is magnified, it can be seen that they are not equal and have a small difference (the two images below). Original frame courtesy of Cinémathèque suisse.

Thus, concretely, when using wavelet-based compression, the decompressed image does not get pixelated. The compression being visually lossless, in projection it preserves approximately the look that was provided at the DCDM step, and does not add any visible digital signs such as pixels. It also preserves the colour space with no change. It does slightly alter the light values, but, as it is designed to be perceptually invisible, that does not degrade the brightness or the levels of black in a significant manner. The sharpness depends on the pixel count as well as the light values, and if there is no 4K-to-2K reduction, it is preserved through this compression. All these characteristics depend then on how the image was created before it was packaged into a DCP, before projection. The compression does not alter the look of the uncompressed image in a visible manner, unlike DVD or other television compressions. The digitally-projected cinema image needed to look substantially different from other digital images (on TV, or other screens such as mobile phones, etc.) in order to be considered worthy of cinema; the same cinema which had been created by photochemical technologies for more than 100 years and had left durable traces in the cultural imaginary of the film industry and film archives. This choice of standard, which distinguished cinema clearly from other media (also using digital technologies), happened surprisingly in a "convergence culture"[152] where media industries are more inclined to connect, rather than diverge. It followed an almost 20-year period, where film production and distribution used hybrid technologies. But cinema projection seemed to still force its own borders.[153]

What digital projection tried to achieve, was to avoid signs of digitality (as it had been established in other – digital – media) and continue in the same way as traditional projection before, which tried to avoid all signs of the materiality of its source image. According to Torkell Saetervadet: "Good projection is transparent projection. […] A cinema [ought] to be a transparent window straight into the minds of the storytellers, free from scratches, shaking frames or stray light from the exit signs".[154] In other words, the technical aspect of projection needed to remain invisible from public eyes, as if only the projected images existed with no relation to their source and technologies. Similarly, the digital projection was also to be free from the visual signs attesting to its digital nature (crystallised in the collective imaginary by pixels and pixelisation). Such a vision focused solely on the projected image, and tried to render invisible the source image, by keeping a somehow similar look in projection (although, as I have underlined, this would be an impossible mission in a strict sense, considering the different technological frameworks). Within the archival community, this vision of a projected image, detached from its material source, was not contested in the beginning, and even claimed in the discourses (by opting for cleaner, sharper images), as I claimed earlier. Then, faced with digital technologies, the technical details of the projected photochemical image which created a specific look on the screen (small unsteadiness, wear and tear signs, graininess, etc.) gained more importance in archival discourses, and the place of its material source was reinforced, as I will explain later in this chapter. There, the archives started diverging from the industry.

[152] To borrow the term introduced by Jenkins, *Convergence Culture: Where Old and New Media Collide*.
[153] Digital projection itself can be considered as a sort of continuity to electronic projection, which was not only realised by television technologies, but also followed many of the same concepts as television notably the instantaneity of distribution and programming of diverse content (live events, sports, films, etc.). For some studies of this subject, and most importantly the concept of Theatre Television, see:
Douglas Gomery, *Shared Pleasures: A History of Movie Presentation in the United States* (London: BFI Publishing, 1992), 231–34. Kira Kitsopanidou and Giusy Pisano, 'L'émergence du hors-film sur grand écran ou la « nouvelle » polyvalence des salles de cinéma', in *Les Salles de cinéma. Enjeux, défis et perspectives*, ed. Laurent Creton and Kira Kitsopanidou (Paris: Armand Colin, 2013), 147–78.
[154] Saetervadet, 9.

Naturally, the look of the projected image is also influenced by the projection machinery, which I will address in the following subchapter.

2.2 Projection Machinery and its Impact on Projection Quality

The industry standard of DCP concerned only the creation of a digital print that would provide the desired projected image on the screen, but it did not specify the actual implementation of the digital projection systems with the aid of electro-optical technologies. Not covered by the standards, this point was left to the market.[155]

Similar to the various photochemical projection systems, digital projection systems can also yield different images. Historically, each film projection system, with its own technical components, created a specific-looking projected image. The projectors not only had different lenses, different light sources (for instance carbon-arc or xenon), but also different configurations of light sources (vertical or horizontal xenon lamps, for example),[156] different film paths (mechanical routes), different configurations of film feed and take-up, etc. Projection was reel to reel for a long time, requiring a changeover between two projectors by the projectionist, whose mastery did indeed impact the projection quality. Its feed and take-up were vertical. Then came the platter projection, with horizontal feed and take-up, which held entire films as one single huge reel, but was rougher on the film itself.[157] The projectors needed to be calibrated. Their light source needed to be changed regularly. Further, the configurations of the screening venue are also important: the distance between the projector and the screen, the size and type of the screen (judged by its light reflection) as well as its shape (for instance its curvature), the position of spectators. These aspects are gathered in a chapter in *The Advanced Projection Manual*, which offers standardised proposals for an "ideal design" of a cinema for the presentation of "modern and historic films".[158]

There are so many variables in a film projection that almost every film projection can be considered unique, an idea which has been theoretically promoted by archivists such as Paolo Cherchi Usai and Alexander Horwath within the community.[159] From a technical point of view, these are (ideally) small differences if nothing goes terribly wrong, but indeed, all of these

---

[155] For a summary of the existing technologies for digital projection by the mid-2000s, with a brief look back on (analogue) electronic projection systems, see Saetervadet, *The Advanced Projection Manual*, 248–58.

[156] Saetervadet, 41–42.

[157] See: Bordwell, *Pandora's Digital Box: Films, Files, and the Future of Movies*, 5–7.

[158] Saetervadet, *The Advanced Projection Manual*, 11–56.

[159] See: Paolo Cherchi Usai et al., eds., *The Art of Film Projection: A Beginner's Guide* (Rochester: George Eastman Museum, 2019); Alexander Horwath, 'The Old Life. Reframing Film "Restoration": Some Notes', *Journal of Film Preservation*, no. 96 (April 2017): 27–34.

factors have influenced the quality of the projected image on the screen; characteristics such as brightness, sharpness, contrast, colours have all depended upon the projection machinery. For example, if the light source were too red or too yellow, the colours would not look as they should. If the light source were at the end of its cycle, the brightness might be affected. Different mechanical routes of the film in the projector would create more or less image stability on the screen, influencing the sharpness. Michel Dind, a long-time collaborator of Cinémathèque suisse, who was at one point responsible for projections, remembers one of the projectors in Cinémathèque's theatre, which blurred a part of the projected image from the first day of its installation during the 1990s. According to him, for a few years, no technician could solve the problem and all the screenings with that projector had a slightly blurry part.[160] Throughout the history of cinema, the same films have regularly been projected on different projectors, making this constant change in the projected image part of the natural processes of cinema. This multiplicity depicts how the concept of an ideal projected image constructed within the cultural imaginary as a model for digital projection does not seem technically a realisable goal.

The same goes for digital projectors, even though they have different machinery based on different technologies. The digital projectors differ from their photochemical predecessors in the fact that the image they input is a digital signal. The output remains light, as per the photochemical image projection (albeit quantified light). Similarly, these projectors also have a light source in the form of a lamp or laser, whose intensity on the screen, compared to the film projector, is modulated according to the digital data instead of emulsion layers on a film having opaque or transparent areas letting light through or not. As was the case with film projectors, changes and differences in the light source might affect the brightness or colours of a digitally projected image. As an example, the laser light of the projector installed in the Paderewski theatre of the Cinémathèque suisse is not a neutral white light, and when black-and-white films are projected, the white parts look slightly green-ish. This defect is not noticed by everyone, but more experienced viewers do notice it.[161]

Another piece of machinery in digital projectors is its light-reflecting plate (which corresponds to the pixel grid). The plate can be implemented via different technologies, which are all based on microelectromechanical systems (MEMS).[162] MEMS are microscopic machines with mechanical moving parts and are enabled by electric signals. Different MEMS-based systems provide slightly different images. The capacity of the plates to represent different intensities

---

[160] Personal discussion with Michel Dind.
[161] Personal experience, in discussion with Caroline Neeser and Sophie Pujol (Cinémathèque suisse).
[162] Or a micro-opto-electro-mechanical system; named after different technologies used in the system.

can be compared in terms of contrast, brightness, colours and sharpness. The main digital projection system available on the market, DLP, is based on DMD technology by Texas Instruments. DMD (digital micromirror device) is a MEMS-based reflective light switch comprised of a large number of aluminium mirrors which can rotate in two different angles, reflecting (or not) the light coming from the light source towards the projection lens. The fast toggling of each mirror between the two angles can produce a greyscale value.[163] DLP was the first digital projection system on the market and has been widely adopted by exhibitors.

Sony's proprietary projection system, SXRD[164] and JVC's joint venture with Kodak under the name of D-ILA, are also MEMS-based, but instead of micromirrors, they use a liquid crystal on silicon (LCoS) technology. The latter is a micro-display composed of a silicon backplane and a liquid crystal layer on top of it which reflects light. The liquid crystal modulator smooths the image by reducing the visibility of high frequency artefacts in it. But even the implementation of the same technologies by two different companies did not give exactly the same results on the screen. JVC's technology, when exposed for tests in 2002, was deemed "not bright enough for cinema",[165] and was gradually side-lined, never making it beyond some prototypes. However, Sony's SXRD system was commercialised in 2004. It was the first system to implement 4K and remained one of the two main systems on the market up to 2020, when Sony announced that it would stop manufacturing digital cinema projectors.[166]

In sum, a digitally-projected image could also look diverse according to the system through which it was produced. The industrial vision did not linger long on these differences, and by standardising the digital print sought to approximately reproduce its desired cinema look

[163] Larry J. Hornbeck, 'Digital Light Processing and MEMS: An Overview', in *Digest IEEE/Leos 1996 Summer Topical Meeting. Advanced Applications of Lasers in Materials and Processing* (Keystone, USA, 1996), https://www.ti.com/pdfs/dlpdmd/107_DLP_MEMS_Overview.pdf, accessed 17 August 2020. More complete version of the same white paper: Larry J. Hornbeck, 'Digital Light Processing: A New MEMS-Based Display Technology', 1996, http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.118.2556&rep=rep1&type=pdf, accessed 17 August 2020. In fact, the invention of DMD by Larry J. Hornbeck was preceded by many years of research and a number of papers and patents, notably : Larry J. Hornbeck, 'Spatial Light Modulator and Method', December 1987, https://patentimages.storage.googleapis.com/db/61/02/0574b4c3eff0ea/US4710732.pdf, accessed 17 August 2020. In this patent, Hornbeck credited the Eidophor projection system as an earlier device using the spatial light modulator technology. The DMD and DLP technologies were then introduced in many papers from 1987 on, such as: Larry J. Hornbeck, 'Deformable-Mirror Spatial Light Modulators', in *Proceedings of SPIE 1150. Spatial Light Modulators and Applications III*, vol. 1150 (San Diego: SPIE, 1990), 86–102. DMD designated Deformable-Mirror Device at the time.

[164] Apart from using LCoS technology in its projectors, Sony had also invested in Grating Light Valve technology (also MEMS-based) but abandoned it later. The GLV was declared as one of the expected solutions for D-Cinema by Torkell Saetervadet in his 2006 *Advanced Projection Manual.*

[165] Slater, 'Digital Cinema: A Major Theme at IBC 2002', 23–24..

[166] Nick Dager, 'Sony to Stop Manufacturing Digital Cinema Projectors', *Digital Cinema Report* (blog), 26 April 2020, https://www.digitalcinemareport.com/news/sony-stop-manufacturing-digital-cinema-projectors.

through any machinery. But the archives, with their museological aspirations, turned more towards the respect of historical projection systems up to a point where even a vision of uniqueness of every projection resonated within the community, thus creating a gap with the industrial vision.

3 The Show Must Go On: Archives Faced with the Digital Roll-Out

Digital projection technologies were (primarily) determined by Hollywood and largely adopted by the whole film industry (in Europe, thanks to national funding schemes). Directed towards the recreation of an ideal projected image, formed through cultural imaginaries, the technologies were malleated to match the film industry's vision. However, despite the initial similarities, this vision did not always correspond with that of archives, which gradually moved in a direction more based on film strip as a material artefact. Based on the growing differences between implemented technologies and archival imaginaries of the time, archives reacted strongly to the roll-out, and, in their theoretical and technical discourse network, new aspects appeared, were reinforced or modified. What follows analyses the reactions of the archival community to digital projection technologies.

Digital projection, although a strong marketing tool and hugely discussed in the industry, did not seem to change much for spectators, at least not obviously. It did not add a distinctive factor such as sound, colour or wide-screen which would be noticed straightway by audiences. Back in 2002, John Belton had already made this observation:

> "Digital projection as it exists today does not, in any way, transform the nature of the motion-picture experience. Audiences, viewing digital projection will not experience the cinema differently."[167]

The digital image standard in projection was consciously conceived in a way that it would mimic, as possible, the experience of a projected photochemical image. Although the ideal model of the photochemical film projection could not be precisely defined, it did represent a rather clear idea of a projected image: temporally discrete and having a certain look. The proximity in the projection of digital and photochemical images could apparently even mislead experts by their appearances, as Jacques Aumont has claimed:

> "At the FIAF Congress in São Paulo, in 2006, a projection was organised which compared film techniques to digital techniques: since then, it became clear to everybody

[167] Belton, 'Digital Cinema: A False Revolution', 104.

> – not without a shudder of horror and melancholy for older participants – that the high-resolution digital projection was of equal quality to film projection. This audience, composed of professionals of film preservation, was even sometimes incapable of telling them apart."[168]

As mentioned before, this anecdote from the 2006 FIAF Congress in Sao Paolo was also recounted by David Walsh, who underlined that "even a sophisticated audience has difficulty in distinguishing between matched digital and film presentations".[169] These remain, however, a very disputed (and of course subjective) statements, and there is no exact way to accept or challenge its veracity entirely in a unique scientific way. There is a certain degree of continuity in look between the way photochemically and digitally projected images may be perceived by spectators, but photochemical and digital image projection might also create different perceptions, notably the visible – however subtle – change of flicker in the two.[170] There could also be cognitive differences in perceiving different technologies, as Laurent Mannoni (Cinémathèque française) mentioned in 2011.[171] While conceding that "perception" was a difficult topic, Mark Paul Meyer had already stressed in 2005 that, as far as spectators' perception goes, "digital projection techniques try to emulate traditional projection techniques" as film offers the "best image".[172] I am not going into detail about the possible differences in image perception here, but only underline that the look of a projected image was controlled by the industry-led technological adoptions, as possible.

The digitally projected image did endeavour to simulate the desired look of a projected film image, despite their different materialities, but even if they appeared entirely the same to spectators, according to José Manuel Costa, archives would still need to decide whether "digital projection can ever be an acceptable substitute for film".[173] This has to be explained in terms of the disparity between industrial and archival visions of the projected image. While industry discourses concerning the development of digital cinema technologies were focused on the quality and look of the projected image, archival discourses also stressed the importance of the

[168] Jacques Aumont, 'Que reste-t-il du cinéma?', *Rivista di estetica*, no. 46 (2011): 18. My translation.
[169] Walsh, 'Do We Need Film?', 5.
[170] This is because of the mechanical structure of the shutter in film projection. See: Jonathan Erland, 'The Digital Projection of Archival Films Project: Phase One', *Journal of Film Preservation*, no. 91 (October 2014): 37–42. I will return to this research later.
[171] Laurent Mannoni, 'De l'argentique au numérique' (Révolution numérique: et si le cinéma perdait la mémoire?, Cinémathèque française, Paris, October 2011), https://www.canal-u.tv/video/cinematheque_francaise/de_l_argentique_au_numerique_intervention_de_laurent_mannoni.7771.
[172] Meyer, 'Traditional Film Projection in a Digital Age', 17.
[173] Cited by Walsh, 'Technical Symposium - FIAF Congress 2006 São Paulo: Film Archives in Transition', 76.

source of the projected image, which could be either some film technology, or digital data. In view of that, the similarity with a photochemical look in projection was not sufficient, as the projected image was considered together with its source material and technologies. Jose Manuel Costa also added that the "difference in the physical nature of the image (against a supposed evaluation of quality)" would change the spectators' perception of a projection.[174] Indeed, archival understanding of the photochemical image depended very much on the film strip, which, although hidden from audiences,[175] was available to archives. The projected image being an ephemeral phenomenon, its source is the main object that archives collect; and a crucial factor in the formation of their viewpoints on the image. With digital cinema, cinema was still projected in theatres via a series of still images running at a certain speed and creating movement; but its source, which had marked archival imaginaries, was not the same anymore. This focus on film as an artefact gained in popularity in contrast with digital projection technologies; before that, as explained at the beginning of this chapter, newer film technologies (although changing the image look) were not contested.

The theoretical difference between archival vision and the implemented digital cinema (based on the film industry's vision) made archives react in a two-fold manner. Firstly, because of the roll-out, mainstream film technologies, which had been dominant until then, risked obsolescence. With the theoretical standpoint of film as an artefact, the potential obsolescence of film understandably created a huge stir within the archival community. A fight for film was thus triggered which aimed to valorise the material (though invisible), photochemical part of the cinema projection machinery, so that it could survive as a living practice, rather than an obsolete technology. Secondly, archives needed to fight for their own position, which was threatened if they did not keep up with the industry's new gadget, digital projection technologies. Their collections would not be seen, and their own cinemas would only be able to show old films.[176] While it is true that archives were largely excluded from the D-Cinema standardisation process, they did face a considerable challenge to adopt the new projection technologies, and to make their practices coincide with the (rather) rigid frameworks of D-Cinema.

[174] Costa and Daudelin, 'De l'avenir des cinémathèques', 14.

[175] Nicholas Rombes, *Cinema in the Digital Age* (London and New York: Wallflower Press, 2009), 31.

[176] An archival discursive position, that which considered archives exclusively as museums for obsolete technologies, did persist, rejecting altogether the acceptance of digital films as archival material. This, however, does not concern the European national film archives which are the main case studies in this thesis.

By insisting on the two-fold reaction of archives, which clung to the previous technologies while adapting to the newer ones, I argue how a so-called transition for archives is never absolute. Examples of photochemical technological changes can help make this statement clearer. Film archives did not dismiss silent films because of the different technologies that were needed for their reproduction or projection. They did, however, adapt the technologies and practices to include both. For instance, when the industry shifted from nitrate to safety material despite some initial resistance, archives, if anything, appreciated the change because of the difficulties in preserving nitrate, and reacted accordingly:[177] most archives did not discard their nitrate collections, but embarked on long-term strategies to preserve them on safety material.[178] They also needed to find solutions for acetate decomposition (vinegar syndrome) in their conservation practices, while still being concerned about the flammability of nitrate collections. Faced with different technologies used in the film industry, many archives created a hybrid functional state, which embraced many of the new and past technologies, up to a point where they could become a "Research Laboratory" for diverse cinema technologies and apparatuses.[179]

The following is divided into two subchapters that will address the fight for the survival of photochemical film and digital archival projection respectively.

3.1 Adapting to the Transitioning Film Ecosystem

As explained in the previous chapter, the perspective of film's disappearance has haunted the archives since the early days of digital technologies. What seemed like a pessimistic view of an uncertain future at the time, grew stronger and more real by the early 2010s with the widespread adoption of digital cinema. In October 2011, at the *Et si le cinéma perdait la mémoire?* conference, Laurent Mannoni, Scientific Director of Heritage at the Cinémathèque française, opened the discussions by evoking the possibility of film's imminent disappearance as a carrier for images. According to him, not only film but also the film laboratories and film knowledge were risking disappearance.[180] For archives, this created both theoretical worries, as well as

[177] Leo Enticknap, 'Nitrate's Still Waiting', *The Velvet Light Trap* 64, no. 1 (January 2009): 86–87. For the details of the industry's shift to nitrate, see: Leo Enticknap, 'Film Industry's Conversion from Nitrate to Safety', in *This Film Is Dangerous. A Celebration of Nitrate Film*, ed. Catherine Surowiec and Roger Smither (Brussels: FIAF, 2002), 202–12.

[178] Of course, some counterexamples did exist, for instance at the Bundesarchiv/Filmarchiv in Germany, many nitrate films were disposed of after duplication.

[179] Term and concept coined by: Fossati and van den Oever, *Exposing the Film Apparatus: The Film Archives as a Research Laboratory*.

[180] See Daudelin's report of the conference: Robert Daudelin, 'Le syndrome du numérique. Et si le cinéma perdait la mémoire', *24 images*, no. 155 (2011): 38–39.

technical obstacles to preservation and access practices, as they still held considerable film collections – which would be inaccessible if film culture did not exist anymore.

3.1.1 Film Equipment, Material and Knowledge Going Scarce

Around 2011, film culture as a whole seemed to face extinction when many commercial film laboratories were closed in several European countries. In Switzerland, the Schwarz Film laboratory in Ostermundigen closed in September 2011, having been in existence since 1945, doing the laboratory work for films such as Jean-Luc Godard's *Je vous salue Marie* (1985). Already in a weak position for a few years, in 2009 the laboratory had been acquired by Egli Film, another Swiss film lab, who decided to close it down as it was "crushed by digitisation". The event was deemed as the "end of an era" and a "black day for Swiss cinema" by the Swiss press.[181] In France, Quinta Industries, which owned LTC laboratories, announced its closure in December 2011. Having been in activity since 1935, the lab became a "victim of the transition to all-digital".[182] The news created a fair amount of chaos at a national level: the CNC gathered a crisis unit to find solutions for employees having lost their jobs, films that were in the midst of post-production, and the thousands of film reels which were left there. The French film industry stood in solidarity with LTC employees, as the lab owners were accused of having missed a "technological shift dating back to 1999".[183] The French association of film producers (APC) expressed its concern over the "drastic reduction of the number of film labs in France".[184] But the financial failure of commercial labs seemed inevitable: "Today, the survival of (film) laboratories is impossible, since there is no more financial turnover, apart from the digitisation of film heritage".[185]

---

[181] See : Valerie Chételat, 'Das Ende einer Ära', Der Bund, 29 September 2011, https://www.derbund.ch/bern/stadt/das-ende-einer-aera/story/15840387, accessed 30 August 2020. Hans Jürg Zinsli, 'Ein schwarzer Tag für den Schweizer Film', *Berner Zeitung*, 30 September 2011, https://www.bernerzeitung.ch/region/bern/ein-schwarzer-tag-fuer-den-schweizer-film/story/30945890, accessed 30 August 2020. Translations are mine.

[182] Quentin Herlemont, 'Une page de l'histoire du cinema se tourne', AFCinema, 8 March 2012, https://www.afcinema.com/Une-page-de-l-histoire-du-cinema-se-tourne.html, accessed 30 August 2020.

[183] Caroline Champetier, 'Solidarité', *La Lettre AFC*, 5 January 2012, https://www.afcinema.com/Solidarite-7416.html, accessed 30 August 2020. My translation.

[184] 'Le laboratoire LTC, pan du patrimoine cinematographique français, en liquidation juridique', *L'Humanité*, 16 December 2011, https://www.humanite.fr/le-laboratoire-ltc-pan-du-patrimoine-cinematographique-francais-en-liquidation-judiciaire, accessed 30 August 2020.

[185] Quote by Tarek Ben Ammar, the main shareholder of Quinta Industries. In: Aurélie Champagne, 'Cinéma : LTC ferme, que vont devenir toutes ces bobines ?', *L'OBS*, 15 December 2011, https://www.nouvelobs.com/rue89/rue89-cinema/20111215.RUE6487/cinema-ltc-ferme-que-vont-devenir-toutes-ces-bobines.html, accessed 30 August 2020. My translation.

In the Netherlands, the Haghe Film Conservation, in existence from 1899, went bankrupt in October 2012, before starting again two months later. The rebirth of Haghe Film was welcomed by Eye Filmmuseum:

> "The restart prevents the disappearing of the knowledge of 35 mm film development and preservation from the Netherlands and makes sure film producers do not have to go abroad for the technical post-production of their films."[186]

When the same story happened in Sweden, and the last full-scale photochemical laboratory (Nordisk Film Post Production) in the country stopped its activities in 2011, the Swedish Film Institute faced a dilemma; they were either to stop doing photochemical preservation work, or they could try to restart the lab. The Swedish Film Institute finally acquired the lab and employed its experienced workforce in order to not only save the machines and the possibility of photochemical film treatment, but also the abilities and institutional knowledge.[187] The Swedish example was the ultimate archival reaction to save film labs. It was presented widely in the archival community, and praised by many, such as Alexander Horwath who mentioned it during his 2011 talk at the *Et si le cinéma perdait la mémoire?* conference. At the same conference, Christian Lurin (Éclair laboratory) presented an upcoming shift in the activities of commercial photochemical labs from post-production to restoration, from new productions to archival collection; which associated any photochemical activity only with film archives.[188] This suggested, somehow tacitly, that saving film labs and film culture could feature among archival responsibilities.

The other concern, the disappearance of film stock as an image carrier was also becoming a reality following the digital roll-out. During the same conference in Paris, amid the chaos ignited by the digitisation of film distribution and projection, Clive Ogden from Kodak gave a presentation in which he reassured the archives that Kodak would continue producing film as they consider it as the "only" long-term archiving format.[189] Despite this, Kodak declared

---

[186] https://www.facebook.com/eyefilm/posts/good-news-for-dutch-film-industry-today-dutch-film-lab-cineco-resumes-as-haghefi/10151126617071331/, accessed 30 August 2020.

[187] See: Jon Wengström, 'The Coexistence of Analogue and Digital Strategies in the Archival Film Collections of the Swedish Film Institute', *Journal of Film Preservation*, no. 96 (April 2017): 63–73.

[188] Christian Lurin, 'Le futur des laboratoires cinématographiques' (Révolution numérique: et si le cinéma perdait la mémoire?, Cinémathèque française, Paris, October 2011), https://www.canal-u.tv/video/cinematheque_francaise/le_futur_des_laboratoires_cinematographiques_intervention_de_christian_lurin.7760.

[189] Clive Ogden, 'A Future for Film' (Révolution numérique: et si le cinéma perdait la mémoire?, Cinémathèque française, Paris, October 2011), https://www.canal-u.tv/video/cinematheque_francaise/en_a_future_for_film_lecture_by_clive_ogden.7762.

bankruptcy merely a few months later, in January 2012. In September 2012, Fuji also announced that it was going to stop manufacturing film from early 2013:

> "Fujifilm has mainly provided negative films for shooting and positive films for projection in its motion picture film business operations. However, in order to adapt to the recent rapid transition of digitalization in the shooting, producing, projecting and archiving processes of motion pictures Fujifilm has decided to shift its business operations to provide products and services designed for digital workflow of motion picture production and projection."[190]

The statement from Fuji seemed to announce indeed the end of film and a total transition into the digital realm, although further in the same press release the company underlined that it "will continue to provide films suitable for long-term archiving".[191] The product that Fuji excluded from discontinuity was ETERNA-DRS 35mm film (that was introduced in Chapter Two), a black and white film specifically designed for digital separation, and conceived for archival work.[192] Technically, Fuji had not closed the door entirely on film manufacturing, maintaining an essential product for film archiving, with which all new digital productions could be shot back to film for long term storage. Moreover, ORWO also continued to manufacture 35mm black-and-white film (Figure 37). But many possible and even dominant film technologies were to be discontinued, and the photochemical workflow could not survive in its entirety with these limited options.

Figure 37 Orwo advertisement, 2013, which appeared in *Journal of Film Preservation* to the attention of archivists.[193]

---

[190] 'Announcement on Motion Picture Film Business of Fujifilm', Press Release (Fujifilm, 13 September 2012), https://www.fujifilm.com/news/n120913.html, accessed April 7, 2021.
[191] 'Announcement on Motion Picture Film Business of Fujifilm'.
[192] For more information, see: https://www.fujifilm.com/products/motion_picture/lineup/eterna_rds/, accessed 4 September 2020.
[193] Orwo, *Journal of Film Preservation*, no. 89 (November 2013): 46.

As I will detail below, the archival reaction did not only concern how it would affect their own practices, but it countered the whole context of film's replacement by digital projection technologies. This motivated archives to join hands with other industry players to save film. In this case, film served as an umbrella term including all or many different film technologies and gauges: colour, black-and-white, 35mm, 16mm, etc. The focus was probably on 35mm film, but by using the general term of film, other types of film were not excluded either. The fight did not stop when Kodak emerged from bankruptcy in September 2013, and reached a point where film advocacy became a continuing parallel trend within archives and the whole film industry.

3.1.2 Archival Reactions: Let's Save Film (Stock)!

The thought of film's disappearance, as explained in the previous chapter, was present well before the digital roll-out, as a pessimistic vision of an uncertain future. The immediate reaction, at the time, was the establishment of the FIAF manifesto in 2008. After the roll-out, when the main film manufacturers stopped production, more concrete solutions were sought within the archival community which could counter the trend of film's disappearance.

One imagined solution was that archives would need to manufacture their own film stock, so that they could continue their practices (such as photochemical preservation or creation of new film prints). The idea of manufacturing film by archives on a "cottage-industry basis" could be a solution, but it was deemed too difficult to realise while also running the risk of not obtaining consistent quality.[194] During the FIAF Congress 2012 in Beijing, FIAF TC also announced a possible joint project with AMIA regarding film manufacture (which did not get realised):

> "The Technical Commission is collaborating with the Preservation Committee of AMIA in an investigation of the feasibility of continuing to produce film stocks in a future world where the current major manufacturers no longer make film stock. This investigation is at a very early stage, and as yet, it is not possible to say how useful this might be."[195]

Another solution was to convince the manufactures to continue producing film stock, while a change of manufacturing landscape was to be expected. At the 2011 *Et si le cinéma perdait la mémoire ?* conference, Christian Lurin imagined a future where smaller manufacturers such as

[194] Charles Fairall, 'FoFA: The Future of Film Archiving', *Journal of Film Preservation*, no. 94 (April 2016): 9–15.
[195] David Walsh, 'FIAF Technical Commission End-Term Report to the FIAF General Assembly 2012', FIAF 2012 Beijing Congress Report (Brussels: FIAF, 13 April 2012), Appendix 4.3.

Orwo would enter the equation:[196] small market, small manufacturer for an object which was to become only an archival property, film. On the other hand, negotiations were envisaged with the main manufacturers. In 2012, the technical commission of FIAF conducted a survey on the use of film stock by archives, whose resulting data was to be used in FIAF's conversation with film stock manufacturers.[197] The FIAF survey announced a yearly consumption of 10,000 reels by participating FIAF archives, most of which were printed in-house and on black-and-white film. The number was, clearly, far from enough to keep the whole photochemical industry alive.[198] Moreover, according to David Walsh (Head of FIAF Technical Commission), there was also a need to prove that these trends were to be continued by archives:

> "Perhaps there is one area where our voices might be heard: film stock manufacture. The recent survey on film stock use in FIAF archives suggests relatively healthy activity here, but it gives no clue to underlying trends, and it certainly does not offer much hope that archival use alone can support the manufacture of colour film once the film industry has turned its back. If manufacturers are to be convinced that the archives offer a secure future market for film, then they will need us to come up with some hard-headed reasons as to why they will still be using the stuff in years to come. Do we all believe our role includes preserving a historic technology, rather than just 'content'? Already there are respectable institutions which have largely given up the business of making photochemical film copies, and if you have sub-zero storage for your film collection and an infrastructure to support all the archival functions in the new media, then where is the justification for expensively producing copies on film? For preservation? That's what the deep-storage film vaults are for. For projection? Fine if you can still find someone to project it competently."[199]

Walsh's remarks sum up perfectly the situation of film archives around 2012-2013. There was extensive chaos and fear in the archival community over the disappearance of film. The new technologies, as conceived based on the dominant industrial vision and focused on the projected image, neglected the source image, leading to its gradual disappearance and the subsequent archival reaction. Partly due to the fundamental differences between different film archives, there seemed however that a lack of consensus existed on the reason why film needed to be

[196] Lurin, 'Le futur des laboratoires cinématographiques'.
[197] Christophe Dupin, 'Editorial', *FIAF Bulletin Online*, no. 5 (June 2013): 2.
[198] To give a comparison measure, 10,000 reels could correspond to the amount needed for the world-wide distribution of one Hollywood blockbuster film (around 2000 prints approximately).
[199] David Walsh, 'Editorial', *Journal of Film Preservation*, no. 89 (November 2013): 3.

saved. It remained, for many archives, the best carrier for long-term preservation. Others intended to preserve the cinematographic experience on film as it was. But, as expressed by Walsh, some institutions were ready to replace their photochemical practices with digital ones, whether in projection or preservation. According to Walsh, the archival reaction needed to clarify its need for film:

> "So yes, let's shout, let's campaign, let's lobby, but let's be sure we have a very clear understanding of why we archivists need film when the rest of the film industry apparently doesn't."[200]

And the archives did campaign – for all their practical reasons, but also for the theoretical standpoint around film and film culture as historical objects and procedures to be saved and continued. The FIAF Congress in Barcelona in 2013 was a pivotal moment where many voices in favour of saving film converged. The Second Century Forum of the Congress, moderated by David Walsh, was entitled "Film Archives after Film" and it focused on the role of film archives in the fight for film's survival. During the discussion, Hisashi Okajima read out a "love letter to film" in which he considered film "culturally, historically and aesthetically significant",[201] and Gianluca Farinelli proposed that archives launch, "under the aegis of FIAF, a SAVE FILM (STOCK) CULTURE project" which would counter the "end of the culture that developed around film stock". By culture, Farinelli was referring to the whole system and machinery of 35mm film, from laboratories to screenings, as well as the actual film knowledge.[202]

Campaigning… Film between Industry and Art

According to Farinelli, the fight needed to go beyond the walls of film archives:

> "Film archives and FIAF are called to play a very active role right now, to create a strong network of film producers, cinematographers, filmmakers, and all those who can be made aware and help raise awareness that film culture cannot be swept away by a blind market. Along with digital formats, we must continue to screen films and encourage all theatre exhibitors not to throw away their traditional equipment. The challenge is great."[203]

Luckily for film archives, they were not alone in this battle, as the digital roll-out and film's disappearance had not pleased everybody. Initiatives by other players in the film industry had

[200] Walsh, 'Editorial'.
[201] Hisashi Okajima, 'A Love Letter to Film', *Journal of Film Preservation*, no. 89 (November 2013): 9–10..
[202] Gian Luca Farinelli, 'Film Archives after Film', *Journal of Film Preservation*, no. 89 (November 2013): 13–14.
[203] Farinelli.

already been launched. The archives, moving away from their initial position in which they were the only entities interested in film's survival, joined these voices of discordance raised from within the industry. On the one hand, successful Hollywood filmmakers such as Christopher Nolan and Quentin Tarantino backed film's survival. This brought Hollywood studios to discuss and ink contracts with Kodak to keep film alive,[204] helping Kodak out of bankruptcy. On the other hand, film's survival was also defended by independent artists and experimental filmmakers who insisted on the diversity of modes of image production – to correspond to every vision.

The FIAF community, which imagined its identity and missions as non-commercial, sided at first with independent artists, most notably Tacita Dean. A British visual artist, Dean had worked extensively with 16mm film. In 2011 as a reaction to film's disappearance, she created a work called FILM for Tate Modern in London. FILM was not Tacita Dean's first work in defence of photochemical film; in 2006, while she was facing troubles to get hold of black-and-white 16mm film, she filmed the Kodak factory in Chalon-sur-Saône (France) as a tribute to a carrier (16mm film) "that's just about to be exhausted".[205] FILM, "a portrait of the analogue, photochemical, non-digital medium of film",[206] was a silent 10-minute film played on a continuous loop, whose image included many signs of film's materiality (such as sprocket holes, scratches, etc.) and all of its numerous visual effects were done photochemically, mechanically or by hand. Photographs of Tacita Dean's artwork illustrated the cover of the *Journal of Film Preservation* in April 2012, which also published her article on the origins of her work as well as her fight in favour of film, "a medium with which [she] was immediately comfortable". This "medium", as a means of expression with specific material and visual qualities (not only as a carrier of moving images), enabled her and other artists to create "much invention and artifice" precisely because of its limitations compared to digital technologies.[207] Dean's article had a similar discourse to that of the FIAF Manifesto on safeguarding film as a medium for recording moving images. Her 35mm experimental FILM, a much-mediatised work extolling artistic creativity of film, was largely celebrated within the archival community. Its

[204] See for example: Ben Fritz, 'Movie Film, at Death's Door, Gets a Reprive', *The Wall Street Journal*, 29 July 2014, https://www.wsj.com/articles/kodak-movie-film-at-deaths-door-gets-a-reprieve-1406674752?tesla=y&mg=reno64-wsj&cb=logged0.10335595766082406; Carolyn Giardina, 'Kodak Inks Deals With Studios to Extend Film's Life', The Hollywood Reporter, 4 February 2015, https://www.hollywoodreporter.com/movies/movie-news/kodak-inks-deals-studios-extend-770300/.
[205] https://www.tate.org.uk/art/artworks/dean-kodak-t12407, accessed 6 September 2020. The film is called *Kodak* (Tacita Dean, 2006).
[206] https://www.tate.org.uk/art/artworks/dean-film-t14273, accessed 6 September 2020.
[207] Tacita Dean, 'FILM', *Journal of Film Preservation*, no. 86 (April 2012): 11–21.

non-commercial, artistic point of view corresponded to an archiving vision promoted by many FIAF archives. Alexander Horwath, whose institution Austrian Filmmuseum specialised in experimental films, expressed his support for this type of film militancy by opposing the film industry's supposedly market-inclined approach with that of artists as well as independent and experimental filmmakers. According to him, "the industrial viewpoint in museums and archives would generally be the one that identifies with or mimics the socially dominant notion of film". On the other hand, "the non-industrial viewpoint in archives would see the above as only one of many applications of the film medium, knowing full well that this is a minority position in our society, but persisting against all odds".[208] In Horwath's view, the "socially dominant notion of film" entirely neglected its techno-cultural history and materiality, and focused only on its content. However, this view can be nuanced by the technical discussion I presented in the previous subchapter, which demonstrates that digital cinema was in fact based on film's material traces in projection and its whole existing cultural history – although detached from its source image as a material object.

This strong standpoint, as declared by Horwath, was an important theoretical drive in the fight for film's survival. In 2013, FIAF members rejected the possibility of accepting commercial archives into their community, although this had been proposed as a common strategy to approach Kodak as potential customers for film. Resistance arose to ally with the bearers of the so-called industrial viewpoint, such as Hollywood and studio archives, since their vision was blamed by archives as having imposed the digital technologies and thus having entailed the disappearance of film in the first place. Despite the lack of consensus among its members, FIAF as a community adhered more easily to this more marginal, resistant, and artistic view of film; expressed by Hisashi Okajima:

> "Let's listen to the voices of our own gene without prejudice. It whispers: 'please don't kill the enthusiasm of the people who want to safeguard film'. Without it, it will be commercial."[209]

Tacita Dean also attended the 2013 FIAF Congress in Barcelona, alongside Guillermo Navarro (the Mexican cinematographer of films such as *Pan's Labyrinth*[210]). Together, the two had launched a call to UNESCO "to recognise the important role that film has played in our culture,

[208] Alexander Horwath, 'Persistence and Mimicry: The Digital Era and Film Collections', *Journal of Film Preservation*, no. 86 (April 2012): 28.

[209] This citation, which was pronounced orally during the Congress, has been recounted in *FIAF 2013 Barcelona Congress Minutes* (Brussels: FIAF, 2013), 6. Here, I have slightly corrected its punctuation to make it more easily understandable as a written statement.

[210] *Pan's Labyrinth*, Guillermo Del Toro, 2006.

by declaring it a World Heritage".[211] They presented their project at the Congress, and asked the FIAF community to join in. The matter was discussed at the Congress and the large majority of members agreed to join this campaign, which, as put by Michael Loebenstein, wished "to emphasise the fact that film, as a medium, a technique and a form of expression, should be considered as part of the World Cultural Heritage".[212]

Tacita Dean and Guillermo Navarro's campaign, "Save Film", went on to attract supporters from all over the film industry; and also found some success in the art industry. Archives, commercial laboratories (such as Cineric), individual film professionals (Steve McQueen, Christopher Nolan, Jonas Mekas, Alexander Payne, Isabella Rossellini, Jane Campion, etc.), festivals (Le Giornate del cinema muto, Toronto International Film Festival, Solothurn Film Festival, Berlinale, etc.) and professional associations (IMAGO – the European Federation of Cinematographers) all joined in and signed a petition that pleaded to maintain film as a means of recording and experiencing moving images:

> "Over the past century, film has changed mankind. From the earliest fragments of captured movement, it has allowed us to watch, educate and depict ourselves in untold ways using just the mechanics of light, lenses and chemistry. It is one of our greatest inventions. […] Now we are on the point of losing it.
>
> With the advent of digital, the medium of film is greatly threatened and might, unless action is taken, simply disappear. Its obsolescence will result in untold tragedy in all that we will no longer be able to see and experience, and also in what we will no longer be able to make, because we will have simply lost the technology to do so.
>
> We cannot allow this to happen.
>
> The debate around film versus digital has been the wrong debate. It has been discussed as one of technological determinism (where only one medium can survive) often for financial, rather than artistic reasons."[213]

The campaign stressed the discourse of loss and obsolescence occurring as a result of the "advent of digital", and called for a change of direction from a film vs. digital view (where digital has been imposed by financial reasons and not for artistic reasons, called "dictatorship of economy"[214] by Jean-François Rauger from Cinémathèque française). According to it, film

[211] Dean, 'FILM', 21.

[212] *FIAF 2013 Barcelona Congress Minutes*, 20.

[213] 'Save Film petition', http://www.savefilm.org/savefilm-org/, accessed 7 September 2020.

[214] Jean-François Rauger et al., 'Roundtable. Que projetterons-nous demain en salle: quel futur pour la projection pellicule, quelle questions la projection numérique soulève-t-elle?' (Roundtable, Toute la mémoire du monde, Cinémathèque française, Paris, 2015), https://www.canal-

could, and should, survive alongside digital. Similar to the museological concerns of archives, this view was object-oriented with the film strip at its centre, and the whole film culture (recording, production, projection, etc.) around it. While the process of technological development within the film industry would accept a total replacement of film technologies by digital ones, such a view considered film as unreplaceable. The Save Film campaign aimed to break the commercial domination – which, ironically, had used 35mm film for more than 100 years as its mainstream standard. As a result, it focused on the artistic qualities offered by film and opposing them to cinema as a commercial commodity:

> "It is now clear that film will not survive if it is left to rely solely on the market. Its commercial viability has been wholly undermined by an industry intent on replacing it."[215]

The campaign did not explicitly make a distinction between film recording and film projection, but its discourse was inherently directed towards the former (although the resistance mostly intensified after the digital roll-out). By relaying the news, it promoted films shot on film, from any horizon, such as *Difret* (2014, Zeresenay Mehari, Ethiopia)[216] – projected only on DCP – or *Inherent Vice* (2014, Paul Thomas Anderson, USA) – projected on DCP and 35mm. On the other hand, it followed archival discourses on the importance of safeguarding film projection.[217] But most ardently – and somehow surprisingly, it celebrated filmmakers cherishing film and their fight within the industry to keep film alive.[218] Indeed, the celebrated "crusade"[219] led by Christopher Nolan seemed to convince the studios to keep film alive, notably by closing a deal with Kodak. Consequently, what seems to have saved the manufacturing of film, was that these independent campaigns were joined by voices from within the Hollywood industry, the same force that had imposed digital cinema.

Based on this discussion, I argue that the relation between industry and art in cinema could not be entirely associated with specific technologies. Indeed, before the roll-out, 35mm film was

---

u.tv/video/cinematheque_francaise/table_ronde_que_projetterons_nous_demain_en_salle_quel_futur_pour_la_projection_pellicule_quelles_questions_la_projection_numerique_souleve_t_elle.17147.

[215] 'Save film petition', http://www.savefilm.org/savefilm-org/.

[216] http://www.savefilm.org/frontpage/difret/, accessed 8 September 2020.

[217] For example: 'The Nitrate Picture Show', http://www.savefilm.org/news/the-nitrate-picture-show/, accessed 8 September 2020.

[218] See for example : 'Film Fighters All in One Frame', http://www.savefilm.org/news/film-fighters-all-in-one-frame-j-j-abrams-judd-apatow-bennett-miller-christopher-nolan-and-edgar-wright/, accessed 8 September 2020.

[219] Pamela McClintock, 'How Christopher Nolan's Crusade to Save Film Is Working', The Hollywood Reporter, October 2014, https://www.hollywoodreporter.com/news/how-christopher-nolans-crusade-save-737191, accessed 8 September 2020. See also: Fritz, 'Movie Film, at Death's Door, Gets a Reprive', accessed 8 September 2020.

dominant within the commercial circuit, but afterwards it lost its previous status and could even disappear entirely. What was sought by campaigns like Save Film, was to continue having the choice to use more traditional technologies, which had shaped for years the moving image culture, rather than adhering all to the new technologies. They went against the idea that every new technology was forcibly better than the previous ones, and underlined their differences which made them special. The liberty of choice could apply to either industrial or independent productions. Members of L'Abominable, a French artists' laboratory established in 1996 (whose members were also among speakers at the FIAF Congress in 2018), wrote a text for a roundtable at Cinéma du Réel festival in 2013 which summarised clearly the complex artistic-commercial relations and what needed to be done for film:

> "There is no reason to feel nostalgic, for example, about the ultra-hierarchical and elitist functioning of the professional 35 mm productions; or to mythify some technologies as opposed to others. We need to look at the practices that the technologies of the here and now induce or make possible, at the relationship they create with machines, and at the logic and economy which they are part of.
>
> Now that the digital highway has been built, what we need to do is invent new side roads."[220]

In sum, campaigns for saving film did not specifically contradict the existence of digital technologies, but they promoted a co-existence of several technologies. While in the mainstream cinema one technology was dominant (once 35mm and then D-Cinema), a multiplicity of technologies was desired to co-exist within their own (smaller) markets and field of utilities: be it 16mm or 9.5mm film stock, or other digital projection technologies (for instance MPEG-2 servers and projectors). This technological diversity was already the case within film history which was filled with different formats, but the fight to maintain it was intensified when faced with the hegemony of D-Cinema, as it could potentially erase the whole film culture preceding it.

3.1.3 Archives as Museums: Saving Film Projection

The tendency to keep film projection alive within the archival community was nourished from the museological viewpoint, whose origins were explored in Chapter Two: a film, coming alive in projection, needed to be shown on film. This was an integral part of many archival discourses.

---

[220] L'Abominable, 'Film in the Digital Age?', trans. Cinéma du Réel, L'Abominable, March 2013, http://www.l-abominable.org/en/history/a-traduire-en-en_us-largentique-a-lheure-du-numerique/, accessed 8 September 2020.

According to the then-director of Austrian Filmmuseum, Alexander Horwath, "showing film as film respects the achievements of our cultural past, and acknowledges the needs of our cultural future". For him, two reasons justified the choice of film projection for cinema's past: firstly, it was the role of film "museums" to give access not only to the cultural artefact, but also to its respective techniques, tools and materials. Secondly, by giving access to film on film, "a film museum also partakes in a tradition that has supported human culture for many centuries: the notion that our heritage can actually remain *generative, potent, procreative* […] in relation to *future artistic achievements*".[221] This motivation goes along with the discourses on film's survival as a means of expression, the artists' and filmmakers' fight. Horwath's discourse was close to that of Cherchi Usai who, as the curator of George Eastman Museum in Rochester, launched the festival "Nitrate Picture Show" in 2015, dubbed as the world's first "festival of film conservation",[222] where only original nitrate prints were screened (mostly on state-of-the-art projectors).

These theoretical discourses behind the necessity of keeping film projection alive were also reinforced on other occasions, notably at a roundtable during the festival Il Cinema Ritrovato in 2015, called "Future of Film". A part of this roundtable gathered Alexander Payne (filmmaker) and Jose Manuel Costa (Cinemateca Portugesa) who explained the differences between film and digital projections as they saw it, leading them to the conclusion that the liberty, creativity and diversity of moving images, in one word the choice, needed to be preserved.[223] According to Payne, film projection was visually distinctive and superior to digital projection, regardless of how the film was originally made.[224] Indeed, for his own film *Nebraska* in 2013, he had filmed the images digitally, but the film was projected both on DCP and 35mm in cinemas. Similarly, Jose Manuel Costa also called for archives to save film projection.

This theoretical approach did not specifically mention the numerous changes of photochemical, optical and mechanical technologies involved in the history of film projection. It focused on

---

[221] Alexander Horwath, http://www.savefilm.org/frontpage/draft-alexander-horwath-director-of-the-austrian-film-museum-believes-that-showing-film-as-film-respects-the-achievements-of-our-cultural-past-and-acknowledges-the-needs-of-our-cultural-future/, accessed 8 September 2020. The italics are in the original citation.

[222] The explanation for this title can be found in: *The Nitrate Picture Show*, Festival Programme (Rochester: George Eastman House, 2015), 22.

[223] Alexander Payne et al., 'Il Futuro della pellicola/The Future of Film' (Promoted by FIAF and Cineteca di Bologna, Lezione di Cinema, incontri sur restauro, Il Cinema Ritrovato, Bologna, 1 July 2015), https://www.youtube.com/watch?v=J427vQTxvbc&list=PLx3uAGILdftAgDkjgyYnA-WJGCQqW8sg2&index=12.

[224] Payne et al.

the fact that projection was realised from a film strip going through the projection machinery, but did not linger on the latter. What seemed to matter was the projection of the film strip, which would secure its survival as a living practice. Technically, as I explained in the previous subchapter, a projector in the 2010s would not project a film as it was seen originally, nor would a restored film strip of the 2010s reproduce the same experience as many decades earlier. They would merely simulate older technologies. However, in close interaction with the theoretical discourses, technical discourses were also developed regarding the practices of film projection, which pushed for an adaptation to the realities of the post-roll-out period and, subsequently, enriched the archival episteme by acknowledging the multiplicity of projection technologies.

The Technical Aspects

As mentioned, the technological diversity was hardly respected when there were only photochemical prints in distribution: not many cinemas, apart from archives' cinemas, had the possibility to project anything else than a standardised 35mm print. A 16mm film had rarer occasions to be projected theatrically. The 16mm prints of many short films, for instance, could only be shown in festivals or in specialised cinemas. Directly after the digital roll-out, there were many efforts to save film projection, as a whole and with no distinction between formats and machines, threatened by the hegemony of D-Cinema (which ironically tried to simulate its visual aspect). These discourses focused on countering the much-feared obsolescence of film technologies in projection and it was rarely specified which film technologies were to be saved, and on which projectors. Then, more sophisticated discussions on the multiplicity of film (and digital) projection paved the way for events such as the Nitrate Picture Show. There was a renewed interest, not just for film projection as a whole, but for different technologies, systems and machines in film projection. For example, at the Il Cinema Ritrovato festival in Bologna, since 2012, projections on a historical carbon-arc projector have been organised. These discourses also ignited more research and interest for older formats and machines, which had in effect been obsolete well before the digital roll-out, as explored at the Orphans Film Symposium in 2014 – entitled "Obsolescence".[225]

In 2016, an article appeared in the *Journal of Film Preservation* that focused on the Norwegian experience of photochemical film projection. The film projection was not celebrated in this article just because it was on film; rather, it was presented as a necessity because not everything could be digitised and most archival holdings remained photochemical prints. Indeed, the

[225] Refer to the keynote of Thomas Elsaesser, 'On Obsolescence' (9th Orphans Film Symposium, Eye Filmmuseum Netherlands, Amsterdam, 30 March 2014), https://archive.org/details/orphans2014elsaesser.

archives could not afford to digitise everything, for financial, political and technical reasons. For instance, most archives received public money to digitise (selectively) their own national film heritage, but could not digitise the prints of foreign films they held.[226] The article incited archives to improve the quality of their film projections in order to catch up with digital projection's "bright images" and "sharp edges". Focused on the technical details of projectors, the article presented how the Norwegian Film Institute had modified their traditional film projector by changing the xenon bulbs to bulbs intended for a digital projector in order to reduce flickering.[227] The film-on-film projection could thus be ensured thanks to a custom-made, hybrid machine, following the basics of film projection but also owing to digital projection's light equipment. By this time, the hybridity – not only in terms of strict technologies used in machines, but also simply as co-existence of different types of projection possibilities – seemed to gain a foothold in the discourses:

> "There's no question that projection of analogue film for presentation has certainly declined internationally over three years, but there is still a very strong lobby in favour of preserving the opportunity to view 'film as film'. Indeed, there is now a strong sense of renewed optimism in the air as producers, audiences, and archivists all come to terms with the hybrid world of digital and analogue. As we enter 2016, it feels as though there is a distinct opportunity for the qualities and experiences of analogue and digital to live together harmoniously."[228]

The technological shift had indeed successfully re-ignited a discussion of photochemical film projection, and film-on-film projection was valued as a museological role that also needed to be technically described. These discourses culminated in the 2019 book *The Art of Film Projection*, by the George Eastman House.[229] Conceived as a technical manual, the book is also a self-proclaimed cultural manifesto on the importance of film as creative work and a "window through which to understand the materiality of film and its de-materiality as projected image".[230] Although it is also a best-practice book, it differs from FIAF's *Advanced Projection Manual* as it was published several years after the digital roll-out, at a time where film projection was not the dominant practice anymore but a niche practice mostly reserved to

[226] I will come back to digitization projects in the next chapter.
[227] Jan Eberholst Olsen, 'Maintaining Analog Film Projection the Digital Age', *Journal of Film Preservation*, no. 94 (April 2016): 53–58.
[228] Fairall, 'FoFA: The Future of Film Archiving'.
[229] Cherchi Usai et al., *The Art of Film Projection: A Beginner's Guide*.
[230] Tacita Dean and Christopher Nolan, 'Foreword', in *The Art of Film Projection: A Beginner's Guide*, by Paolo Cherchi Usai et al. (Rochester: George Eastman Museum, 2019), 14.

archives' cinemas or alternative circuits (some arthouse cinemas, festivals, etc). In this regard, *The Art of Film Projection* has a more pronounced museological aspect to it. Believing that "film projection is the ultimate achievement of film preservation",[231] the book defines film projection as an activity related foremost to film archives and film preservation. In this sense, film projection goes beyond film as a source of a projected image, and includes the whole historical culture (technologies and knowledge) surrounding it and preserved from decades prior.

Programming a Film Projection

Finally, regarding film projection, the question of programming and curation needs also to be taken into consideration. The digital roll-out did not entail the disposal of all film projection equipment, despite the widespread replacement on the commercial circuit. Indeed, some cinemas, particularly art-house cinemas, were equipped with digital projection while conserving their traditional projectors. In Switzerland, by 2017, there were 119 cinemas (out of a total of 585) that had maintained the technical possibility of projecting 35mm film.[232] In Paris, the network of "Cinémas Indépendants Parisiens (CIP)" maintains a program called "photochemical tendency", regularly showing 35mm films.[233] Such initiatives remain of course exceptional events rather than the norm, but they do persist. While the dominant projection method had changed on commercial circuits, alternative distribution circuits – which had always existed – did not disappear after the roll-out (such as festivals, archives, art-house and repertory cinemas, cine-clubs, etc.).

What changed indeed was which material could be provided to cinemas equipped with film projectors to show on film. In the case of film archives and museums, they could simply continue their original programming as film on film on their own premises – as long as the prints remained available. But mainstream cinemas, and many art-house cinemas, which were mostly focused on new films, did not often receive film materials to project anymore.[234] If

[231] Dean and Nolan, 19.
[232] This percentage may be significantly different in various countries. Moreover, most of these cinemas conserve the 35mm equipment, but rarely use them. A non-exhaustive list of cinemas with 35mm projectors can be found here: https://www.sprocketschool.org/wiki/List_of_analog_film_exhibitors, accessed 20 August 2021.
[233] In French, *tendance argentique*. For more information, see: https://www.facebook.com/tendanceargentique/, and http://www.cinep.org/, accessed on 20 August 2021.
[234] For a discussion of 35mm programming in and out of archives' premises, see: Brian Meacham, 'Between the Archive and the Multiplex: 35mm Film Programming in the Post-Film Era', *Journal of Film Preservation*, no. 97 (November 2017): 27–36. In this article, Meacham discussed how 35mm film projection has become a rare "event" in non-archive cinemas, as well as a marketing tool, and he underlined the challenges of programming

cinemas were to continue showing 35mm, they needed to rethink their programming. Ironically, 35mm programming at a larger scale – outside of archives' cinemas – was not facilitated by archives, due to the scarcity and fragility of photochemical prints. This discourse went back to the early 2000s, notably with Paolo Cherchi Usai's statements declaring every print is unique.[235] The digital roll-out intensified these discourses. Since 2010, the FIAF Programming and Access to Collections Committee has worked on the strategic issues related to D-Cinema's generalisation, and they have presented reports on the increasing importance of projection prints and emphasised the necessity of conserving them better.[236] As a result, the archives would lend their holdings more restrictively, "due to the borrower being incapable of handling or projecting the prints in a correct way".[237] Archives have thus been fighting for maintaining film projection, to which they restrict access themselves.

For archives, it has therefore been necessary to re-evaluate the place of film technologies, in a world where 35mm film is not dominant anymore, through different theoretical, technical and curatorial aspects. During this process, the archival imaginary has evolved: in the beginning, a theoretical artefact-centred vision, alongside some practical reasons, reunited all voices within the archival community to save film against the presumed external threat of digital cinema, before getting to a point where the plurality of film technologies was attested and valorised, in co-existence with the now-dominant digital technologies.

3.2 Digital Projection: Archival Adoption and Adaptation

Parallel to their fight for the maintenance of film and film projection, film archives needed to adopt, at the same time, the imposed D-Cinema standards: "It is clear that – even if we uphold and celebrate FILM – we operate in a digital environment".[238]

Archives had been engaged in discussions regarding a so-called digital future from the early 2000s, suggesting diverse solutions. When the digital roll-out was fulfilled, they needed to move forward to concrete action. The question was not anymore if film or digital were more suited to projection or any other archival activity, rather how diverse film and digital technologies needed to be adapted to different activities. The technologies were all desired to

---

film on film (in terms of selection, but also availability of films) by studying the cases of four art-house cinemas in New York. This article is the written version of a conference Meacham gave during the 2017 FIAF Winter School in Cinémathèque française, where the view considering 35mm projection as an "event" was dominant.

235 See for example: Cherchi Usai, 'Film as an Art Object'.

236 FIAF Programming and Access to Collections Commission, 'PACC Report to the FIAF General Assembly'.

237 See: Jon Wengström, 'Access to film heritage in the digital era – Challenges and opportunities', *Högskolan I Borås, Nordisk Kulturpolitisk Tidskrift* 16, no. 1 (2013): 125–36.

238 Michael Loebenstein, 'Editorial', *Journal of Film Preservation*, no. 91 (October 2014): 3.

co-exist. During the FIAF Congress in Oslo in 2010, a 70mm film festival was held; and at the same time, a joint technical symposium on digital challenges and opportunities was organised, where the need to accept digital cinema – despite different views which considered it in continuity to traditional cinema or a rupture compared to it – was felt increasingly. Writing in 2011, Michael Loebenstein underlined the importance of the changes to come:

> "2010 brought many revelations. The Oslo Joint Technical Symposium has demonstrated how complex the challenges in transition from grain to pixels are, and how urgent it has become to develop 'best practices' for born-digital works. The Technical Commission's most recent paper on the deposit and acquisition of D-cinema elements, the CDC's involvement with developing standards for the interoperability of film databases, as well as PACC's initiative in developing models for a collection policy, are necessary steps towards the aim of neither falling behind technological advances nor blindly subscribing to industry trends."[239]

From this statement, it is obvious that archives were indeed conscious that the industrial technological turnover would inevitably bring them to rethink several of their practices. At the same time, they rejected the idea of a total adhesion to the industrial trends. The two FIAF Commissions, TC and PACC, were each leading a part of the research which would prepare archives from technical and strategic viewpoints. The European Commission also recommended, through a clear discursive position with regards to digital cinema, that film archives equip their cinemas with digital equipment, while preserving film projection:

> "- Cinematheques need to get equipped with digital projectors, so as to project digitised or born-digital films. Structural funds may be used to this end.
>
> - Analogue projection technology should also be preserved."[240]

As explained in Chapter Two, during the late 2000s, the PACC was heavily invested in the investigation of archival identity and film heritage and made efforts to strengthen them. The Oslo discussions, most notably the presentation on Norway's D-Cinema roll-out, which was well underway, were followed by a PACC workshop in which the strategic issues of the roll-out were evoked. The PACC, while inciting archives to keep their film projectors and save their distribution prints, announced that the *Advanced Projection Manual* would shortly be updated by Torkell Saetervadet. As Saetervadet was closely involved in the Norwegian roll-out, he was

---

[239] Michael Loebenstein, 'Editorial: A Changing Landscape', *Journal of Film Preservation*, no. 84 (April 2011): 3.
[240] European Commission, 'Film Heritage in the EU', 4th Report on the Implementation of the European Parliament and Council Recommendation on Film Heritage 2012-2013, 1 October 2014, 19.In the preceding reports, there was no mention of preserving "analogue projection technology".

ready to work on this addition when the SMPTE standards were fixed.[241] The result, *FIAF Digital Projection Guide*, was published in December 2012. In the meantime, Saetervadet, who was also a corresponding member of FIAF TC, prepared answers to the many questions from the archival community regarding D-Cinema,[242] and presented several times in archival conferences.[243] What was primarily detailed in these documents on digital projection, was in fact the non-digital technologies of projection (light sources, the characteristics of the image projected by light on a screen) and the question of digital print was less subject to discussion.[244] These documents contained information on the machines enabling the "D-Cinema playback system", and the goal was to practically assist archives in choosing a projector (similar to what had been done for photochemical projectors in the *Manual* in 2006).

The differences between D-Cinema and E-Cinema were also extensively covered by Saetervadet (but again with no emphasis on the technical details of the digital print). E-Cinema is an umbrella term that has been used for several technical possibilities of digital electronic projection. Since the digital roll-out, it has come to englobe any digital projection that does not satisfy the requirements of the standardised D-Cinema.[245] E-Cinema was directly frowned upon in the US by third-party commercial technology providers such as Qualcomm as early as 1998, and it was distinguished from the "ultimate" digital cinema: "Small venues showing a projected copy of a movie on a stretched bed sheet screen could be considered electronic cinema."[246] However, before the film industry (led fiercely by Hollywood studios) imposed the digital cinema standards, E-Cinema, most notably in Europe and through public national funding, opened the door to many experimentations and was at the heart of several projects since the mid-1990s. It was seen as a chance for widening the diversity of films in cinemas (with a focus on smaller films, documentaries, "specialized films that are so characteristic of European film culture", in an attempt to "create a new chance for European film culture in order to survive the

[241] It should be noted that standards, in general, are ongoing processes. A standard publication may be modified, complemented or replaced by the same group of standardisations throughout years. In the case of SMPTE standards for D-Cinema, a first version was published in 2008, and the next – complementing the previous – in 2011.
[242] Torkell Saetervadet, 'D-Cinema Equipment Frequently Asked Questions', Digital Technology Guidance Papers (FIAF, 2012), https://www.fiafnet.org/images/tinyUpload/E-Resources/Commission-And-PIP-Resources/TC_resources/D-Cinema%20FAQs%20release%20FIAF%202012%20V1.1.pdf.
[243] For example, at the 2013 FIAF Congress in Barcelona and at Pordenone in 2012.
[244] As previously noted, the DCI specifications for digital prints were extensively discussed already in *The Advanced Projection Manual* in 2006.
[245] As an example, the programme bulletin of the Cinémathèque suisse designates every DCP projection as D-Cinema and any other digital material (Digibeta, BluRay, ProRes or H264 files, etc.) as E-Cinema.
[246] Morley, 'Making Digital Cinema Actually Happen – What It Takes and Who's Going to Do It'.

overwhelming influx of American movies”.[247] After the standardisation of D-Cinema, the E-Cinema projects and activities were reduced heavily. Having been familiar with E-Cinema, archives had categorically rejected it, believing it to have an inferior quality in projection. In Saetervadet’s recommendations, D-Cinema was also believed to ensure the “best possible film experience”, and it would fit the audiences accustomed to see clearer, brighter, sharper images, deemed by him as “high quality”:

> “Today, people are surrounded by high quality moving images everywhere. As moving images of high quality are becoming the norm, the eyes of the audience are getting more and more critical. While one could easily project a hammered and faded 16 mm film print of a rare title some 20 years ago, today’s audience will complain – or worse: Never return to the cinema. […] With this backdrop, why should the audience accept a sub-standard experience at national museums celebrating the film heritage (as most film archives are supposed to be)? If the cinematheques can’t provide a reasonable guarantee that the audience is seeing something as close as possible to the original film experience, why should the cinematheques even exist? Hardly because they are generally better at putting films into context than a large number of online services, one would imagine.”

With this statement, Saetervadet was arguing for the adoption of D-Cinema, as the closest to the “original film experience”. He even considered that the film archives could not have done without it, because the new audiences, as he imagined them (in line with the industrial view), preferred seeing “high quality” images. The fact is that film technologies, as well, were gradually moving towards such images believed to be technically of higher quality (through newer film stock and machines), forming a new cultural understanding of what a good projected image was. The so-called high-quality cinema image, despite its plural facets, seemed to converge in one vision: the audiences, as well as the industry and archives, had all become used to watching cleaner, less grainy, sharper images. D-Cinema, which had been conceived through its similarity with film experience, maintained the high-quality expectations of cinema.

Despite this fact, according to Saetervadet an E-Cinema projector – if satisfying some requirements – could be a cheaper compromise to D-Cinema systems: for example, one light modulator per colour channel (in order to avoid colour compression in projection), minimum native HD (which is close to D-Cinema’s 2K), minimum contrast ratio of 2000:1 (which avoids the impression of flatness of the digital image), a xenon light source (similar to newer film

---

[247] Kees Ryninks and Bjorn Koll, ‘European DocuZone (EDZ)’, in *The EDCF Guide to Digital Cinema Production*, ed. Lasse Svanberg (Burlington/Oxford: Focal Press, 2004), 115–20.

projectors as well as DLP projectors, but not Sony digital projectors[248]). These characteristics make the E-Cinema image look more like D-Cinema, and therefore more like a projected film image. Another technical difference between E-Cinema and D-Cinema – which was not addressed in the FAQ document – concerned their digital prints. E-Cinema is in effect a digital video projector, whose inputs are digital video files, while the basic idea behind digital cinema was to provide films as an image sequence similar to photochemical cinema, with a specific digital compression, JPEG 2000. A series of still, distinct, images produce the movement when played at a certain speed, while video signals encode images together in a way that the original digital frame might not be individually accessed anymore.

Through the "Digital Technology Guidance Papers", the FIAF Technical Commission also encouraged archives to adopt the D-Cinema standard, despite the fact that the imposed aspect ratios of DCPs did not coincide with that of most archive films, neither did the imposed digital frame rates.[249] According to the TC, acceptance of D-Cinema was inevitable:

> "The change in industry practice will have fundamental and far reaching effects, not only for new films, but also for heritage film distribution and presentation. It is important that FIAF embraces the new technology (as has for instance been the case with the use of polyester films), or the relevance of the organisation will be diluted."[250]

It was indeed true that archives were also reluctant in the 1980s and 1990s to accept polyester support, although it had already existed since the 1950s.[251] During the 1987 Joint Technical Symposium, Karel Brems (Agfa-Gevaert) had introduced their research on the deterioration of cellulose triacetate film, and underlined the superiority of polyester film as an archival support immune to the well-known decomposition problems of nitrate or acetate films. The presentation was met with some scepticism from archivists at the time, and Harald Brandes (Bundesarchiv) questioned Brems about the possible degradations of polyester film.[252] Three years later, at the Ottawa Joint Technical Symposium, Brems (and other researchers from Agfa-Gevaert), presented a paper precisely on the possible degradations of polyester, presenting it as a very

[248] Sony used laser light source in its digital cinema projectors.

[249] FIAF Technical Commission, 'Digitisation for Film Archives – Assorted Complications', Digital Technology Guidance Papers (FIAF, 2012), https://www.fiafnet.org/images/tinyUpload/E-Resources/Commission-And-PIP-Resources/TC_resources/Digital%20Complications%20v1.1.pdf.

[250] Thomas Christensen, 'Report of the Technical Commission', FIAF 2011 Pretoria Congress Report (Brussels: FIAF, 4 April 2011), Appendix 5.3.1.

[251] See for example: Deane R. White et al., 'Polyester Photographic Film Base', *Journal of the SMPTE* 64, no. 12 (December 1955): 674–78.

[252] Karel Brems, 'The Archival Quality of Film Bases', in *Archiving the Audiovisual Heritage. A Joint Technical Symposium*, ed. Eva Orbanz, Proceedings of the 2nd JTS in Berlin on May 20-22, 1987 (Berlin-West: Stiftung Deutsche Kinemathek, 1988), 31–36.

stable support.[253] Acetate or Polyester was also one of the main topics of the 1993 manual of the FIAF Preservation commission.[254] After the digital roll-out, the TC assimilated the acceptance of D-Cinema to a process that archives had already known with regards to polyester. It should be noted that the resistance to digital cinema was somehow weak post-2012 (although not inexistent), as the standard had already been adopted by the industry a few years prior. In 2012, during the Il Cinema Ritrovato festival in Bologna, a discussion was organised which explored the possibilities and problems of digital and film projection of film heritage. There was already the viewpoint that neither were perfect, and their co-existence would be beneficial.[255] Most importantly, all technologies needed to be adapted to archival practices (and vice versa).

How to Adapt to D-Cinema?

The confrontation of archives with D-Cinema was not limited to the acceptance (or not) of digital projection. It seemed crucial to know how the new digital technologies worked, before aiming to master them, especially as it seemed that producing a DCP within archives was not too complicated. According to Nicola Mazzanti, it was even more accessible to archives than producing a film print (which needed to be done at a laboratory):

> "The reality is that producing a DCP is something that already is much more easily within the reach of an archivist and an archive than printing and processing a film print. And it is so much cheaper – even now when it is still a 'new process' – whether it is done in-house or if it is outsourced to the many companies offering the service. Considering all of this, I see no reason why archives shouldn't get equipped to carry out the process in-house."[256]

This view could somehow prove polemic, as, contrary to DCP, which was a new technology, archives were familiar with traditional technologies of processing and printing – and were used to them. But the DCP remained an unknown domain, and needed to be technically understood first. In 2010, a FIAF document prepared by Arne Nowak (Fraunhofer Institute), detailed not only the structure and packaging of DCPs, but also gave insights on how to produce a DCP

[253] Norman Allen et al., 'Factors Influencing the Degradation of Polyester Based Cinematographic Film and Audio-Visual Tapes', in *Archiving the Audiovisual Heritage. Third Joint Technical Symposium*, ed. George Boston, Proceedings of the 3rd JTS in Ottawa on May 3-5, 1990 (Rushden: Stanley L Hunt (Printers), 1992), 40–51.
[254] FIAF Preservation Commission, *Technical Manual of the FIAF Preservation Commission* (Brussels: FIAF, 1993).
[255] Peter von Bagh et al., 'La proiezione dei film del patrimonio tra pellicola e digitale, problemi e possibilità' (FIAF Restoration Summer School, Il Cinema Ritrovato, Bologna, 29 June 2012).
[256] Nicola Mazzanti, 'Digital Cinema Technologies from the Archive's Perspective. Part 2', *AMIA Tech Review*, no. 3 (April 2011): 1–15.

from an archive film (assuming it is already digitised), introduced the EasyDCP player (a playback software for digital cinema developed by the Fraunhofer Institute), and celebrated the fact that digital cinema could increase access to archive films: "With the Digital Cinema Package there is also an efficient way to distribute archive films in a very high quality to digital cinemas".[257] Nowak, a digital cinema researcher and technologist at the Fraunhofer institute at that time, had been previously associated with the EDCINE project from 2006 to 2009. EDCINE "intended to expand on the Hollywood DCI (Digital Cinema Initiatives) proposals for digital cinema, in the hope of producing a standard more in line with the needs of archive film presentation".[258] Its three fields of application were:

- Advanced applications of digital cinema beyond DCI
- Digital cinema distribution (focused on streaming content to cinema theatres)
- Digital cinema archiving and access to digitised archival material[259]

This European public project was conceived based on the fact that differences existed between DCI specifications and the eventual state-of-the-art implementations. While not questioning the look of the projected image as determined by the JPEG 2000 compression, it functioned precisely on the grey areas where some flexibility could be performed. Its goal was to "[keep] in conformance with DCI while meeting European requirements".[260] Cinémathèque royale de Belgique (represented by Nicola Mazzanti) was a partner in the project, Paul Read also acted as a consultant, and this way, archives were involved in the development and implementation of EDCINE system. The question of adapting digital projection for film heritage was taken into consideration, requiring that "the cinema projection of heritage films (best defined as films shot and released prior to digital projection becoming used or standardised) be authentic and as faithful a representation on the screen of the projected original film as possible".[261] The desired authenticity was defined through a non-exhaustive list in one of the first documents published by EDCINE:

---

[257] Arne Nowak, 'Digital Cinema Technologies from the Archive's Perspective', Digital Technology Guidance Papers (FIAF, 2012), https://www.fiafnet.org/images/tinyUpload/E-Resources/Commission-And-PIP-Resources/TC_resources/Nowak%20-%20Digital%20Cinema%20Technologies%20v2.0%20FIAF-TC_final%20V1.1.pdf. Originally published as: Arne Nowak, 'Digital Cinema Technologies from the Archive's Perspective', *AMIA Tech Review*, no. 2 (October 2010): 1–12.

[258] As recounted by David Walsh, 'Joint Technical Symposium 2007. Audiovisual Heritage and the Digital Universe (28-30 June, Toronto)', *Journal of Film Preservation*, no. 74–75 (November 2007): 57.

[259] The question of long-term digital archiving will be explored in Chapter Four.

[260] Pedro Costa, 'D1.1 User Requirements and General Conditions', Public Deliverable, EDCINE, 15 April 2007, 38.

[261] 'EDCINE/Archives. A Summary of the EDCine Project - Archival Applications', Project Summary, EDCINE, March 2008, 4.

> "1. The resolution of the projected screen image should not be visually lower than that of original film image (it is appreciated that this requirement is difficult to quantify).
> 2. The framerate of a digital cinema projection should be the same as that of the original film.
> 3. The aspect ratio of the image should be that of the original film.
> 4. If appropriate to the original period, a film programme of mixed aspect ratio content should be shown using common height principles."[262]

At this point, while it was accepted that the correspondence in "resolution" between photochemical and digital projected images is not precisely measurable; there was still a desire to compare them, and make a digital image similar to the photochemical image in terms of factors such as sharpness and clarity. I will come back to the other criteria later in this chapter. What is crucial to underline here is that the authenticity did not indicate a replication of original technologies, but of particular image characteristics, which could be simulated through any technological system including digital projection.

In what concerned archives, the overall goal of EDCINE project was to "develop and test a concept for digital film archiving that addresses both long-term archiving of digital data and the access to already archived digital material."[263] It was supposed to provide a solution for digital preservation, which would not only store files, but also allow fast, easy and reliable access, notably for digital projection in cinema theatres. The EDCINE project was conducted before the roll-out, but after the publication of DCI recommendations and in the midst of the standardisation in progress. It imagined a filmless future, in which digital projection would become necessary:

> "Cinema archives, in particular, will continue to consider film formats as long as this is possible, as it is a worldwide well established standard and exchange format. However, once film lab services diminish and become scarce, expensive or non-existent, preventing the replacement of prints, and raising the intrinsic and heritage value of existing prints, will drive the digital projection transform forward at an increasing pace. Therefore digital projection of archived material will become more and more evident in the future for the following use cases for which an appropriate workflow and dissemination model for digitised content must be defined:
>
> - projection in archive's own facilities

[262] 'EDCINE/Archives. A Summary of the EDCine Project - Archival Applications'.
[263] https://www.iis.fraunhofer.de/en/ff/amm/for/forschbewegtbildtechn/edcine.html#tabpanel-1, accessed 22 August 2018.

- cinematheques
- film festivals
- commercial cinemas
- art house cinemas"[264]

For EDCINE, the digital cinema delivery could vary according to the venue where the digital film was to be projected. It could adhere to "maximum interoperability" with commercial cinemas, while the projection at archives' own facilities could go more towards the "maximum reproduction of heritage format". Through the second possibility, the EDCINE proposal intended to remedy the shortcomings of DCI/SMPTE with regards to film heritage in terms of "frame rates, image and audio specifications, etc".[265] EDCINE did not start the D-Cinema research from scratch, it was based on the industry standards (that it could not alter, being a European research project with no influence in the mainstream film industry). But it recognised the problems faced by archives in adopting the DCP technology, proposed solutions to get around these and implemented tools such as the EasyDCP player, a PC-based software developed to decode and playback DCPs on a computer, bypassing a cinema server. The EasyDCP player could be a useful tool in film archives by enabling a visual control of the DCP content.

An important contribution of the EDCINE project for archives was the scientific explanation it provided regarding the performance and implementation of D-Cinema's compression and the details of the digital frame. Nowak regularly presented at archives' conferences from 2007, where he would explain not only EDCINE's digital archiving system, but also the more general DCI-compliant JPEG2000-based D-Cinema. The documents that Nowak prepared for archives and the conferences in which he participated were helpful in deconstructing the idea of a digital black box as the source of the projected image. Although on the discursive level, most archivists remained doubtful about digital cinema, they were regularly informed and updated about the technical details of DCPs. Nowak would detail the encoding and decoding of JPEG2000 and explain the wavelet transforms and entropy coding at the core of its compression. In doing that, he stressed the fact that JPEG2000's intra-frame coding preserved the independence of each film frame. "Cinema" was still projected from a sequence of still images (Figure 38), which were "visually lossless", so they could achieve the authenticity aspired by film archives.[266]

---

[264] Arne Nowak et al., 'D6.5 Definition of Detailed Workflow and Format Specifications for T6.3', Public Deliverable, EDCINE, 28 May 2007, 15.
[265] Nowak et al., 15–16.
[266] Arne Nowak, 'Fraunhofer Digital Cinema' (AMIA Conference, Rochester, 26 September 2007).

Figure 38 Arne Nowak presented at AMIA Conference in 2007 how the Digital Cinema Package conserved the principle of image sequence as in photochemical cinema.

The Problems of D-Cinema Standards

The DCI recommendations and the standards did not include the case of presenting film heritage in their original form. This had become apparent from the early demonstrations of digital projection technologies in the archival community in the mid-2000s, for example regarding frame rate or aspect ratio.[267] The archival community at the time was exposed to a newly awakened interest for the respect of the historical projection characteristics of films, as the 2007 FIAF Congress had shown by addressing many film formats and projection systems, which "allowed to raise a real awareness and responsibility with regards to the safeguarding of a material heritage in view of enabling the recreation of the original spectacles".[268] At the same time, archives were hoping that digital projection technologies could solve these compatibility problems between different systems. In a Nordic archival meeting in 2006, Jon Wengström

[267] See for example: Paul Read, 'Hollywood's Proposals for Digital Cinema, Digital Projection of Heritage Film Content at Original Frame Rates', *Journal of Film Preservation*, no. 74–75 (November 2007): 61–70.
[268] Jean-Pierre Verscheure, 'Synthèse analytique du symposium. Researching the Origins: Archival Study of Short-lived Film Formats (Tokyo, avril 2007)', *Journal of Film Preservation*, no. 74–75 (November 2007): 35–56. My translation.

criticised the problems of adapting new silent film prints to modern photochemical projectors (by step-printing them to 24 fps or using widescreen aspect ratio instead of full-frame), and hoped that the digital print would help solve the incompatibility formats.

> "[Instead of creating compatible film prints] I would prefer to have only proper full-frame prints screened in theatres able to vary the speed of the projectors, even though this means having to maintain a very restrictive lending policy. I would instead wait for the instalment of proper digital projection in external theatres, and provide borrowers with good-quality digital copies, while continuing to screen actual prints on our own premises, and lend them to the limited number of theatres suitably equipped."[269]

When the rigid digital projection standards were set, it became clear that not every particularity of old film technologies had been taken into account. The film industry, which had conceived its D-Cinema based on the state-of-the-art film image, did not show much interest in engaging in discussions regarding film heritage. As a result, archives needed to find solutions and adapt to the limiting industry standards themselves, just as they had been doing during the long years of 35mm's domination: they had restored their films originally in unusual gauges and formats onto 35mm, or presented silent films on sound projectors with a slightly different aspect ratio. The mainstream film industry's economic and technological domination continued the already-existing archival concerns and the same problems needed to be solved again.

Among the problems of adaptation to archival material, which originated in the too-strict framework of DCP, two were more regularly discussed: aspect ratio and frame rates. Most of these restrictions were in fact not the result of a specific technical necessity *per se*, and were only imposed via standardisation. Three aspect ratios are accepted for DCPs, which are 1:1.85 (1998x1080 in 2K – called Flat in DCI terms), 1:1.89 (2048x1080 in 2K – called Full Container) and 1:2.39 (2048 × 858 in 2K – called Scope).[270] Most archival films have in fact other aspect ratios, and their DCP packaging requires the use of Pillarbox or Letterbox. As the pixel count of the DCP is also fixed to either 2K or 4K, the mismatch in aspect ratio for archival films represents a loss of quality. For example, if a DCI 4K uncompressed image in 1:1.37 aspect ratio (4096 pixels horizontally, 2988 pixels vertically) needs to be packaged into a 4K flat DCP, it has to fit inside a 3996x2160 frame.[271] This means that instead of 4096x2988, the DCP image

[269] Jon Wengström, 'Report from the Nordic Archive Meeting in Tromso, 7-9 September 2006', *Journal of Film Preservation*, no. 72 (2006): 82.
[270] In DCI definitions, these are called "container formats".
[271] This is in fact the best-case scenario. The scope format would reduce the spatial resolution even more.

will have a pixel count of 2960x2160, the rest is complemented by black pixels (pillarbox) (Figure 39).[272] The DCP image is thus degraded in this sense.

Figure 39 The dimensions of the 4K picture on top, in 1:1.37 aspect ratio, are 4096x2988. When the image is packaged into DCP, it needs to fit into the aspect ratio of 3996x2160. As seen in the bottom image, the height is therefore reduced from 2988 to 2160 pixels, and the DCP width of 3996, which is too big for the new image dimension of 2960 pixels, is filled on the sides by pillarboxes. Simply put, the image is described with a smaller number of pixels. This digitised frame comes from the 4K restoration of *Venus vom Tivoli* (Leonard Steckel, Switzerland, 1952). Courtesy of Cinémathèque suisse.

[272] This problem has been evoked in the archival community, notably by Mikko Kuutti, 'The Pixel' (FIAF Restoration Summer School, Il Cinema Ritrovato, Bologna, June 2014).

The digital image, technically, has no obligation to be only in these aspect ratios. A computer can accept an image in any aspect ratio,[273] but there are only three that are accepted (and thus implemented technologically) in D-Cinema. For archives, this problem revived an old problem in the photochemical reproduction of silent films. If the silent films were to be presented on a modern projector, they needed to be printed in a widescreen aspect ratio so that the full frame (1:1.33, 24.9x18.6mm on the film) could be fit into the smaller frame of sound cinema (1:1.37, 21.9x15.9mm on the film). The problem was regrettably not solved in the new cinema standards, it just changed technologies (and with that, the adaptive solutions of archives needed to account for it again).

Another problem related to aspect ratio was that of films with mixed aspect ratios. In this case, photochemical prints favoured the same height, rather than the same width. This practice had not been maintained in analogue or digital video technologies, where the height of the whole film did not remain constant according to different aspect ratios of its images. As I cited the EDCINE requirements for authenticity, it was desired by the archival community that the rule of the same height be generalised to DCP as well.[274] This was not defined in the standards, and could be implemented in different ways. Technically, there are several possibilities in making a DCP by adding black pixels horizontally or vertically. For archival formats smaller than 1:1,85, the height could easily remain constant while the width is adapted to the aspect ratio.

As for the frame rate, it was defined very restrictively in the DCP requirements, and, in the 2008 version of the standards, no frame rates less than 24 fps were allowed, which did not suit archival applications. This was the most contested aspect of digital cinema by film archives, as it had also been a constant problem before with the photochemical reproductions. Traditionally, in order for silent films to be screened at the right speed in commercial cinemas and on most modern projectors, the films needed to be step-printed. Step-printing was a technique that consisted in doubling certain frames in order to fit the 16 frames making up a second into a 24-fps structure.[275] The efforts and lobbying of the FIAF Technical Commission from 2008 led to the introduction of silent film speeds (16, 18, 20, 22) as voluntary standards into the later versions of D-Cinema requirements from 2011. However, as these were voluntary, they were

---

[273] But the possibility of presenting other aspect ratios needs to be implemented by server and projector manufacturers.

[274] This problem was also raised at the FIAF Congress 2007 by Jean Pierre Verscheure. See: Verscheure, 'Synthèse analytique du symposium. Researching the Origins: Archival Study of Short-lived Film Formats (Tokyo, avril 2007)'.

[275] For a complete discussion of the problem of frame rates in silent films' historical presentations, see: Maral Mohsenin, 'Silent Film Speeds throughout Film History: Standards and Practices', *Journal of Film Preservation*, no. 101 (October 2019): 8–18.

not implemented by DCP manufacturers. Therefore, the same concept of step-printing, as in doubling of certain frames, needed to be digitally implemented when creating DCPs as well, in order to have the correct frame rate. The FIAF TC continued fighting for this cause:

> "The Technical Commission has been made aware that recently adopted D-Cinema standards for incorporating slower than 24 fps projection in D-Cinema systems are largely being ignored by the manufacturers."[276]

Hoping to counter this, FIAF TC contacted Doremi with the request to implement it. But a year later, during the 2013 FIAF Congress, the TC announced that they were faced with the "complete indifference of manufacturers! Industry [is] more interested in HFR (high framerates), we redouble efforts when they have sorted out HFR".[277] Disillusioned, the TC let the matter be further pursued by the European Digital Cinema Forum:

> "Currently the European Digital Cinema Forum is trying to find a way of encouraging system suppliers to support the archive frame rate standard, and we await any progress with interest."[278]

In 2015, withdrawn from the fight, FIAF TC became an (enthusiast) observer, hoping for change, without being actively engaged:

> "There are continuing initiatives both in USA and Europe to try to find a solution to the challenge of showing DCPs at less than 24 fps without involving digital systems' manufacturers any major modifications to their systems. These may hold some promise, and we continue to monitor the situation."[279]

One of the initiatives that was going on at that time, was launched by Jonathan Erland, under the aegis of the non-profit Pickfair Institute for Cinematic Studies. The research was conducted by an ad hoc special interest group that intended to facilitate the digital projection of archive films in their original frame rates. This project tried to simulate digitally the same mechanism as a film projector had (Figure 40).[280] Instead of simply fitting 16 images into the DCP-standard 24 fps, this method considers the actual performance of a film projector with a three-blade

[276] Walsh, 'FIAF Technical Commission End-Term Report to the FIAF General Assembly 2012'.
[277] David Walsh, 'FIAF Technical Commission End of Year Report to the General Assembly', FIAF 2013 Barcelona Congress Report, (Brussels: FIAF, 4 April 2013), Appendix 4.1.
[278] David Walsh, 'FIAF Technical Commission End of Year Report to the FIAF General Assembly 2014', FIAF 2014 Skopje Congress Report (Brussels: FIAF, 14 April 2014), Appendix 4.1.
[279] David Walsh, 'FIAF Technical Commission End of Year Report', FIAF 2015 Canberra Congress Report (Brussels: FIAF, 23 March 2015), Appendix 7.
[280] See: Erland, 'The Digital Projection of Archival Films Project: Phase One'; Jonathan Erland, 'Frame Rates, Old and New' (The Reel Thing, FIAF 2016 Bologna Symposium, Bologna, 26 June 2016).

shutter,[281] where an image is flashed once, then a black frame, then the image is flashed a second time, again a black frame, the image is flashed a third time, and finally another black frame. This research, which focused on silent films, was then taken up by the FIAF TC, which applied the same logic to films run at 24-fps. By introducing the black frames resulting from a two-blade shutter, which was more common for sound cinema, a 24-fps film would become a 96-fps DCP, reducing the flicker.[282] In order to recreate the function of projectors, it becomes important to know how many blades a given projector shutter had; but it is still difficult to simulate exactly how the shutters worked because of their different shapes. Solutions of this type tried to include at least parts of the original characteristics of film technologies within the standardised technological frameworks, instead of a fundamental opposition to DCP. This solution is reminiscent of an older archival practice when a three-blade shutter was added to state-of-the-art projectors in order to project silent films.[283]

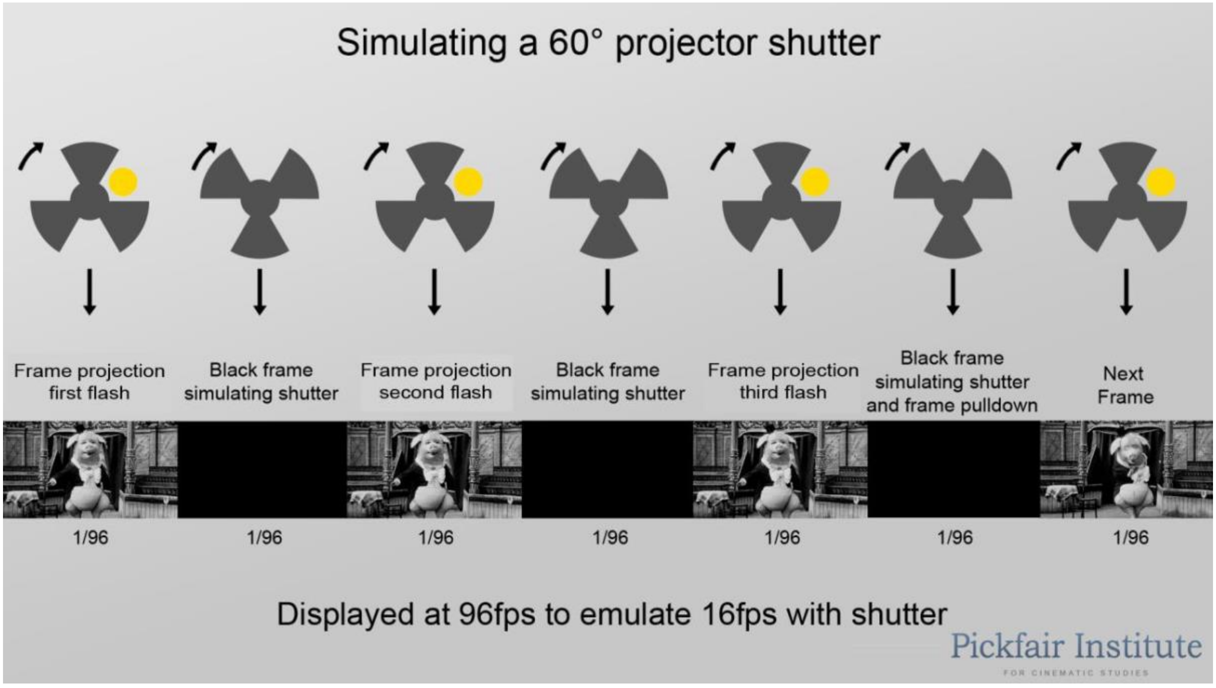


Figure 40 Simulating the performance of a three-blade projector shutter.[284]

To sum up, the digital roll-out for film archives did not comprise of the replacement of photochemical projection technologies with digital ones, but rather adding them to the

[281] Different projector shutters had different numbers and shapes of blades. During the later silent era, most projectors in the Western world had three-blade shutters, while for sound cinema, the norm was a two-blade shutter. For more information, see: Cherchi Usai, *Silent Cinema*, 81–83.
[282] This research was notably presented at the Technical Commission's workshop at the Il Cinema Ritrovato festival in Bologna in June 2019. The reason that flicker is reduced in this way has to do with the fact that the insertion of black frames hides slightly the differences in lighting between subsequent frames.
[283] Cherchi Usai, *Silent Cinema*, 313.
[284] Erland, 'The Digital Projection of Archival Films Project: Phase One'.

traditional technologies. Archives still had film collections which were to be projected, either on digital or film projectors, and for this, they needed to conserve and use different types of technologies, systems and machines. Film technologies – in a relative diversity at least – needed to survive, and digital technologies needed to be adopted in order to conform to the industry's requirements; but also adapted to the archives' need; just like older practices had been adapted several times before to simulate specific projection technologies – already in extinction. This is not a question of digital vs. photochemical projection, but a series of technologies that are modified regularly – as rightly put by Michael Loebenstein, "Change is constant".[285]

4 Chapter Conclusions

In this chapter, I have covered the digital roll-out and its consequences for projection within film archives and the industry. I have shown how digital projection technologies were developed and standardised within the film industry based on an existing cultural imaginary, formed by the 100-year-old tradition of film projection. During this time, archives were not on the front row of collaboration with the scientific and technological actors behind the new technologies (notably because projection went way beyond their borders), and they did not always agree with the industrial vision either. Instead, they were mostly receptors of these technologies. Despite that, their adoption of the new technologies was not absolute, and their theoretical viewpoints and technical needs were crucial in determining the actual way to go ahead.

The technical study that I have provided underlines the techne-episteme interrelations by illustrating how the new technologies interacted with the industrial discourses, and how this prepared for their adoption, adaptation or rejection. The vision of the film industry, which was the force behind the standardised D-Cinema and the choice of JPEG 2000 as its compression scheme, did not necessarily always correspond with that of archives. In fact, as I have argued, they were rather similar prior to the roll-out, but diverged considerably afterwards, leading to a discrepancy between them. The industrial vision, thinking about the market, focused primarily on what the spectators saw, and tried to make the look of the digitally-projected image resemble that of an image projected from film. But archives viewed films first and foremost as material objects. The specific effects of the film's materiality (such as breathing effect or graininess and even damages) were appreciated by archives when created through a film projection system, despite the fact that the digital look imitated the photochemical look. In the process of

[285] Loebenstein, 'Editorial'.

technological development and adoption, what was enough for the technical wing of the mainstream film industry, was not for archives (and a number of filmmakers of different horizons such as Tacita Dean or Christopher Nolan). Moreover, the standardisation of digital technologies left out specific problems of film heritage. Because of these disparities, the technologies, which were malleated to approach the industrial vision as closely as possible, did not match what archives had in mind.

The weight of industrial discourses and the processes of technological developments, adoption and standardisation did echo considerably within the archival community. This influenced the archival episteme, and generated reactions which formed, reinforced or modified the theoretical and technical discourses within the archival community. Before the digital roll-out, the archival discourses regarding projection were focused on best technical quality (which, according to them, would be achieved on state-of-the-art projectors and by the best source image, 35mm), joining the industry's discourse, where sharper, clearer images were judged superior. The new technologies were influenced by the existing traditional technologies and corresponded to an idea of cinema defined in contrast to other mediums and screens (such as television), and culturally accepted for audiences, within the film industry and largely within archives.[286] But after the roll-out, the archives became more attentive to the multiplicity of film technologies. Although the term film regrouped all different technologies and inherently it was understood to be 35mm, it did revive an interest in other types of films and projections (nitrate projection, carbon-arc projection, etc.). By this time, the archives embraced more their museological role and privileged more their artefact-based approach.

Historically, film archives were regularly faced with the concept of technological simulation. Old films, which at the time of their original release had been projected with certain machines, had constantly been re-presented as restorations or duplications (or even as vintage prints) on modern projectors. The machinery could be different (for instance, two-reel vs. single-reel projection), the light source could be different (carbon-arc vs. xenon projection), etc. As I have argued, this could indicate that any projection of old films on modern film projectors was indeed a simulation. The projected image from old and new projectors would inevitably look different, even though the difference could be small. Digital projection was also a simulation in terms of the projected image.

[286] Further technological developments and uses, such as higher frame rates, may diverge gradually from the traditional concepts and understanding of cinema, without radically changing its ontology.

For archives, the big difference, as argued, was the source of the projected image. While modern film projectors project from an image inscribed on a film carrier, digital projectors project from a digital image (decoded by a server from digital data). The changing materiality of the print represented a real problem for archives, as it was the object they conserved. They tried to embed film and film culture into the new environment of film viewing practices, by defining it as a crucial part of the projection machinery. As a result of the fight for film's survival, film technologies, on the verge of obsolescence at one point, regained a legitimacy that reinforced the existence of a (niche) culture around it. To 2022, this film culture continues to exist and thrive as a parallel movement and a technological possibility embedded in the multi-faceted cinema landscape. It is difficult to predict if film is definitively saved for posteriority or if one day it will become extinct and obsolete, but currently, it is indeed still very much part of the picture, although by no means dominant in the mainstream circuit.

Faced with the digital roll-out, film archives had to attenuate their dialectical approach to the question of film vs. digital, and move towards a co-existence and hybridity of technologies. While they clung to the traditional film projection technologies, they also needed to integrate the new technologies into their practices. It might have been inevitable for film archives to adopt new projection technologies, but it is important to note how they adapted them to their own use and also modified their practices in the process. Be it for frame rate, aspect ratio, or projection light, film archives had to (re)invent solutions that would correspond to the constraints caused by the standards as well as the requirements of their own practices. The digital technologies even in their most rigid form, did not invade archival practices invariably, and were subject to some degrees of flexibility. Keeping this technological diversity in mind, the idea of a rupture does not hold. There was indeed an industrial shift in exhibition from 35mm to DCP, and an obvious transition of main market power from one to another (that is what defines the digital roll-out), but for film archives many diverse projection technologies remained as living activities.

Projection was the first step of the digital roll-out which was addressed by film archives. The next step needed to focus on the consequences of the roll-out and their influence on other archival practices: conservation and digitisation. I will investigate these in Chapter Four.

Chapter Four. Multiple Image: Archives Coming to Terms with Digital Image Technologies

By 2014, the digital roll-out was almost wrapped up and most European national film archives had already executed their adaptation plans to the new projection technologies, while also preserving (and sometimes reviving) the traditional ones. During the second half of the 2010s, film archives were inclined to focus mostly on the consequences of the roll-out with regards to existing film heritage (mostly on photochemical carriers) and in-production film heritage (mostly born-digital). Indeed, new challenges needed to be addressed so that film archives could "keep up with the industry".[1] A multitude of digital image technologies, which had before been adapted and adopted by film archives for restoration, access and projection – discussed in the three previous chapters respectively –, was now omnipresent, as cinema's so-called digital era had debuted. Of course, the mutations of archival practices during the digital era had been imagined and discussed years before, as I have shown up to here, but during the second half of the 2010s, they were concretised. Indeed, the theoretical-archival discourses were renewed in conjunction with the growing abundance of hands-on experiences and in-depth technical studies, which were either absent or limited beforehand. By 2014, the archival community seemed to have arrived at the conclusion that digital technologies were there to stay:

> "The era of analog production and presentation has morphed into a new age of massive digital potential. […] As our world explodes with possibilities, the challenges for archives expand in parallel with questions of relevance and capacity to adapt to these new demands. We straddle two worlds filled with movement, excitement, history, and increasing need for currency and accessibility."[2]

The dialectical vision of film vs. digital, which had most importantly been formed during the 2000s, as I demonstrated in Chapter Two, still persisted by the mid-2010s, qualifying film and digital as two different "worlds". It had, however, become clear that digital technologies were now considered as part of cinema, and, as such, they fell into the legitimate responsibilities of film archives – as per photochemical technologies.[3]

---

[1] Thomas Christensen and Mikko Kuutti, 'A Digital Agenda for Film Archives', ACE Position Paper, March 2012, https://ace-film.eu/wp-content/uploads/2012/03/A-Digital-Agenda-for-Film-Archives-2012.pdf, accessed 26 July 2020.

[2] Meg Labrum, 'Editorial', *Journal of Film Preservation*, no. 92 (April 2015): 3.

[3] This observation needs, of course, to be nuanced with regards to different discursive and technical tendencies within the archival community. At this point, I am considering it as a dominant approach in national film archives. The examples given later in this chapter will take into account the differences.

Covering the period roughly between 2014 and 2020, in this chapter I retrace the evolution and establishment of new archival practices and imaginaries, constructed upon an existing archival socio-technical culture. The goal is to depict how, departing from a divided imaginary of film vs. digital, the archives finally came to terms with the co-existence of technologies. Indeed, archival collections consisted of films, carriers, and machines from the whole history of cinema, where the technological changes had always been part of the picture. By this time, they were finally recognised as such. Consequently, I will argue that the archival imaginary came to somehow accept the plurality, multiplicity and hybridity, whether at the macrolevel of strategies and methods, or at the microlevel of image technologies. It should be noted that the hypotheses claimed in this chapter needs to be treated more cautiously, as this period is too recent for strict historical assertions.

It is important to contextualise the archival discussions of this period in the specific political framework within which they evolved. In the first part of this chapter, through a short overview of political discourses at the European transnational level between 2005 and 2014,[4] I will illustrate how, by 2014, an aura had been created which was full of promises around digital technologies. According to these discourses, the latter could not only reproduce old films in an effort to save them from oblivion, but also be a serious contender for the conservation of films. Between 2011 and 2014, these transnational political discourses were sometimes accompanied by national funding schemes for digitisation, which helped many archives devise and engage in a series of digitisation projects and technical studies. Through some examples, I will strive to investigate how these (early) projects generated a shift in the archival imaginary of the time during the 2010s, by confronting the political discourses with the technical realities. Furthermore, the political implication and national funding also enabled some projects for digital conservation within archives from the mid-2010s onwards.

Driven by the political and theoretical discourses as well as the technical realities, in conjunction with the rich 100-year-old archival history in reproduction and conservation, the archival focus of the 2010s has been particularly on digitisation and digital conservation. By emphasising concepts such as authenticity in reproduction and archivability in conservation, archives sought to address one main question: do digital technologies provide an unprecedented opportunity for film archives to preserve all their holdings (past and future) in digital form, as promoted by political discourses? This would mean that digital technologies would not only be

[4] In 2005, the first European recommendations for film heritage were published, which were then followed by four implementation report and other studies. The last implementation report was published in 2014.

liable to conserve digital-born material forever, but would also represent the best method to save the film-born material. In this chapter, I will investigate the socio-cultural evolution of archival discourses on digital image technologies in use in digitisation and digital conservation, in order to explore which technologies specifically, and how, were adopted and put to use by the archival community.

Of course, both digitisation and digital conservation had been discussed previously within the community, but by this time the discourses were enriched thanks to technical experiences, directly related to the necessity of dealing with real challenges after the roll-out. Therefore, these practices were undergoing changes. In the process, the archival definitions of concepts of authenticity and archivability also changed somehow: these were not anymore absolute conditions but qualitative measures to which archival practices could get closer or further. For digitisation, I will offer a technical study of reproduction processes and machines (in the digital case, scanners) which deconstructs the concept of authenticity, and will argue that any reproduction creates its own image look. For conservation, I will analyse how the concept of archivability can technically be interpreted and redefined through image carriers and formats, and how this leads to an acceptance of multiple types of digital images as conservation elements. The image technologies in question in this chapter are more diverse and mixed compared to previous chapters, as many operations are going on simultaneously.

From a theoretical stance, this chapter reconsiders both digital and material turns. Giovanna Fossati has described the latter as accompanying the former: an alternative tendency and a renewal of interest for the material raised from a reaction to the digital turn.[5] Thus, inspired by Fossati, and contrary to research which studies them separately, either the digital turn or the material turn, either digital[6] or photochemical film,[7] I intend to underline their co-existence even at the technical and scientific levels of the image. As such, there will be an emphasis on the materiality of the cinematographic image throughout the whole chapter, whether through its traces, its links, its carriers, its technologies, etc. The question of transition, theorised in Fossati's seminal work and discussed later by scholars Trond Lundemo and Diego Cavallotti,[8]

[5] Fossati, *From Grain to Pixel: The Archival Life of Film in Transition*, 2018, 18–20. See also: Fossati, 'Film Heritage Beyond the Digital Turn'.
[6] For instance, studies that analyse the mutations of cinema in the digital ecosystem, see: Malte Hagener, Vinzenz Hediger, and Alena Strohmaier, eds., *The State of Post-Cinema: Tracing the Movie Image in the Age of Digital Dissemination* (London: Palgrave MacMillan, 2016).
[7] See for instance: Kim Knowles, *Experimental Film and Photochemical Practices*, Experimental Film and Artists' Moving Image (London: Palgrave Macmillan, 2020).
[8] Fossati, *From Grain to Pixel: The Archival Life of Film in Transition*, 2009. Cavallotti, 'From Grain to Pixel? Notes on the Technical Dialectics in the Small Gauge Film Archive', accessed 30 January 2021.

will also be central to my discussion: firstly, from a technical point of view, I apply it to the mutations of the image (and its carriers) into new forms derived from its characteristics from previous forms. Secondly, from a more conceptual point of view, I consider it in scientific ideas and technological design and implementation, as well as their basic understanding, as has been done by media scholars such as Sean Cubitt.[9] My study intends to enrich these theoretical positions through a detailed technical study of images in their multiplicity.

1 A Political Dream: An All-Digital Future for European Film Archives?

During the time that the digital roll-out was under way, a discourse network was established which went beyond the scope of film archives, focusing on how the new technologies were to change the film archival landscape from wider political and industrial viewpoints. This network was embedded in a European transnational framework in which studies were conducted and strategies were proposed in order to determine the main lines of an archival transition into the digital era. From a political point of view, the transition was to be a short-term project to provide archives with all they needed to perfectly function within a so-called "digital era".[10] The goal of the political discourse was to prepare archives, on the one hand, to digitise all their holdings in order to supposedly save them while also enabling public access to them, and on the other hand, to secure the archiving of digital-born material, which was on the rise. It emphasised the probability of loss if action was not taken on national levels. This all-inclusive and lossless imaginary that reigned in political discourses had inevitable repercussions in archival theoretical discourse and technical applications.

The political discourse network in Europe was constructed around the recommendations, studies, expert groups and conferences of the European Commission, in close interaction with the Association of European Cinematheques (ACE). Indeed, the latter assumed a more political responsibility as a lobbying organisation in favour of (trans)national funding possibilities for European film archives during the few years that preceded and succeeded the digital roll-out in Europe. The starting point was the publication, in 2005, of a series of recommendations on film heritage, followed by four implementation reports in 2008, 2010, 2012 and 2014; as well as a

Trond Lundemo, 'Conversion, Convergence, Conflation: Archival Networks in the Digital Turn', in *The Archive/L'Archivio. Filmforum 2011. Atti Del 18° Convegno Internazionale Di Studi Sul Cinema.*, ed. Alessandro Bordina, Sonia Campanini, and Andrea Mariani (Udine: Forum Edizioni, 2012), 177–82.

[9] Cubitt, *The Practice of Light: A Genealogy of Visual Technologies from Prints to Pixels*.

[10] A common term in political discourses, notably from DAEFH.

second series of recommendations in 2010 which addressed the question of digital technologies more closely.

The initial recommendations demanded that the member states foster better exploitation of the industrial and cultural potential of European film heritage by "encouraging policies of innovation, research and technological development in the field of conservation and restoration of cinematographic works",[11] without focusing particularly on digital technologies. However, it did predict a "gradual switchover to digital technologies" and encouraged the increasing use of these in "collection, cataloguing, preservation and restoration of cinematographic works".[12] Later, when the digital roll-out was a certainty, the discourse focused on adaptation to the "challenges of the digital era" in collecting and storing digital material and giving access to analogue material via the internet.[13] The Council of European Union recognised in 2010 that "continually evolving technologies and changing ways of distributing and using cultural content may have an impact on the traditional concepts of film, cinema and heritage", and invited member states to "consider film heritage while designing their cultural policies", as well as its needs and roles in the digital era.[14] It was thus accepted that the impact of the digital roll-out on many archival practices needed to be addressed on a higher political level by the member states.

ACE participated in the production and promotion of these discourses on two different levels: firstly, it was actively involved in the subgroup of Film Heritage within the EU Cinema Expert Group, organising conferences where archivists, archive experts and EU officials could exchange ideas (2008-2014). In this way, ACE provided the opportunity to influence European policies. Secondly, it created resources and workshops for European archives on how, more concretely, to implement the strategic and political recommendations (without going into technical details). To achieve that, a position paper was prepared by Mikko Kuutti and Thomas Christensen in 2012,[15] and then, a series of workshops entitled "Management Strategies for

[11] European Parliament and Council, 'Recommendation of the European Parliament and of the Council of 16 November 2005 on Film Heritage and the Competitiveness of Related Industrial Activities', *Official Journal of the European Union*, no. L 323 (16 November 2005): 57–61.

[12] European Parliament and Council.

[13] 'Commission Staff Working Document on the Implementation of the Recommendation of the European Parliament and Council of 16 November 2005 on Film Heritage and the Competitiveness of Related Industrial Activities' (Brussels, 4 August 2008), 10, https://ec.europa.eu/archives/information_society/avpolicy/docs/reg/cinema/report/swp_en.pdf, accessed 9 September 2020.

[14] The Council of European Union, 'Council Conclusions on European Film Heritage, Including the Challenges of the Digital Era', 3046th Education, Youth, Culture and Sport Council Meeting (Brussels, 18 November 2010).

[15] Christensen and Kuutti, 'A Digital Agenda for Film Archives'.

Archives in the Digital Age" were organised from 2012. The ACE position paper incited film archives to "go digital" in order to "keep up with the industry":

> "It is not for the archives to decide how films are produced or to define on which carriers they should be laid on. The role of the archive is to receive the final products of a film production chain, whatever their technical format and properties, and keep them forever."[16]

Departing from this statement, the paper enumerated archival practices which would undergo changes following the introduction of "new concepts" resulting from digital technologies, such as the concept of "content" and its relative independence from its carrier. It is important to underline that the position of ACE at this point was radically different compared to the role it had during the 1990s with Gamma Group. While the latter was entirely axed on technical studies, ACE's turn to lobbying meant that only the macrolevel political view of digital challenges were addressed, in a way that it could even sometimes contradict the technical realities of film archives. For instance, in 2012, Nicola Mazzanti stated in an ACE workshop that archives needed to plan mass digitisation as soon as possible, alongside "long term digital preservation" in order to enable a "life after digitisation",[17] while technically, archival resources at the time were very limited, attesting to the impossibility and unpracticality of the all-inclusive digitisation and move into the digital era. It was assumed that lobbying would bridge the technical realities with political discourse by enabling national financial support, thanks to which archives could "go digital" in order to "ensure diversity in access to film heritage"; and, simply put, become "digital archives".[18]

By the end of 2010, the European Commission ordered a study, *Digital Agenda for European Film Heritage (DAEFH)*, entrusted to Peacefulfish company, which in turn subcontracted other partners including Nicola Mazzanti. The latter was employed at the time by the Cinémathèque royale de Belgique, and was also at the head of ACE, but his position within the DAEFH project was strictly limited to political lobbying in order to promote the importance of national funding. He presented the report as a "political document", not a "technical one", which was "meant for a specific target group", i.e. political institutions.[19] The DAEFH report in 2011 predicted that if, in 7 years, analogue collections in Europe were not digitised yet, they would be as good as

[16] Christensen and Kuutti.
[17] Nicola Mazzanti, 'DAEFH... What Now?' (Workshop Management Strategies for Film Archives in the Digital Era, Il Cinema Ritrovato, Bologna, 28 June 2012).
[18] Christensen and Kuutti, 'A Digital Agenda for Film Archives'.
[19] Mazzanti, 'DAEFH... What Now?'

lost, as only digitised films would remain accessible (because of the "progressive disappearance of the whole sector of analogue film technology").[20] The discourse of loss imagined European film heritage "at a crossroad between memory and oblivion", where without a total digitisation, "[European] cinema will simply disappear, the European culture will suffer the loss of 120 years of history, and the industry will lose the possibility of exploiting commercially the whole past catalogues".[21] As a result, digitisation was presented as the way to save film heritage, but it did not mean that photochemical film conservation was to be ceased as an archival practice; rather, if a film was not available digitally, it was lost in the all-digital world. This point was also underlined in the 4th implementation report of EU recommendations:[22]

> "FHI have to evolve towards hybrid archives, taking care both of analogue film collections and digital or digitised collections. New technologies offer enormous possibilities for cultural, educational and recreational access to film heritage, as well as new business models for commercial exploitation."[23]

Of course, the ACE paper also reminded that "traditional film archiving will have to be continued".[24] Indeed, the digital future did not intend to erase the photochemical past for archives. On the contrary, archives were to become hybrid entities dealing with all types of material. But it was presumed that film could become merely an archival/museological commodity, and therefore, any film heritage not digitised would become invisible. The language of loss and disappearance here did not necessarily concern physical objects, but dreaded the films' omission from collective memory. The digital opportunities that Europe looked for were primarily a wider access to European film heritage, as an incarnation of European culture and memory.

From this viewpoint, it was obvious that the technical or technological details did not feature in these political and strategic discourses. The concept of the digital era (or digital future, or digital age) was far from a technological concept, but was used more as an umbrella term regarding the (varyingly) evolving situations of film archives as a consequence of the generalisation of a series of new digital (and sometimes hybrid) technologies. While discursively useful – for funding purposes notably –, technically the terms in use did not carry

[20] Nicola Mazzanti, 'Challenges of the Digital Era for Film Heritage Institutions', Executive Summary, DAEFH: Digital Agenda for the European Film Heritage (Brussels: European Union, 2011), 6.
[21] Mazzanti, 25.
[22] Although this was not necessarily the case, and many archives still struggled with photochemical conservation because of lack of adequate vaults, etc.
[23] European Commission, 'Film Heritage in the EU', 37.
[24] Christensen and Kuutti, 'A Digital Agenda for Film Archives'.

any particular reference to any technology. Naturally, the macrolevel political recommendations, when applied to national levels, resulted in different funding schemes, project definitions and implementations in different archives.[25]

The financial contribution of the national institutions, which followed the European discourses in some countries, seemed to be thought politically as a punctual help for national film archives to digitise everything; but considering the high costs of digitisation equipment and tasks, and also their developments, this did not end up to be the case. The political discourse was tempered within archives in order to devise strategies corresponding to both theoretical and technological aspects of digital challenges. Digitisation and digital conservation came both under scrutiny through archival practices and discourses, in the process of technological adoption. Was a total transition into the digital era through digitisation and digital conservation a realisable goal? How did the archival episteme formed around them evolve?

2 Digitisation: Towards a New Life for Photochemical Film?

The concepts of duplication, restoration and preservation, englobing diverse practices, had been extensively debated within the archival community from the 1980s on, as I briefly covered in Chapter One.[26] In view of the challenges of the so-called digital era, these concepts were brought again into interrogation, this time in association with digital technologies. The political push towards digitisation renewed archival terminological confusion, as the term needed to be re-placed within the vast archival landscape of practices. What was the place of digitisation in relation to duplication, restoration or preservation? From an archival perspective, the term digitisation had been mostly associated with access during the 2000s (see Chapter Two). However, with the generalisation of digital cinema (see Chapter Three), this definition did not seem adequate anymore and needed to be enhanced to fit better into the new technological situation. Indeed, during the second half of the 2010s, digitisation was to come under scrutiny from a technical point of view, paving the way for many detailed discussions on scanners and how photochemical images are reproduced digitally. Before this period, such critical-technical views of scanners and the reproduction process were not common. Here, I claim that the state

[25] This was also evident from the implementation reports. For more information, see: Mari Sol Pérez Guevara, 'Challenges for European Film Heritage from the Analogue and the Digital Era', *Journal of Film Preservation*, no. 88 (April 2013): 31–33.

[26] See Chapter One, 1.1. Of course, these concepts continued to be much debated not only in scholarly works, but also archival conferences, see: Marie Frappat, 'Histoire(s) de la restauration des films', *Journal of Film Preservation*, no. 94 (April 2016): 42–52; Krista Jamieson, 'Ethical Film Restoration and Concepts of "Original"', *Journal of Film Preservation*, no. 93 (October 2015): 9–14. Luke McKernan, 'What Is Restoration? FOCAL International Conference Report', *Journal of Film Preservation*, no. 89 (November 2013): 35–38.

of archival imaginary by this time, heavily enriched through theoretical discussions of the 2000s and the early 2010s (before and after the roll-out), as well as the practical projects conducted after the roll-out in conjunction with their contemporary political discourses, was crucial in the shift of attention towards scanning and details of (digital) reproduction.

In the first place, it is important to note the understanding of digitisation as a practice within archives, rather than a technological act. In 2013, Paolo Cherchi Usai qualified digitisation as a catchword:

> "Digitization does not equal digital restoration, in the sense that 'analog' moving images are turned into digital files, regardless of their original condition. A 'digitized' moving image is not necessarily 'restored'. […] Digitization is the process of converting analog photographic material into digital files for the purposes of public access." [27]

According to this statement, an ambiguity reigned in archival discussions of the time between digitisation and restoration, which reminded the similar discussions from the 1990s about duplication vs. restoration. Simply put, what distinguished digitisation from restoration, according to Cherchi Usai and others,[28] was the level of (digital) manipulation. Moreover, for him, as a fervent promoter of strict museological viewpoint in the archival community, digitisation still remained a practice uniquely destined to widen access; a view which was not uncommon within the archival community.[29] It could also be correlated to the political discourses, which promoted digitisation as a means to preserve films from loss and oblivion in collective memory, by enabling access to them. Such an understanding of digitisation introduces it as a new archival practice, similar to restoration, but with a different goal and a different technical process.

On the other hand, the term digitisation may harbour a wider meaning from a technical point of view: it is the act of reproducing a source photochemical (or analogue) image (whether on negative, positive or intermediate film, or video) through digital means. A digitisation needs not be limited to access practices, and the image it produces could also be very well used for conservation. It can be conducted through different means (and machines), in different technical qualities, towards different goals, and satisfying diverse technical requirements. This way, the technological act of digitisation is not necessarily associated with preservation or access, but

[27] Paolo Cherchi Usai, 'The Digital Future of Pre-Digital Collections', *Journal of Film Preservation*, no. 88 (April 2013): 9–16.

[28] See for example: Jeanne Pommeau and Jiří Anger, 'The Digitization of Jan Kříženecký's Films', *Iluminace* 31, no. 1 (2019): 104–7.

[29] For example, at the Cinémathèque suisse, the acts of restoration and digitisation are distinguished according to their level of digital manipulation, as well as their goal.

could serve both, according to how it is done. This technological meaning also became commonplace within the technical discourses in the archival community. By the mid-2010s, the technological act of digitisation itself was discussed abundantly within archives, as I will illustrate, regardless of how the digitised images were to be used afterwards (if they were going to go through digital restoration, printed back to film, etc).

In this subchapter, I will strive to show how the theoretical understandings of digitisation are related to its technological understanding. I will first go through the archives' practical experiments, which enriched their theoretical and technical discourses around the subject of digitisation, and argue how the concept of authenticity was shaped and refined in these processes after the digital roll-out. I will then present a technical study of images going through digitisation, which deconstructs this concept, and claims instead the long-lasting influence of different materialities and technologies on the look of an image.

2.1 In Practice: Implementation of National Digitisation Projects

As noted, digitisation could embody different meanings within political or archival-theoretical discourses, also owing to archives' frameworks, visions and histories. The archival-theoretical views, which shape (at least partially) the practices, are related to archives' understanding of film, as Giovanna Fossati demonstrated in 2009. Indeed, as Fossati argues, archives adhere to different theoretical frameworks (consciously or not) and manifest, as a result, certain tendencies in their practices.[30] This multiplicity made way for different practical models to be applied in different countries through national initiatives, although they all responded to the same political European call for (mass) digitisation. I will investigate in this part three cases of France, Sweden and Germany in the early 2010s. What is important is that the question of film, and inevitably film image, was central in the practical conception of national projects, where political recommendations interacted with archives' diverse theoretical viewpoints. The examples below underline how archives conceived and technologically implemented their projects, and how, in this process, the very concept of digitisation evolved in view of the technological adoption and adaptations, leading to a re-definition of archives' relation to digitised film images, and a re-questioning of their theoretical views.

2.1.1 France: A Technically-Flexible Digitisation Scheme

In France, the CNC implemented in 2011 one of the earliest digitisation projects in Europe following the digital roll-out, in the form of a "specific funding scheme for digitisation of

[30] Fossati, *From Grain to Pixel: The Archival Life of Film in Transition*, 2009.

cinematographic works which present a particular patrimonial interest".[31] It was proposed as a solution to the challenge of "digital turn", assimilated to the "Copernican revolution" by the French Minister of Culture and Communication at the time, Frédéric Mitterrand.[32] The French case was authorised by the European Commission,[33] and regularly presented at national and international archival conferences as an example of a successfully-implemented mass digitisation scheme. Archives or copyright holders presented diverse digitisation projects to the CNC, whose specialised commission decided to allocate funding to films or not; and how much. Technically, the scheme focused on the preparation of (French) films[34] in formats and technologies of the digital era and did not provide limiting technical constraints: "Restore, digitise and promote our film heritage, to preserve it but also to distribute it as largely as possible, on all types of screen".[35] In its access policy, the scheme also considered the market tendencies of film heritage, and the national funding was a (generous) "aid", whose amount was supposed to be "adapted on a case-by-case basis taking into account the money-making potential of the work concerned."[36] Englobing "the costs of physical restoration, digitisation and, if necessary, digital restoration",[37] this large-scale digitisation scheme in France was reminiscent of their Nitrate Plan in the early 1990s, which aimed at safeguarding their cinematographic heritage.[38] The projects were sufficiently funded,[39] in a way that they could,

[31] Joaquin Almunia to Alain Juppé, 'Aide d'État SA.33489 (2011/N) – France. Plan de numérisation d'oeuvres cinématographiques de patrimoine', 21 March 2012. My translation. The digitisation funding allocated by CNC was part of a bigger funding called "Le Grand emprunt" (programme d'investissement d'avenir) which helped French cultural sector in the digital age. The digitisation plan was legislated in the French Law on 9 May 2012, https://www.legifrance.gouv.fr/jorf/id/JORFTEXT000025837924?r=sNBPyQSf9r, accessed 29 November 2020.
[32] 'Discours de Frédéric Mitterrand, ministre de la Culture et de la Communication, prononcé à l'occasion de la signature de l'accord sur la numérisation du patrimoine cinématographique' (Cannes, 15 May 2011).
[33] 'State Aid: Commission Approves France's Plan to Digitise Its Film Heritage', European Commission Press Release, 21 March 2012. CNC, 'La Commission européenne autorise l'aide sélective du CNC à la numérisation du patrimoine cinématographique', Press Release, 21 March 2012, https://www.cnc.fr/professionnels/communiques-de-presse/la-commission-europeenne-autorise-laide-selective-du-cnc-a-la-numerisation-du-patrimoine-cinematographique_113507, accessed 29 November 2020.
[34] See the requirements for the nationality of films in the Article 511-5 of French Law, https://circulaire.legifrance.gouv.fr/codes/section_lc/LEGITEXT000020908868/LEGISCTA000030226217/, accessed 29 November 2020.
[35] Eric Garandeau, 'Introduction' (Lancement du plan de restauration et de numérisation des films du patrimoine, CNC, Paris, 2 April 2012). My translation.
[36] 'State Aid: Commission Approves France's Plan to Digitise Its Film Heritage'.
[37] CNC, 'La Commission européenne autorise l'aide sélective du CNC à la numérisation du patrimoine cinématographique'. My translation. This was noted in all communications regarding the project, including the article of law which concerned it.
[38] See: CNC, 'Retour sur le "Plan nitrate"', 30 July 2019, https://www.cnc.fr/cinema/actualites/retour-sur-le-plan-nitrate_1027210, accessed 14 April 2021.
[39] According to the statistics provided by the CNC, between July 2012 and July 2014, some 400 projects received a total amount of around 24 million euros, which was considerably higher compared to other countries, as I will mention later through the examples of Sweden and Germany. See: 'Présentation du

in many cases, afford an advanced level of digital image manipulation (see, for instance, Figure 41).

Figure 41 A tear removed during the 2013 restoration of *La Chienne* (Jean Renoir, 1931), as presented at Il Cinema Ritrovato Festival. Having received 70'000 euros from CNC, this restoration was conducted in the laboratory Digimage[40] and included rather complex operations of image restoration.[41]

Despite the scheme's technical flexibility, the accepted projects needed to conform to some technical recommendations by CST,[42] which fixed the minimum scan definition to 2K, promoted – without imposing it – the IMF format[43] for digitisation and required a shoot back to film at the end of the project. The more precise technical choices were left to a case-by-case analysis. There was thus no restrictive control over technical image quality (apart from the minimums required). For example, the restoration of Jacques Rivette's films was done in 4K, in High Dynamic Range (HDR) and with a bit depth of 16, while many other films were restored in 2K, such as Gaumont's catalogue (destined for use in all contexts: film theatre, TV, online, etc).[44] The decisions fell on those who conducted the digitisation projects, rather than the policymakers or the CNC. The 2K definition, which was the minimum for digital cinema, enabled a conceptual move beyond the two-level regime of image quality between preservation

dispositif d'aide à la numérisation des films de patrimoine du CNC' (CNC, October 2014), 11, https://www.cnc.fr/documents/36995/156986/pr%C3%A9sentation+du+dispositif+d%E2%80%99aide+%C3%A0+la+num%C3%A9risation+des+films+de+patrimoine+du+CNC.pdf/34ea822b-eec6-6771-3845-32b53f77002f?t=1532441816248.

[40] Renamed Hiventy in 2016, this lab is based in the Parisian suburb of Jointville-le-pont and is capable of doing both photochemical and digital restoration.

[41] Hervé Pichard, Bruno Despas, and Léon Rousseau, 'Film Restoration Case Study: Une Partie de Campagne and La Chienne' (FIAF Restoration Summer School, Il Cinema Ritrovato, Bologna, June 2014).

[42] Commission supérieure technique de l'image et du son, 'Recommendation technique CST-RT-021 : Fichiers numériques d'échange et d'exploitation des œuvres numériques "dits Mezzanine"', v1.0 (Paris: CST, 15 July 2012).

[43] Interoperable Master Format. IMF, which was in course of standardisation by SMPTE in 2012, was chosen by CST because it could contain different profiles of digitised files.

[44] https://www.dvdclassik.com/news/gaumont-devoile-les-25-premiers-films-restaures-dans-le-cadre-du-grand-emprunt, accessed 4 October 2020.

and access. The same digitised master files could be used to create DCPs for cinema screening, be transcoded for other distribution channels (such as web or DVD) for digital access, or could also be shot back on film for conservation. To achieve these diverse goals, many different technical ways were imagined and accepted.

2.1.2 Sweden: from 2K to 4K, from Cinema Access to Preservation Elements

The Swedish Film Institute started negotiations with Swedish political authorities in 2011 to convince them of the eventuality of a loss of film heritage if no action was taken, conforming to what transnational political discourses had suggested:

> "It is highly unlikely in the very long run that screenings of heritage films in original format will be possible even in our own venue. Furthermore, analogue prints are worn by every projection, and the possibility to replace damaged prints will cease to exist in a relatively near future, due to the demise of film stock manufacturing and photochemical laboratory services. Therefore, analogue film heritage must be digitized in order to be accessed at all in the future."[45]

Through the discourse of potential loss, similar to the European discourses, the Swedish Film Institute finally secured funding for digitisation in September 2013. The amount of €4.2 million allocated was to finance a project, driven by the national archive and in its own facilities, from 2014 to 2018 to digitise 500 Swedish films on a selective basis,[46] in addition to their existing activities.

Unlike the French case, which focused on a mass preservation of film heritage in digital formats and included many restorations with a considerably higher budget, the Swedish case was mostly directed towards cinema access. However, it did intend to remain "faithful to the original films", "to make digital preservation elements, and to make digital viewing copies which as far as possible emulate the look of an analogue print as it was perceived at the time of its release".[47] The curatorial work conducted by the archive was thus two-fold, one that dealt with the selection of works, and the other which determined how the digitisation was to be performed.[48] The archive launched its internal digital and photochemical labs, acquired equipment and hired

[45] Swedish Film Institute, 'Policy of Digitization of Film Heritage', June 2014.
[46] Factual information extracted from presentations by Jon Wengström, notably: Jon Wengström, 'Co-existence of Analogue and Digital Strategies in the Swedish Film Archive' (Film:ReStored_01. The Film Heritage Festival, Deutsche Kinemathek, Berlin, 24 September 2016).
[47] Swedish Film Institute, 'Policy of Digitization of Film Heritage', 3.
[48] Jon Wengström, 'Digitizing Analog Collections. Selection and Curatorial Policies' (FIAF 2015 Canberra Symposium, Canberra, 14 April 2015).

staff to carry out the task at hand. As the project gathered a mix of co-existing technologies implemented in-house and staff with different backgrounds, the archive also created a policy document "in order to facilitate the establishing of some common principles to which all involved in the project should adhere, and in order to make an efficient workflow possible".[49] At the beginning of the project, Swedish Film Institute decided to use mostly interpositives as the source of digitisation instead of original negatives. This type of element would enable them to scan films at 2K, rather than 4K. Further reasons for this choice were detailed:

> "Another reason to use inter-positives as source elements is that some basic grading already exists in the material, which substantially reduces the amount of work needed to be spent on digital grading. Furthermore, the inter-positives in the collections are often in better physical condition than the original negatives (in particular when original negatives have been used for striking prints), which also substantially reduces the need of restoration."[50]

The tendency was thus towards creating digital elements which needed less digital restoration. However, digital manipulation methods such as slight de-graining[51] or damage-removal were not ruled out. Indeed, "there [was] really no limit to the extent of work that [could] be allocated to the removal of defects", although "it [was] not possible within the digitization project to fully remove all damages".[52] But later, this uniformed workflow evolved. Increasingly, negatives were being used as the digitisation source, the preferred pixel count became 4K (compatible with what was believed to be the "international standard for digital restoration"), and more work was dedicated to "improving" the quality of digitised films by removing scratches, dirt and dust. The project which had started as mostly a mass digital duplication for cinema access, turned into a continuous multi-practice project, which operated on five levels:

1. Digital adaptation: transcoding of already-available digital elements.
2. Digitisation: digitising threatened original film material for preservation
3. Digital copy: simple digital duplication
4. Digital restoration: the new standard of the project
5. Full digital restoration: only for a few prioritised titles.[53]

[49] Swedish Film Institute, 'Policy of Digitization of Film Heritage', 3.
[50] Swedish Film Institute, 4.
[51] When the original grain was enforced in scanning.
[52] Swedish Film Institute, 'Policy of Digitization of Film Heritage', 9.
[53] Swedish Film Institute, 'Digitizing and Making the Swedish Film Heritage Available', Report of the Digitization Project, January 2017.

The example of Sweden demonstrates how a rather fixed practice evolved into a technologically-diverse set of practices with an emphasis on higher-definition, cleaner digital images, out of earlier-generation film materials.

2.1.3 Germany: No Compromise in Quality!

During the first edition of the FilmReStored festival in September 2016 held by Deutsche Kinemathek in Berlin, Jon Wengström (SFI) and Eric Le Roy (CNC) presented the respective digitisation schemes of Sweden and France.[54] Although the Federal German Film Board (FFA)[55] had been financing film digitisation in Germany since 2012, the lack of a nationwide digitisation policy was felt, not only by German film archives, but also by others (film historians, professionals, journalists, etc). The federal aid for digitisation could go up to 1 million euros yearly, with a maximum €15,000 per film,[56] and it was awarded on a selective basis to archives, catalogue-owners, copyright-holders or producers. The technical work was carried out in commercial laboratories.

In November 2013, towards the end of the digital roll-out, Helmut Herbst, a German historian and filmmaker, wrote about his concerns for the future of German film heritage.[57] In this article, Herbst evoked the example of France, where film digitisation was done with support from the government, and called for similar governmental support also in Germany to supposedly save German film heritage by digitising it. At the end of 2013, very soon after the publication of this article, a public campaign was launched, by film historians Jeanpaul Goergen and Klaus Kreimeier, called *Filmerbe im Gefahr* (Film Heritage in Danger).[58] The campaign submitted a signed petition to the German Parliament and the Minister of Culture and Media in 2014. It was a reaction against, on the one hand, the perceived inactivity of German film archives, and on the other, the lack of political support, funding and policies. The goal of the campaign was to rely on the social aspect of culture to engage the public in the fight, because it concerned "our cultural heritage" which needed to be saved (by digitisation) for "a broader public". According to them, the conservation of German film heritage, which was "discussed and controlled by

[54] See the Festival's program: https://www.deutsche-kinemathek.de/sites/default/files/public/presse/PM/2016/2016-08-02_PM_Festival_FilmRestored.pdf, accessed 30 November 2020.
[55] The national political instance in charge of funding film production, promotion and archiving in Germany. The FFA is in charge of financially supporting the digitization, according to the FFG (Film Subsidy Act).
[56] Considerably less generous when compared to the French case.
[57] Helmut Herbst, 'Wer hat Angst vorm Vinegar-Syndrome?', Kameramann.de, 11 November 2013, https://www.kameramann.de/branche/wer-hat-angst-vorm-vinegar-syndrome/, accessed 29 November 2020.
[58] Filmerbe.org, accessed 30 November 2020.

experts" needed to be democratised.[59] These discourses did not necessarily meet the usual archival discourses and technical requirements. They hardly differentiated between access and preservation, and did not mention technical details, but primarily demanded the availability of all German film heritage, albeit with compromised quality and with a focus on online availability.[60] This discursive point of view was close to the political discourse promoted by the EU, and similarly detached from technical problems and realities.

In contrary to what was implied by the campaign, German film archives were already actively engaged in their own fight to respond to the so-called challenges of the digital era. Firstly, they promoted a better conservation policy for photochemical material. The archives tried to rectify previous practices, such as the disposal of nitrate films after duplication, having conformed to the FIAF Manifesto since the mid-2000s. It was feared that this practice, historically common at the Bundesarchiv/Filmarchiv after photochemical duplication up to the 2000s, would be reiterated following digital duplication. Secondly, film archives addressed the question of digitisation in a more practical manner, to secure how that needed to be carried out. Reunited under the aegis of Kinematheksverbund (abbreviated to KV), the archives demanded curatorial sovereignty over such archival practices.[61]

In 2015, the German Film Board (FFA) ordered a study to be conducted by PwC[62] as a step forward towards policymaking for the digitisation of national film heritage. For technical matters, the study drew on the results of an earlier study ordered by FFA to Fraunhofer IIS, which offered recommendations and technical specifications for "digital film archives". The Fraunhofer study emphasised uncompressed conservation of digital-born material and underlined the necessity of developing a digital infrastructure for high-end digitisation (4K for

[59] 'About This Campaign', Filmerbe im Gefahr, accessed 14 April 2021, https://filmerbe.org/page.php?1,500,0,0.

[60] Helmut Herbst, 'Na dann priorisiert mal schön', 2017, https://kinematheken.info/na-dann-priorisiert-mal-schoen/, accessed 30 November 2020.

[61] In Germany, the task of a national film heritage institution is divided between several archives and other institutions, out of which, none is the national film archive in charge of conservation of all German films. These institutions come together in the KV, formed in 1978, which coordinates their works and practices (although they may have considerably different approaches). The KV is the coalition of the three main archives in Germany, Bundesarchiv/Filmarchiv, Deutsche Kinemathek and Deutsches Filminstitut. Other archives, such as Filmmuseum Munich, are their cooperative partners, and catalogue-owners DEFA Stiftung and Murnau Stiftung are the guest members. For KV's views on the digitisation subject, see: Kinematheksverbund, 'Digitalisierung des Filmerbes: Die Position des Kinematheksverbundes', Position Paper, December 2015, https://kvb.deutsche-kinemathek.de/wp-content/uploads/2015/05/Digitalisierung-des-Filmerbes-Die-Position-des-Kinematheksverbundes-20151.pdf, accessed 30 November 2020. The KV Position paper was updated in October 2016, October 2019 and February 2020. The papers can be found at: https://kvb.deutsche-kinemathek.de/positionen/, accessed 30 November 2020.

[62] Pricewaterhouse Coopers consulting company.

35mm), and in "standard formats", according to a unified (European) workflow and complemented with quality control tools. Aiming for digital "preservation", it considered photochemical prints as "back up" copies.[63] Based upon these technical considerations, the PwC study was carried out two years later, in collaboration with the archives of the KV, to present a cost-estimation for a nationwide digitisation scheme.[64] It took into account the "archive criteria", and instead of a total mass digitisation, it proposed a prioritised digitisation plan. The KV welcomed PwC's proposal, which featured a "three-pillar model" formulated by the archives, and fixed digitisation technical quality requirements in consultation with representatives from film technology companies.[65] The three-pillar model was a prioritisation system based on three factors: commercial potential, conservation needs and curatorial reasons.[66] Practically, a 500-film list was prepared by the KV, updated yearly with new proposals (from film historians also).

Two possibilities of technical workflow were proposed by the PwC study (Figure 42):

- Basic: minimum workflow required to "secure"[67] the film heritage. This workflow included preparation of film material, scanning and digital archiving.
- Basic + Addendum: more complex workflow to make the digitised material "usable"[68]. This workflow also included digital restoration ("remastering") and distribution strategies (which remained open to discussion at the time of the report's publication).

The first workflow corresponded more to a simple digital duplication, while the second was a more comprehensive digital restoration work, similar to what the Swedish case had evolved into. The minimum pixel count was fixed to be 2K, but it could go up to 4K (with no colour subsampling and with a bit depth of 16). Throughout the project, while the pixel count requirements remained the same, the tendency went towards a better "revival" of old films.[69]

[63] Siegfried Fössel and Julia Emrich, 'Recommendations and Specifications for Digital Film Archives', Research carried out by Fraunhofer IIS, by order of German Federal Film Board, 18 October 2013.
[64] PwC, 'Zusammenfassende Ergebnisdarstellung Kostenabschätzung zur digitalen Sicherung des Filmischen Erbes' (Berlin: FFA, 20 July 2015).
PwC, 'Ermittlung des Finanzbedarfs zum Erhalt des Filmischen Erbes' (Berlin: Der Filmförderungsanstalt (FFA), 19 November 2015).
[65] Kinematheksverbund, 'Digitalisierung des Filmerbes: Die Position des Kinematheksverbundes'.
[66] PwC, 'Zusammenfassende Ergebnisdarstellung Kostenabschätzung zur digitalen Sicherung des Filmischen Erbes', 19.
[67] In German, Sicherung.
[68] In German, Nutzbarkeit.
[69] In German, Wiederinbetriebnahme. See: Kinematheksverbund, 'Digitalisierung des Filmerbes: Update zur Position des Kinematheksverbunds zum „Förderprogramm Filmerbe" (2020)', Position Paper, February 2020, https://kvb.deutsche-kinemathek.de/wp-content/uploads/2020/03/Update_Digitalisierung_Filmerbe_20200225_hq.pdf, accessed 14 April 2021.

In 2019, a German national standard (DIN) was also established for the "Digitisation of Cinematographic Film",[70] which required the digitisations to be "equivalent to the analog original".[71] However, the question remained how to achieve that.

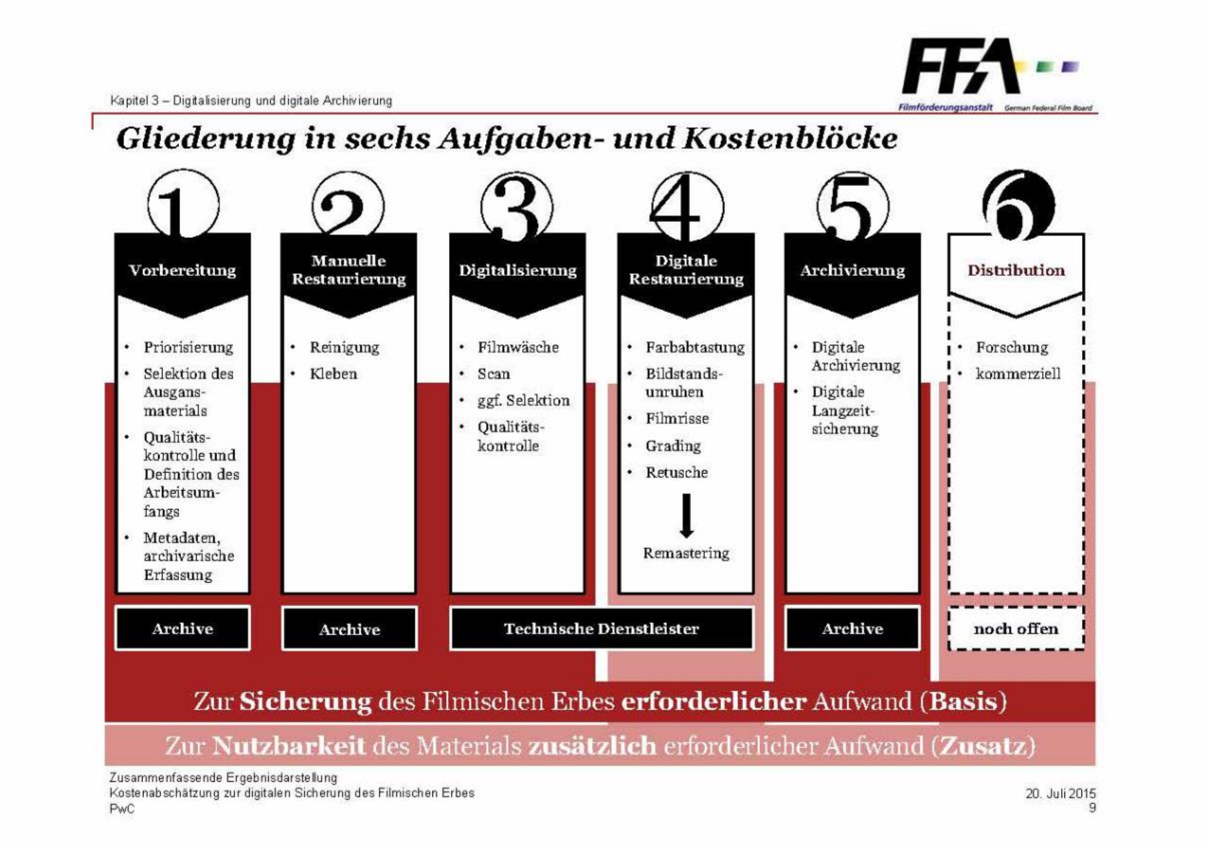


Figure 42 The different tasks of the digitisation and restoration processes, as proposed by PwC study for the German film heritage. As seen above, two different models of "basis" and "zusats" were proposed; the latter adding more tasks to the former.

2.1.4 From Mass Digitisation to Authentic Reproductions

These three examples demonstrate how film digitisation projects were implemented differently in each country, according to the missions and realities of film archives, and with regards to their own practices and contexts. I have underlined how different uses of (digital) technologies were envisaged in the projects: whether digital restoration methods were to be used; if yes, how, to what extent, and under which circumstances; how much photochemical treatment was to be done; which original elements were to serve as the basis for digitisation; if the result was to be shot back on film or if the production of a 2K or 4K DCP would suffice. I claim that these

[70] DIN, *Empfehlungen zur Digitalisierung von kinematografischem Film. DIN SPEC 15587:2019-04* (Berlin: Beuth Verlag, 2019).
[71] Egbert Koppe and Jörg Houpert, 'DIN SPEC 15587 – the New Standard for the Digitization of Cinematographic Film', Updated and translated from an article in FKT (German Magazine for television, film and electronic media in the professional field), 1 February 2019, https://www.cube-tec.com/en/news/announcements/fkt-din-spec-15587.

technical decisions, different according to the national schemes within which they were implemented, resulted in the production of images with diverse looks and in different technical qualities. Moreover, the projects did not remain static; they were already flexible to different degrees, and while they were in progress, they aspired to become supposedly better. This could indeed mean different things, such as higher pixel count, earlier-generation original elements, use of digital restoration, more visual similarity to the photochemical source, etc.

In the projects, a tendency can be detected to go towards a technically higher quality (4K instead of 2K, more restoration, higher bit depth, use of earlier-generation film elements, etc.) – which would not only provide access, or even cinema access, but also provide elements suitable for digital conservation so that films would be safeguarded from loss.[72] However, as I have shown, the desired increase in quality was not without limits in archival applications, as it was tempered with another factor, that of resemblance with its immediate photochemical source. One reason for this was the fact that the photochemical source could be of different generations, which meant that the digitised image could look different according to different sources. Indeed, the final digital image, when projected on a screen, would not necessarily look like an existing photochemical print. If the source were of earlier generations, for instance the negative or the interpositive, the digitised image could look sharper and more detailed compared with the photochemical print. I will detail this point later in this chapter.

Technically, such digitisation of film elements, coupled with digital manipulation methods, could yield a supposedly "better than original image", in terms of resolution and sharpness. This was a highly disputed practice, which was dismissed by many archivists, notably by Jose Manuel Costa (Cinemateca portugesa):

> "The idea of promoting an alleged restoration as 'better than the original' must be banished from museological practice. The invitation to watch a work 'as it was never seen before' can refer only to an explicit and voluntary corruptive act."[73]

David Walsh (head of the TC at the time) prepared a chart opposing film element's "inherent quality" vs. the damage it contained (Figure 43).[74] This chart, which has been presented by Walsh at several conferences since 2011,[75] prohibited the image enhancement beyond its

[72] The digital elements could be conserved digitally, or shot back onto film as in the case of France. I will come back to the concept of digital conservation later in this Chapter.

[73] Jose Manuel Costa, 'The Place of Analogue and the Double Life of Digital', *Journal of Film Preservation*, no. 98 (April 2018): 22.

[74] David Walsh, 'The Restoration Threshold, or When to Apply Grain Reduction', *Journal of Film Preservation*, no. 88 (April 2013): 26.

[75] For example, at the FIAF Congress 2016 in Bologna.

inherent quality as "unacceptable image improvements": "remove the damages as you like, but do not carry out digital manipulations to improve the inherent quality of the film beyond that of an original print".[76] What Walsh was warning against, was digital manipulation techniques which, for instance, upscaled the image, sharpened it, de-grained it, etc. According to him, each digitally-reproduced image was to be compared with its own direct photochemical source, and the idea was that it should keep the image characteristics as they were on the source.

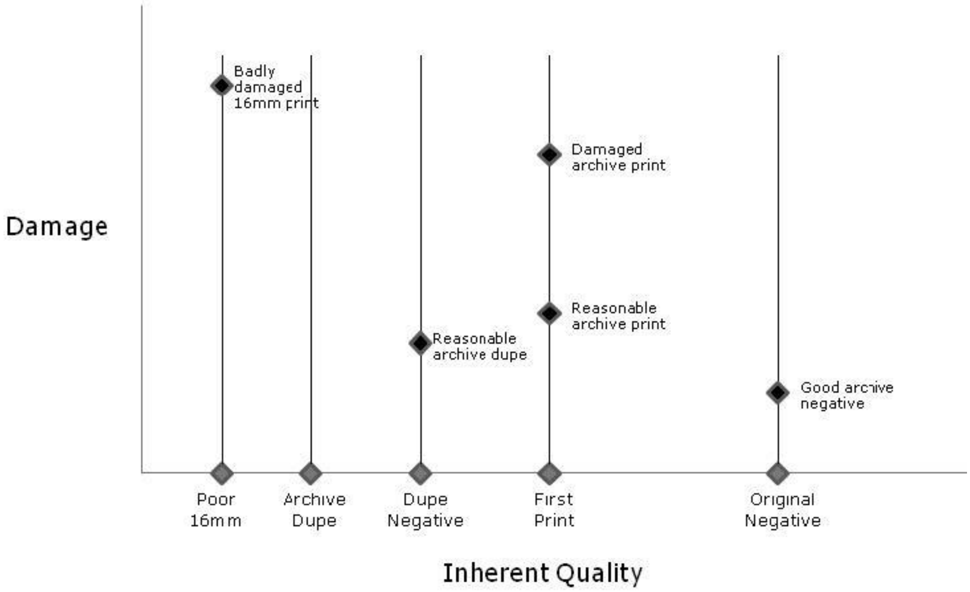


Figure 43 David Walsh's graph of Inherent quality vs. Damage.[77]

In sum, theoretically, what archives qualified as better quality by this time did not always mean only more K's in pixel count and a higher bit depth, but it also included the search for the recreation of a specific look belonging to the photochemical source: this was defined as "authenticity" in the archival community. Digital manipulation technologies potentially presented a danger to that goal: they could go beyond that look and create something different, which was not acceptable in the archival understanding. Built up from practical experiences and theoretical reflections of the years prior, the authenticity seemed to become the general tendency as demonstrated by discussions at two archival conferences in Autumn 2011, respectively in Krems (Austria) and Paris, entitled *Digital Restoration within Film Archives*[78] and *Et si le cinéma perdait la mémoire?*. Indeed, many archivists had come to be convinced

[76] Walsh, 'The Restoration Threshold, or When to Apply Grain Reduction', 27.
[77] Walsh, 26.
[78] Kerstin Parth, Oliver Hanley, and Thomas Ballhausen, eds., *Work/s in Progress. Digital Film Restoration within Archives* (Vienna: Synema, 2013).

that digital restoration was to be conducted with “as less digital interference as possible”,[79] avoiding digital artefacts,[80] and preserving the look of the film image. While digital manipulation technologies were to be reduced to the minimum necessary, digitisation needed to be conducted in a certain way in order to obtain the wanted image, whose characteristics (such as sharpness and fine details) deviated the least possible from those of its source photochemical image.

Based on this study of projects and discourses in the early 2010s, I argue that a conceptual move can be identified in archival tendencies from the political push to mass digitisation towards a more selection-based, but more authentic reproduction via digital means. Obtaining authenticity in reproduction was theoretically described as impossible by Erwin Panofsky who wrote in 1930 that “the authentic is an irreplaceable ingredient [of the original]”.[81] Seen from a Panofskian perspective, an “authentic reproduction” would be an oxymoron. It is, however, a frequent expression within the archival community.[82] In what follows, I will first detail how the concept of reproduction was theoretically understood within film archives; then illustrate how archives tried to technically achieve a so-called authentic reproduction in their practices, and finally, I will argue through a technical study how these notions and discourses need to be nuanced.

2.2 Theorising (Authentic) Reproduction

The act of transforming an image inscribed on an (archival) photochemical film to a digital image generated a wide range of theoretical discourses within the archival community. These discourses were produced in a context of political promotion of integration in the so-called digital era, and they focused specifically on the change of materiality in digital reproduction, as well as the multiplicity of technological possibilities. Within the archival community, two contradictory theoretical approaches reigned with regards to digital reproduction.

[79] Fumiko Tsuneishi, ‘Pragmatic Solutions for Problematic Sources’, in *Work/s in Progress. Digital Film Restoration within Archives*, ed. Kerstin Perth, Oliver Hanley, and Thomas Ballhausen (Vienna: Synema, 2013), 67.

[80] Giovanna Fossati, ‘The Restoration of Beyond the Rocks’, in *Work/s in Progress. Digital Film Restoration within Archives*, ed. Kerstin Perth, Oliver Hanley, and Thomas Ballhausen (Vienna: Synema, 2013), 111–20. Fossati’s intervention at the Conference was in fact entitled differently: ‘Grain and Pixel. Preserving, restoring and presenting films in Transition’, but it did address the same issues.

[81] Erwin Panofsky, ‘Original and Facsimile Reproduction [1930]’, trans. Timothy Grundy, *RES: Anthropology and Aesthetics*, no. 57–58 (2010): 330–38.

[82] For instance, at the presentations of FIAF Technical Commission during the Congresses and at Il Cinema Ritrovato in 2018 and 2019.

One approach made a clear distinction between film and digital reproductions. From this perspective, the reproduction from film to digital represented a break, referred to by terms such as translation, imitation, mimicry or simulation; while reproduction from film to film was seldom contested despite all the technological changes and machines involved. Owing to the museological viewpoint, this approach was object-based, with the film artefact (as a complex material object and source of cinematographic spectacle) occupying a central place, and it considered photochemical reproduction as one which belonged naturally to this artefact, while the digital reproduction did not. This was remarked upon by artist and filmmaker Lis Rhodes, with regards to Tacita Dean's work (whose fight for the survival of film was joined by the archival community):

> "Film is not translatable. Lossless conversion is a fallacy. Conversion entails translation and modification – a facsimile or imitation. The reading may confuse the conversion for something else, for something else is the certain result of conversion."[83]

The basic idea behind this remark was that an image produced on film (whatever film that may be) could not be reproduced digitally with no "loss". The politically sought-after digitisation, which was supposed to save film heritage from loss, was therefore inevitably considered as prone to loss itself. It would create something different, instead of reproducing, as political discourses expected, the exact same thing. Considering the digital image itself, it could mimic the photochemical image regarding quality and look, as explained by Jose Manuel Costa:

> "In order to vanquish analogue, digital has thus had to develop the equivalent of some of those lost attributes, and, during its first decades, that development was clearly designed to achieve an image resolution and a standard of reproduction of the light spectrum that was based on patterns established by the older technology."[84]

Despite that, according to Costa, even a hypothetically-perfect image reproduction would not suffice, since film archives also assumed a museological role where the film as an artefact needed to be considered as an intrinsic part of the reproduction system. Similarly, Alexander Horwath (Filmmuseum Austria), discussing "mimicry" back in 2012, re-placed film in a "complex process of media hybridisation, media mimicry, or remediation". According to him, this media mimicry had shaped the origins of film, and it was also shaping the origins of the digital image (trying to mimic the photochemical image). The division was clear for Horwath,

---

[83]Lis Rhodes, 'Play it Again?', in *FILM Tacita Dean: A book about film and the importance of analogue in the digital age*, ed. Nicholas Cullinan (London: Tate, 2011), 113. Cited by Simona Monizza, 'Stretching the Borders. Preserving the Installations of Marijke van Warmerdam', in *Work/s in Progress. Digital Film Restoration within Archives*, ed. Kerstin Perth, Oliver Hanley, and Thomas Ballhausen (Vienna: Synema, 2013), 70.
[84] Costa, 'The Place of Analogue and the Double Life of Digital', 21.

film and digital were two different mediums, and the reproduction of one through the other did not fulfil the museological role of film archives.[85] Horwath's position strengthened throughout the years. In 2017, he qualified restoration as "imitation" and "quotation" which mimicked the "original", by citing Enno Patalas (Filmmuseum Munich), who considered every restoration as a translation. Patalas's view concerned the philological aspect of restoration and not its image, but Horwath expanded it also to "today's digital moving-image culture, with its imitation of many 'filmic' traits or, in the promotional arena, its visual 'citing' of celluloid strips and sprocket-holes".[86]

Speaking at the 2016 FIAF Congress, Nicola Mazzanti (Cinémathèque royale de Belgique) identified every restoration as a lossy reproduction, whether done photochemically or digitally. But he distinguished between film and digital technological systems with the metaphor of "horse vs. camel" meaning that film and digital have each their own possibilities and characteristics, and that "a horse is not a camel": while the photochemical reproduction (although lossy) would mean remaining in the same realm according to him, the digital reproduction could become a "simulation at best" or "translation". This distinction brought him to dismiss entirely digital preservation of digitised material, while digital restorations remained in his view possible in order to make the heritage available: "cinema must go everywhere, it is not supposed to stay in museums".[87] Mazzanti had held this view for a few years, distancing himself from the political role he had assumed for DAEFH. At the FIAF Restoration Summer School in 2014, he had presented the "creation of a high-tech copy" of a film as a "simulation" which could be justified because he considered cinema as a system, and film as one of its components, and regarded it impossible to "bring back the original experience".[88] Mazzanti's view and his horse vs. camel metaphor still represented an approach based on the film vs. digital dichotomy, with "simulation" as a way to bridge the two.

As Simona Monizza (experimental film curator, Eye Filmmuseum) has underlined, the digital "translation" of films entailed two questions: that of image quality, and that of medium specificity, by which she referred to the specific use of "celluloid as a canvas for […] artistic expression".[89] While the first might have been overcome (only addressed with regards to pixel

[85] Horwath, 'Persistence and Mimicry: The Digital Era and Film Collections'.
[86] Horwath, 'The Old Life. Reframing Film "Restoration": Some Notes'.
[87] Personal notes taken during the presentation of Nicola Mazzanti, 'Digital vs. Analog, or "A Horse Is a Horse"' (FIAF 2016 Bologna Symposium, Bologna, June 2016). While the terms are exact, the phrasing of the statement may have been slightly changed, as they were announced orally and are not published in a written form.
[88] Nicola Mazzanti, 'It Is All in the Workflow, Folks!' (FIAF Restoration Summer School, Il Cinema Ritrovato, Bologna, June 2014).
[89] Monizza, 'Stretching the Borders. Preserving the Installations of Marijke van Warmerdam', 71.

count in her text), the second problem would make the images lose their "conceptual link" to their medium. Concerning the second, Monizza did not limit her observation to the film-to-digital transition, but claimed that the conceptual link with the medium would disappear in a film-to-film transition as well. According to her, the work of experimental filmmakers, such as Marijke van Warmerdam whose work she studied in her article, which needed to be presented on 16mm loops on specifically-modified projectors, already faced technological obsolescence as these materials and equipment were not easily available anymore.

This brings me to present the second approach, which considered any reproduction, whether through photochemical or digital means, as a simulation; and identified it as a constant change throughout the film history, regardless of the type of technologies in use. The word "simulation" had indeed been used in this meaning by others, most notably Giovanna Fossati within the heterogenous technological continuity of film history.[90] Indeed, as Fossati had already rightly explained back in 2009, simulation did not necessarily need to be between film and digital, it could represent any reproduction, as they all involved loss and change of technological framework. The same goes for other terms such as "translation". In a discussion with Horwath at the FIAF Congress 2016, Martin Koerber picked up the same vocabulary of "translation" between technological systems but, by situating them into a whole larger mixed technological history of film, arrived at the exact opposite conclusion compared to Horwath: technologies, for Koerber, were the solution to save the content amid constantly-changing systems.[91] The dichotomy of film vs. digital did not exist in his view, and the "translation" did not carry inferiority connotations (even if it generated loss). Both photochemical and digital reproduction methods were considered in this view as part of cinema's technological history. Based on the technical explanation that I will provide further in this chapter, I also adhere to this second viewpoint.

From the theoretical discussions evoked above, it becomes clear that, in the comparison between the source and result of a reproduction, one could aim to achieve authenticity on two levels: firstly, recreating, as authentically as possible, film as part of an original technological system in a museological sense, which could never be achieved through digitisation, and secondly, the recreation of an authentic image look. In the first case, the very idea of authenticity in reproduction was challenged by some (who believed any photochemical or digital reproduction was a simulation) and embraced by others (who primed photochemical

[90] Fossati, *From Grain to Pixel: The Archival Life of Film in Transition*, 2009, 142–44.

[91] Martin Koerber and Alexander Horwath, 'The Old Life. Reframing Film Restoration' (FIAF 2016 Bologna Symposium, Bologna, June 2016).

reproduction over the digital) as explained above, creating a divided archival imaginary on the subject. In the second case, the authenticity refers to how close an immediate reproduction of an image resembles it, and if any image information is lost in the process of reproduction, for example between a negative image reproduced on positive stock or into a digital image. Here, the tendency towards reducing (and ideally eliminating) the difference was amplified in view of the presumed possibilities of digital technologies, although, as underlined by David Walsh, it could not be totally achieved with state-of-the-art machines as every technology engraved its own "imaging structure" onto the image:

> "Present-day scanners operate at a similar resolution and dynamic range to film, and hence impose their own imaging structure on the result. Not until film-capture operates completely transparently without any trace of the intervening technology can we truly claim to have fully described the original."[92]

Could image authenticity be technically achieved through digitisation? Could such a system ever exist? These questions will resonate through the following subchapters, where they will be deconstructed through my technical analysis.

2.3 Technical Quest of Authentic Reproduction

As discussed up to here, the archival imaginary formed by the mid 2010s searched for methods that would losslessly reproduce the cinematographic images: in other words, it aimed for authentic reproduction. The latter does not concern the material part of the reproduction process, but represents the tendency to recreate image characteristics as close as possible to the photochemical source. It does not mean that the reproduced image should be equal to its source either, but that the visual deviations from it should be reduced to a minimum when it comes to redeeming image details. Some other characteristics, such as contrast or colours, are modified voluntarily in most (archival) reproductions.

The image authenticity did not remain as a theoretical concept and became also eventually a technical goal actively pursued by the archival community, most notably led by the FIAF Technical Commission (TC). Indeed, it was addressed regularly in the technical recommendations published by FIAF TC from 2012 on how to face the challenges of the digital era.[93] Regrouped under the title "Digital Technology Guidance Papers", these documents paid particular attention to digitisation in its first, most basic meaning: the digital reproduction of the photochemical (or analogue) image. The question of digital image manipulation was

[92] Walsh, 'Slow Disasters: How Neglect Continues to Destroy Our Film Heritage', 27.
[93] Walsh, 'FIAF Technical Commission End-Term Report to the FIAF General Assembly 2012'.

relegated to the background, and scanning was discussed in more detail. While up to then scanning had been viewed as an almost neutral prerequisite for digital restoration or digital distribution, by the mid-2010s it gained more momentum in archival discourses. The quest for authenticity would shift the focus from the interventions on the digitised image to the digitisation moment of the photochemical image. Thus, the scanner and its specific technologies (optical, mechanical, analogue, digital) became crucial by this time. If the digitised image were to look like its photochemical source, the scanner details needed to be discussed.

In this subchapter, in order to challenge the notion of authenticity in digitisation, I will first provide an archaeology of scanners, before reviewing the technical discourses on the state-of-the-art machines within the archival community in the 2010s. This study will clarify how the core function of a scanner, sampling, would make authenticity impossible.

2.3.1 For an Archaeology of Scanners

Historically, there has been a variety of imaging machines, with different technologies (mechanical, electronic, etc.) and different use cases, that have preceded modern scanners. The word scanner in the film and television industry has not always referred to digital technologies, but goes way back, evoking the transfer of (moving) images to a transmittable form. It has been inherently related to electronic technologies,[94] whose signals could carry information. The scientific question was how to encode image information into electrical signals (which could be transmitted via wire or wireless) and how to decode the electrical signals into an image again. Here I mention the research in two distinct fields of television and photo-telegraphy as early scanning methods, in order to identify its recurring patterns.

In television research, inspired by the telegraph, from the 1870s on, machines were proposed and implemented for creating and transmitting electronic images, such as the “telectroscope” (1877), which “intended to transmit to a distance through a telegraphic wire pictures taken on the plate of a camera”, with a camera-like device (Figure 44).[95] The lens was attached to a perforated plate (A), which had small holes as near to each other as “practicable”, filled with selenium, a semiconductor element. Through each of these holes, a small wire went towards another plate (B). Each selenium element sampled a point of the image by changing the light intensity to electricity, which would then circulate through the wire. Selenium, like other

[94] Mechanical power transmission does exist, via gears, shafts, and mechanical machines using these pieces. As do hydraulic and thermal power transmissions. But these are irrelevant in the case of image transmission.

[95] Constantin-Marie Senlecq, ‘The Telectroscopre’, *Scientific American* 9, no. 275 (9 April 1881), https://www.gutenberg.org/files/8195/8195-h/8195-h.htm.

semiconductor elements (such as germanium or silicon) has a photoelectric (or photovoltaic) effect: it changes light into electricity. It can also modify electricity passing through it, by directing or amplifying it.[96] The telectroscope sampled images spatially, but the electrical current value each of its selenium cells produced was not quantified, therefore it can be considered as a half-continuous, half-discrete device. The photoelectric effect of a semiconductor element remains, up to now, the main infrastructural part of electronic and digital technologies of scanning. For some time, selenium was used the most, then germanium, and finally silicon has become the dominant element since the 1960s.

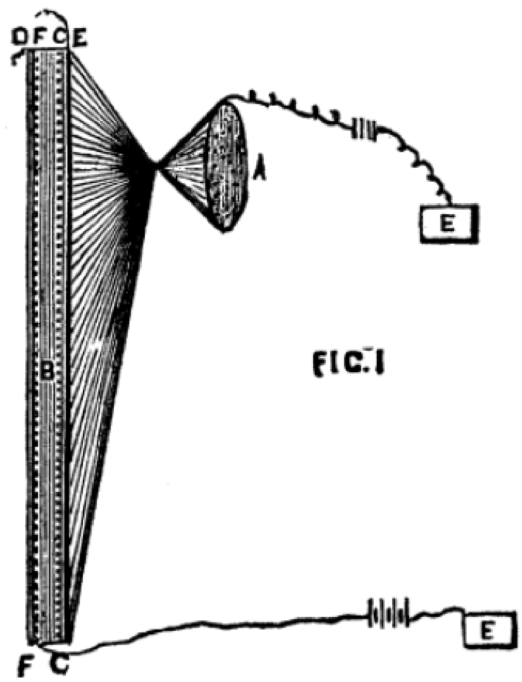


Fig. 1

Figure 44 Telectroscope, as illustrated in *Scientific American* in 1881.

The scientific research in this direction, focusing on telegraphic-like image transmission, came to be called "seeing by electricity" during the 1880s. John Perry and W. E. Ayrton presented in 1880 their conceptual device in *Nature* magazine (which had not been implemented because of its "elaborate nature" and "expensive character"): "Our transmitter at A consisted of a large surface made up of very small separate squares of selenium". The illumination directed towards the selenium plate, whose "squares" were each connected to wires, would then create "electromotive force", where "the strength of electrical current in each telegraph line would

[96] Willoughby Smith, 'Effect of Light on Selenium During the Passage of An Electric Current', *Nature* 7, no. 303 (20 February 1873).
For more information on semiconductors, see: Thomas Vandervelde, 'Beyond Silicon: The Search for New Semiconductors', The Conversation, 10 March 2016, https://theconversation.com/beyond-silicon-the-search-for-new-semiconductors-55795, accessed 9 January 2021.

depend on the illumination of its extremity".[97] In this type of research, images were sampled electronically for transmission, and the electronic sampling was achieved through the implementation of a "mosaic" of photoelectric cells. Technically speaking, this perception is close to how modern digital sensors function (whether in scanners or cameras).

In the scientific television research of the time, the goal was to produce and transmit electronic images directly. The photo-telegraphy, on the other hand, focused on the transmission of existing photographs. The technical challenge was close to that of television: to transform an image into electrical signals via illuminating it, but for existing images. Several machines were proposed,[98] for instance by Noah Steiner Amstutz, whose "Electro-Artograph" was patented in 1891:

> "Prior to transmission, photographs underwent a chemical process to provide a surface height variation proportional to the silver density on the photograph. Amstutz's system used a needle attached to a variable resistor that produced varying voltage output as the needle was scanned across the surface of the specially prepared photographs."[99]

Amstutz's system did not imagine a plate composed of semiconductor cells that would sample the image, but scanned the image in a continuous, line-based manner – and with chemical and electromechanical technologies. The line-reading was also imagined in later systems such as that of Arthur Korn, a German professor in Munich between 1902 and 1913. Korn's machine included a glass cylinder around which the (transparent) photographic film was wrapped up. A point light crossed a small surface of the image and reached a selenium cell which then transformed it into electricity and transmitted it through wires. The cylinder would then move slightly so that the next small surface of the image would face the light and selenium cell. Thanks to the step-movement of the cylinder, all the surface of the image would be covered, and the scanned image would be an analogue signal carrying consecutively information of each sampled point of the image.[100] In this case, instead of a 2D plate of selenium cells (which resembled a sensor), there is only one cell which receives a sequence of information (similar to a sequence of 0s and 1s as in a digital image).

[97] John Perry and W.E. Ayrton, 'Seeing by Electricity', *Nature* 21, no. 589 (22 April 1880).
[98] For a more in-depth discussion of these systems, see: Thorn Baker, *Wireless Pictures and Television: A Practical Description of the Telegraphy of Pictures, Photographs, and Visual Images* (London: Constable and Co., Ltd, 1926). André Lang, Histoire de la télévision, 2018, https://www.histv.net/?lang=fr, accessed 9 January 2021.
[99] Edward R. Dougherty, *Electronic Imaging Technology* (Bellingham: SPIE Optical Engineering Press, 1999), 7.
[100] See for example: Arthur Korn, 'The Transmission of Photographs and Drawings by Wireless Telegraphy, The Wireless World', *The Wireless World* 1, no. 6 (September 1913): 353–57.

The later systems for moving image transmission were, scientifically, following the same logic of transforming light images into electronic images, as explained in the *Journal of the SMPE* in 1927:

> "As the first step in such a transmission, the space variations in brightness from point to point in the view must be translated into time variations in an electrical current that can be sent over the channel of communication. This translation may be accomplished by a scanning process that operates on the view to produce the same effect as if the view were cut up into a single long strip and passed rapidly in front of a light-sensitive cell to generate an electrical current varying with the brightness along the strip."[101]

The scanning of moving images by this time assembled together film and television technologies in one device. A film projector would project the image onto a dissector tube, which read the light information of the image along a number of horizontal lines and thanks to its photoelectric cathode, the information was translated into electrical signals:

> "The 'scanning' of the picture [is the act of] the tracing of a small spot over the picture point by point along some predetermined pattern, which at present consists of a series of closely spaced lines drawn one after the other horizontally across the picture and completely covering it."[102]

During these times, television images were only destined for transmission ("peculiar transient character of television signals"[103]), but from the 1950s on, the signals could be recorded on magnetic tape. Scanning (as in the transformation of a light image into an electronic image), thus, did not necessarily need to respond to a transmission demand, but could simply identify the transfer of image information from a photochemical carrier to a magnetic one. Other technologies were also implemented in film-to-TV scanners (telecines), such as a cathode ray tube (CRT) projecting light onto the film image, collected then by a photoelectric cell transforming it into electrical signals. In 1979, a CCD telecine was also developed, where the CRT was replaced by a xenon bulb and the photoelectric cell used CCD technology (which, as explained in Chapter Two, is one of the main technologies in use in modern digital scanners). If the signal were then run through an AD convertor, it would yield a digital image.[104] In this

---

[101] Gray, Horton, and Mathes, 'The Production and Utilization of Television Signals'.

[102] Pierre Mertz, 'Television – The Scanning Process', *Proceedings of the I.R.E* 29, no. 10 (October 1941): 529–37.

[103] Axel G. Jensen, 'Film Scanner for Use in Television Transmission Tests', in *Proceedings of the I.R.E*, vol. 29, 1941, 243–49.

[104] For a summary of available telecine systems by early 1980s and the addition of digital technologies into it, see: Ray Matchell, 'Digital Techniques in Film Scanning', *IEE Proceedings* 129/Part A, no. 7 (September 1982): 445–53.

case, the digital part, then, would take place only at the end of the scanning process, itself achieved through different analogue technological implementations.

This retrospective look sheds light on the complexity and diversity of scanning processes, not only in technological terms, but also from a conceptual point of view. Sampling an image, as does a scanner, has continually been part of the media landscape in a hybrid manner, it has been conducted for different reasons and via different technological configurations. The core concepts, such as a grid of photoelectric cells or line-based scanning, originated under totally different circumstances, but have been redesigned digitally and adapted to modern machines. All these systems would sample the source image in a specific way, thus creating a simulacre of it, rather than authentically reproducing it. While achieving authenticity through scanning would prove impossible, how did the film archival community try to get closer to it?

2.3.2 State-of-the-Art Scanning:[105] Towards Closer Reproductions

> "Never think that it is possible to put a film on a scanner, push the button, and capture a perfect digital representation of the film. 2K scanning at 10 bit depth can produce an adequate digital version of a 35mm film for presentation, but not a preservation or restoration copy. 4K scanning at 12 bit (or 16 bit) is much better, and may capture most of the effective image information, but only if it is done properly. A bad scan is still a bad scan even at 4K (or 16K), because scanning a film requires skill."[106]

By the 2010s, the act of scanning was not anymore considered as a neutral prerequisite for digital restoration, but one that could provide supposedly a "perfect digital representation" of films suitable either for preservation or (cinema) access. It was conceded that the digitised image was but a "representation", but it needed to be visually indistinguishable from its photochemical source. The FIAF recommendation emphasised the retrieval of "most of the effective image information" upon scanning, and mentioned the complications related to the human factor and the need for understanding both digital and film technologies, so that the photochemical image could be correctly reproduced:

> "Scanning a perfectly graded print in good condition should require the minimum effort to set up and scan, but any one of the following introduces complications: a range of exposure levels, splices, damage, grading notches, non-standard framing, soundtracks.

[105] I am focusing here on the characteristics of scanning, and I will not go into a comparison of different scanners available to archives on the market. For a list of modern scanners in archival use, see FIAF TC's online resource: https://www.fiafnet.org/pages/E-Resources/Film-Scanners-Forum.html, accessed 14 December 2021.

[106] FIAF Technical Commission, 'Digitisation for Film Archives – Assorted Complications'.

> Common problems are unsteadiness at splices, poor response to very dense negatives, insufficient exposure latitude from scene to scene with ungraded material. Scanning film is a process which requires dedication, experience and a good understanding of both film technology and digital technology."[107]

In order to tackle the digitisation problems, the FIAF TC prepared a document specifically on the machines used for this task, called "Choosing a Film Scanner". In the midst of the roll-out in 2012, this document was concerned mostly with scanning characteristics that fit, in the end, the DCP standard. It focused on how a DCP would present images ("what can the audience see?") before giving recommendations on how to scan them (at which bit depth, in which definition, with which treatments).[108] The discourse stressed therefore on the image itself as it would be seen, rather than on the actual technologies and machines reproducing it. The technologies remained quite opaque in archival knowledge:

> "Unlike traditional photochemical technology, and unlike the world of professional stills imaging, film scanner manufacturers do not generally provide much information regarding the response of their scanners to exposure levels. Nor does the digital film world have standardised systems for controlling and managing colours and levels."[109]

It should be noted that the photochemical technologies had not necessarily always been very transparent either (especially when archives worked with external laboratories). But at this time, archives were familiar with these, while they lacked experience with digital technologies. There was thus a need to work on this aspect, and specifically on the machines that achieved the digitisation, i.e. scanners. The "Choosing a Film Scanner" document was updated in 2016 by the TC, where more in-depth technical information regarding the scanner design was added on sensors, film transport and light sources.[110] These technical discourses were to be complemented continually during the second half of the 2010s, most notably through a large technical research project conducted by FIAF TC, called the Digital Statement. The Statement, alongside other technical studies by FIAF, sought to refine the details of scanning in order to determine how the reproductions should be. Although it was attested quite early that

---

[107] FIAF Technical Commission.

[108] FIAF Technical Commission, 'Chossing a Film Scanner', Resources of the Technical Commission (FIAF, 2012), https://www.fiafnet.org/images/tinyUpload/E-Resources/Commission-And-PIP-Resources/TC_resources/Choosing%20a%20Scanner%20v1.1.pdf, accessed 19 February 2021.

[109] FIAF Technical Commission, accessed 19 February 2021.

[110] FIAF Technical Commission, 'Choosing a Film Scanner', Resources of the Technical Commission (FIAF, 2016), https://www.fiafnet.org/images/tinyUpload/E-Resources/Commission-And-PIP-Resources/TC_resources/Film%20Scanners%20v1%202.pdf, accessed 19 February 2021.

authenticity, in an absolute term, would be impossible to achieve, FIAF TC's goal was to move towards closer reproductions.

The Digital statement

In November 2016, David Walsh stepped down and was replaced as the head of the TC by Céline Ruivo (Cinémathèque française). Soon, following in the same research direction, the new commission launched a project called the "Digital Statement", first announced at the FIAF Congress 2017 in Los Angeles:

> "The TC is aware that FIAF institutions have different budgets, capabilities, politics, and models, and our Digital Statement will try to recommend the best practices and standards for restoration and digitization according to the different limitations or missions of film archives. Meanwhile, such material limitations should not restrain us from providing standards and guidelines in order to be closer to a proper reproduction of an original work of art."[111]

At the first presentation of the project, the preferred term for reproduction was "proper", which carries a lesser connotation of closeness to the original compared to authentic. However, the desire to be "closer" to the original work was already there. Aware of the multiplicity of technologies as well as archival possibilities and experiences, the Digital Statement did not intend to uniformise all practices. In a more nuanced way, it presented the diverse routes and the context, between preservation and access, which decided for or against specific practices. It recognised the fact that its role was to provide infallible technical expertise "for an ideal world", while it also needed to remain pragmatic and attentive to the reality of film archives.[112] An important place was accorded to scanning in the Statement.[113] The goal of the TC was to determine "to what extent the digitization result output by the scanner (after capture and processing of the raw scanner readings) is an 'archival clone' (within the technical limitations of any process) of the photochemical original at hand".[114] In this context, there was no reproduction reference in the sense of a vintage print (something which spectators saw): the

---

[111] Céline Ruivo, 'FIAF Technical Commission Report to the General Assembly', FIAF 2017 Los Angeles Congress Report (Brussels: FIAF, May 2017), Appendix 7.
[112] FIAF Technical Commission, 'The Digital Statement. Part I', Resources of the Technical Commission (FIAF, 2018), https://www.fiafnet.org/pages/E-Resources/Digital-Statement.html, accessed 18 December 2020.
[113] The discussion on scanning was enriched partly by the TC's encounter with scanner manufacturers at the IBC Amsterdam in September 2018. The TC also provided "Scanner Forum" as a complementary online resource on the FIAF website which inventories the scanners in use for archival film, offering an overview of their technical details.
[114] FIAF Technical Commission, 'The Digital Statement. Part I', *Journal of Film Preservation*, no. 99 (October 2018): 18.

point was only to digitally reproduce an image on a film (whether a negative or any other type of film) in a way that the result would authentically mimic the visual characteristics of the source. Thus, the "cloning" could be authenticated by relating the characteristics of the digitised image to their "photographic equivalents".[115] In order to achieve that, the technologies in use were supposed to remain as neutral as possible to preserve the original look. For instance, in the Statement, area-based and line sensors were preferred to area colour chips (Bayer filter). Indeed, the latter is a more algorithm-based approach and less dependent on the actual information registered on the film, as it estimates the colour information of pixels in comparison with their neighbouring pixels. Therefore, it does not correspond to the archival criteria of authenticity: which meant to digitise more closely rather than recreate the image aspect digitally based on mathematical algorithms. Further tests and studies on different technologies in use in digitisation led the TC to conclude that the scan is not a clone, but can come very close to it if certain technologies are chosen over others.[116]

Moreover, the Statement also promoted the possibility of removing scratches present on the original material at the scanning step, instead of the digital manipulation step. The 2012 "Choosing a Film Scanner" document had already declared digital restoration prone to errors:

> "Any digital restoration software working on the scanned image must necessarily attempt to distinguish the wanted image from the unwanted blemishes which have become an integral part of the image, and is therefore prone to error."[117]

Clearly, the archival imaginary regarding digital technologies' potential and possibilities had changed by this time compared to the early 2000s, when it perceived digital manipulation as a powerful tool to solve all image problems. According to the Statement, it was preferred to avoid reproducing damages at the time of the scan directly rather than digitally correcting them with the use of restoration software:

> "They can be regarded as not only more effective than digital post-production tools, but also superior in restoration terms because they do not retouch defects by interpolation or by extracting the missing image information from neighbouring frames."[118]

This way, the reproduction, which required less intervention later, was deemed as more authentic and thus preferable. Instead of solving the problem with digital tools, it was to be

[115] FIAF Technical Commission, 18.

[116] FIAF Technical Commission, 'The Digital Statement. Part II: Preservation Scans', Work in Progress Version, Early 2021 (FIAF, 2022). Thanks to Anne Gant (Eye Filmmusem, head of TC since 2020) for sharing the unpublished document with me.

[117] FIAF Technical Commission, 'Chossing a Film Scanner'.

[118] FIAF Technical Commission, 'The Digital Statement. Part I', October 2018, 20.

solved with optical and mechanical tools (such as wet-gate or diffuse light). The example of a 2000s restoration *Das Boot ist voll* (that I mentioned in Chapter One) shows how the then-dominant view contradicts the new view: the negative of *Das Boot* was photochemically duplicated with all its problems (and added problems acquired through duplication) and then the damages were all corrected digitally. By the late 2010s, it was preferred to use a wider range of all technologies available, rather than only digital manipulation technologies. The scanners' many different technologies were to be exploited more consciously in order to reproduce the image. This way, the differences between scanners and the needs of each film to be scanned were to be considered in the decision-making process, as no scanner was perfect.

The FIAF TC was not the only party interested in a study of scanners. At the University of Zurich, Barbara Flückiger's group also conducted research on film scanning in the framework of the Swiss project DIASTOR (2013-2015), and then the ERC (European Research Council) project FilmColors (2016-2020). The result of their scanner study, published in 2018, emphasised theoretically the "principles of material-scanner interaction" as in "understanding the underlying principles of the scanners in operation and analysing the material properties of several different film stocks".[119] Aiming for "the most accurate possible reproduction" of (colour) films, the study mixed its mathematical modelling of optical characteristics of film with various tests on different scanners and offered thus a possible scientific method for some systems of colour film reproduction. It focused on the modelling of colour systems (such as Dufaycolor, Tinting, etc.), not the actual film element being scanned (the generation, the printing specificities, the film stock, inherent image quality, etc). It did not linger on different methodologies, cultural habits and technical preferences either, which shaped the way each archive or laboratory designed its digitisation workflow. Finally, the study concluded that "every digitization is a reading under certain conditions".[120] This is an important outtake, as any scientific method is based on a type of mathematical modelling which inevitably considers a number of characteristics while leaving some others out.

There is indeed a certain degree of subjective preference in methodological decisions and practices, and the Digital Statement, in line with the changing archival imaginary of this time, tacitly recognised this multiplicity, by not considering any reproduction method as the only

[119] Barbara Flueckiger et al., 'Investigation of Film Material–Scanner Interaction', Version 1, 2018, https://www.zora.uzh.ch/id/eprint/151114/1/FlueckigerEtAl_InvestigationFilmMaterialScannerInteraction_2018_V_1-1c.pdf, accessed 19 December 2020.
[120] Flueckiger et al., 82.

one, and by defining the "authentic" as an unreachable ideal to which any reproduction might only get close.[121]

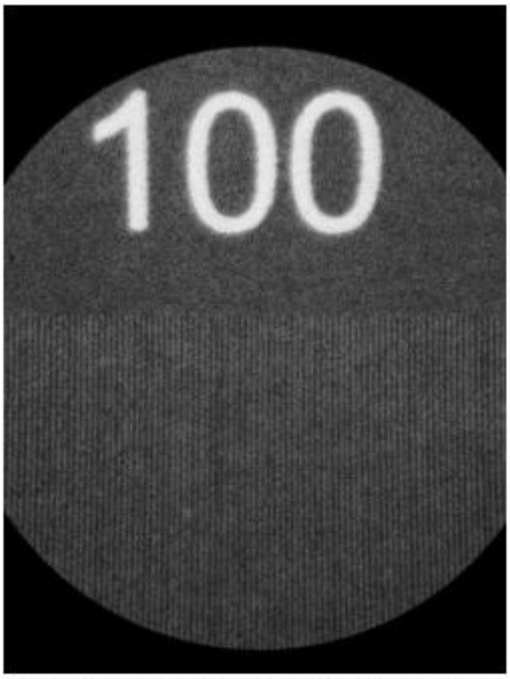
Tests on Film Grain and Scan Resolution

At the Los Angeles FIAF Congress in 2017, the TC presented its intention to also conduct tests on grain and scan resolution. While originating as separate projects, the results of both these pieces of research were included in the Digital Statement, part II.[122] The main tests related to the film grain, as introduced in 2017, were conducted at the ANIM lab of Cinemateca portugesa by Tiago Ganhão. They aimed to compare photochemical and digital reproduction routes:

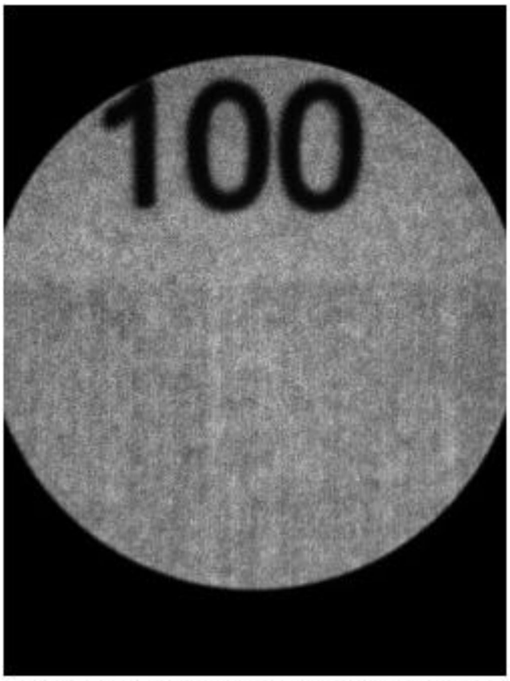
> "Complementing our Digital Statement are tests on grey patches with both photochemical and digital workflows. This is a method to analyze the response and sensitivity of new emulsions, developed and printed differently. These emulsions will be compared to digital scans made on at least two different scanners, equipped with different sensors."[123]

Other tests of this type had already been conducted by the previous TC, when in 2015 David Walsh requested CNC's lab reproduce a film on film through photochemical and digital routes, respectively with direct photochemical printing and digital intermediate. These tests, published on the FIAF website in 2016, were not accompanied by a conclusion or interpretation of results.[124] That was left to archivists. However, the images published did not in fact facilitate the task, as they are not always necessarily of the same size, and open the door to different (subjective) interpretations. According to Nicolas Ricordel, who worked on these tests at the

[121] FIAF Technical Commission, 'The Digital Statement. Part II: Preservation Scans'.
[122] FIAF Technical Commission.
[123] Ruivo, 'FIAF Technical Commission Report to the General Assembly'.
[124] FIAF Technical Commission, 'Film Duplication Resolution Tests', Resources of the Technical Commission (FIAF, 2016), https://www.fiafnet.org/pages/E-Resources/Duplication-Tests.html, accessed 19 December 2020.

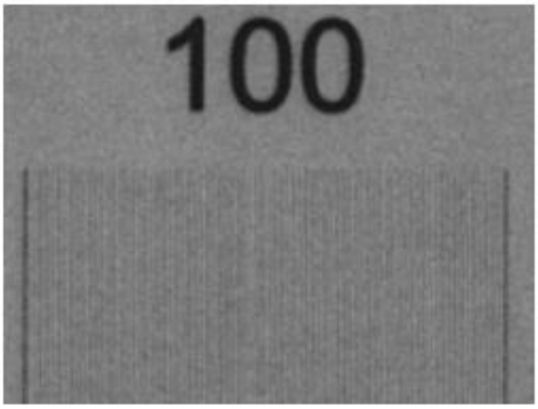


Original negative 100 lp/mm vertical (micrograph)



Fine Grain Positive (BHP printer) 100 lp/mm vertical (micrograph)

4K Scan showing response at different line pairs per mm (Director)



4K Scan recorded to film negative showing response at different line pairs per mm (4K scan of resulting negative)

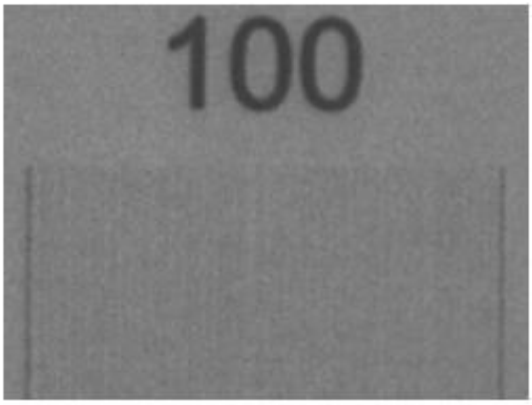


Figure 45 FIAF Resolution tests, 2016. The top left image is how the original negative image is presented through micrography. The top right image is the photochemical reproduction of it on the BHP printer (again, micrographed). The third image is the 4K scan of the original image (an intermediate step), and the forth image shows the printed scan. The goal of the tests was to determine if digital or photochemical route yielded a better result in terms of reproduction quality. The images, as presented on the FIAF website and reproduced here, did not make it easy for archivists to arrive at a definitive conclusion.

time at CNC's lab, the digital reproduction route (using Director Lasergraphics scanner in 4K and Aaton film recorder, also in 4K) had a closer result to the original element.[125]

The scanned image seems to have the best quality compared to the printed image and the scanned-recorded image (Figure 45). In this sense, the digital imaging system presents visually less distortion, less loss with regards to the source element, compared to the photochemical reproduction and the digital-intermediate route.[126] This technical comparison, as presented on the FIAF website, takes place between two images before and after their reproduction, and does not take into account the ethical debates of which original should be aimed for. It remains at a technical level, where a photochemical source image needs to be duplicated into a digital image. At this point, the goal of the tests was to determine the superiority of one method compared to the other, but due to their non-conclusive nature, these tests did not provide any real comparison between different methods and remained as a demonstration (which could probably have also been the desired result by the TC).

The new FIAF tests did not repeat the comparison between digital and photochemical routes merely in order to designate a winner, but mostly in an effort to make the image produced by the digital route look more like the photochemical image that was being duplicated. In other words, the focus was shifted towards a search for authenticity: to achieve a specific look that archives determined to be a film look. The TC was aware that these new tests would not evade a degree of subjectivity,[127] as the tests were to be interpreted visually, but it tried to determine a scanning pixel count which would authentically reproduce grain structure without presenting any digitisation artefact. The idea in these tests seemed to be to find a digital route which would preserve what was on the original film element (whether a negative, a print, or anything else). This was already technically unattainable in photochemical reproduction, where the grain structure of the destination film would inevitably influence the graininess of the source film in reproduction, but with finer-grain material the difference was less visible. Similarly, digitisation was also expected to respect this visual aspect of the source image.

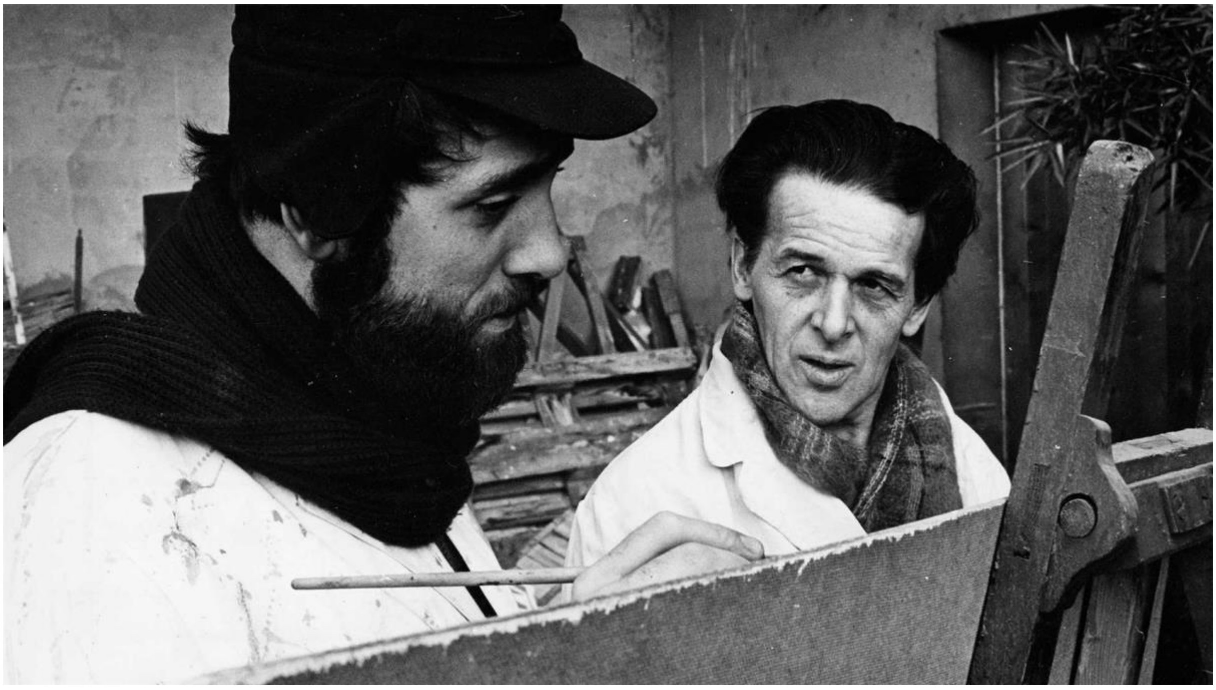
The tests compared a 35mm film and its 4K DCP reproduction.[128] It demonstrated that the graininess was not the same from one to another, and that the difference was more visible in the grey areas of the digital image. This was (at least partly) attributed to a specific type of

[125] Thanks to Nicolas Ricordel who provided me with contextual and analytical details regarding these tests.

[126] This observation needs to be put forward very cautiously, as the original element was also "duplicated" via micrography.

[127] FIAF Technical Commission, 'The Digital Statement. Part II: Preservation Scans'.

[128] First presented at the Il Cinema Ritrovato Festival in Bologna in 2017 and then again at the Prague Congress in April 2018.



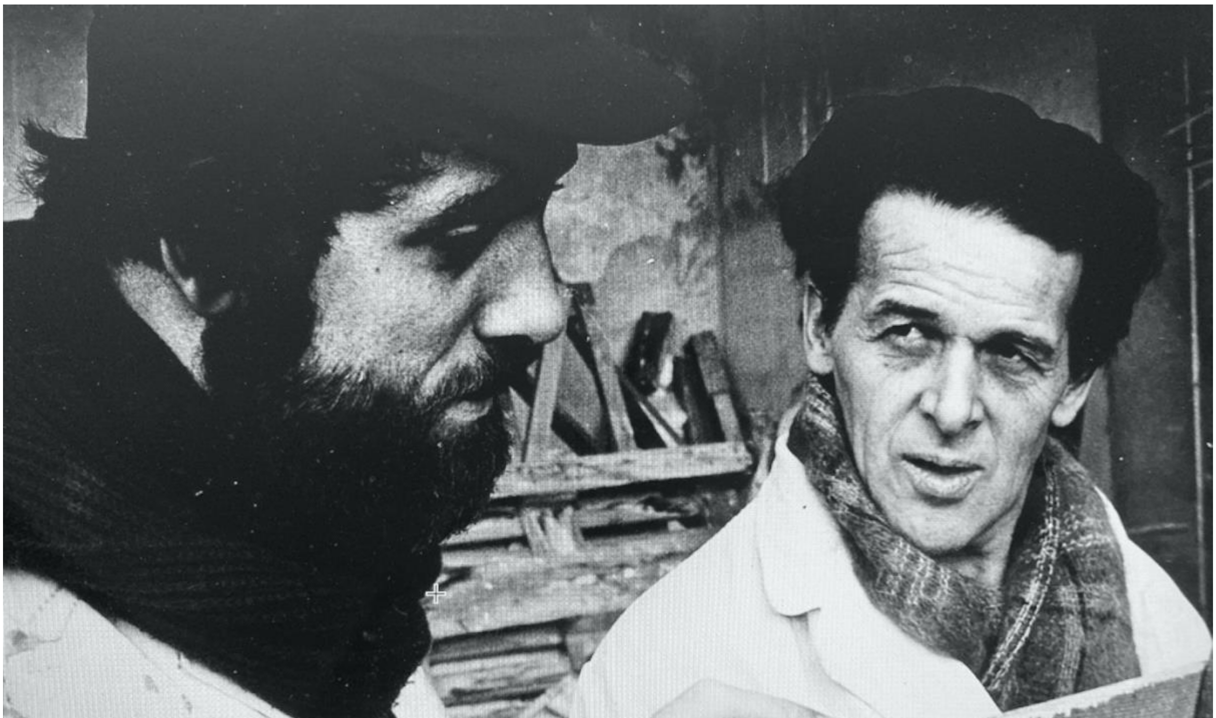


Figure 46 The top image is a 4K JPEG digitised frame of the film *Charles mort ou vif* (Courtesy of Cinémathèque suisse). The bottom image has been taken digitally by a cellphone camera from the computer screen presenting the original image. The aliasing effect is visible all over this reproduction, most notably on its bottom left corner, as some curved lines which do not exist on the original. This has happened because of the high spatial frequency of the screen, which cannot be correctly reproduced on the cellphone camera. The same phenomena may happen during the digitisation of images which have concentrations of high spatial frequency (i.e., very small details such as grain).

digital artefact called the aliasing effect. Related to digital sampling,[129] aliasing occurs if the number of samples per area is insufficient to reproduce a sampled signal correctly. An insufficient spatial sampling rate in an image can create either pixelisation, where the information of too many image points is approximated to only one value; or it can create aliasing, where different information in an image area overlap to make up a pixel value which does not correspond to its original (Figure 46). Due to this sampling error, the original information cannot be reconstructed correctly in the resulting digital image. In order to counter aliasing, FIAF TC advised scanning at higher pixel counts. This way, aliasing would be avoided at the scanning step directly, instead of being wiped out by digital corrections later, thus preserving the image authenticity.

I argue that in such comparisons, other factors can also prove crucial. Firstly, when a DCP is projected, what is on the screen is a reconstructed (decompressed) image. Although the JPEG-2000 compression of DCP is an almost transparent digital container, it may still introduce small compression errors. Therefore, the DCP image should be more cautiously used to represent the small digitisation inaccuracies, as they might get mixed up with compression errors. Moreover, when a 4K-digitised image is transformed into a 4K flat DCP, a slight reduction in definition may occur (from 4096 to 3996 pixels horizontally) which could also be at the origin of aliasing depending on the image details. Secondly, and more importantly, the photochemical image is considered in most archival discourses as definitely having a higher resolution than a 4K digital image. This means that any 4K digitisation would violate the Nyquist–Shannon sampling theorem, which demands that the sampling rate be at least twice the maximum spatial frequency. As explained, for an image, the highest spatial frequency concerns the smallest distance between two pieces of image information. The size of the samples (i.e., pixel size) must be smaller than this distance. But what, in fact, is that smallest distance? As concluded in Chapter Two, this cannot be calculated in a precise manner, and remains dependent upon too many factors (notably the optics and the light which had created the image). Thus, it needs to be addressed on a case by case basis, film element by film element, machine by machine – and with regards to different settings available on each machine. Reproducing digitally such an image on film is also dependent upon many factors, not solely the scanning pixel count: light, optics, sensors of the scanner can all influence the final aspect of the image. A too-high digital

[129] What I describe here (and which was discussed by the FIAF TC in relation to resolution) is spatial aliasing. But aliasing may also occur in relation to temporal sampling or motion compression, as mentioned in FIAF Technical Commission, 'The Digital Statement. Part II: Preservation Scans'. These can indeed happen in DCP (whose temporal bitrate has an upper limit) and video files (which may do temporal and motion-based compressions), but in the case of image-by-image digitisation only spatial aliasing might occur.

spatial sampling rate for a film whose approximative photochemical resolution (calculated via MTF or by visual impression) is not high enough can in effect harm the authentic reproduction, as it may pick up more noise rather than actual image information. The relation between a digitisation artefact such as aliasing is therefore not linear with the scan pixel count, and depends most importantly on the source image as recorded on film.

In order to provide further recommendations for authentic grain reproduction, FIAF TC also conducted specific studies and research on the chemistry of the film material. Ulrich Ruedel (Hochschule für Technik und Wirtschaft Berlin), a TC member, presented this research first at the 2019 FIAF Congress in Lausanne, and underlined the very small size of the physical grain, which would never be entirely captured by current pixel counts. This is of course true, but the question is, when the archival community discusses grain reproduction, which grain is it talking about? As I explained in Chapter Two, the photographic grain is not the same as the graininess of the image. The latter, although loosely related to the former, is a visual impression which is not directly linked to the material, chemical grain through a mathematical formula. The size of the grain does not necessarily mean that the image is less or more grainy.[130] According to the FIAF TC:

> "The random nature of film grain is uniformly sampled in film scanning. Particular attention is paid to the resulting texture (usually described as 'grain' or 'noise') of scanned film images: there are two different kinds of 'information' present in film – the actual image detail and the photographic grain through which this is manifested."[131]

For film archives, the technological act of digitisation needed to recreate the graininess as is on the digital image. According to Ruedel, the pixel counts could anyhow never reach a state where they could represent the microscopic physical grains, thus archives needed to let go of their unfeasible temptation to authentically reproduce it, and focus instead on the (subjective) visual recreation; so, the graininess. The distinction between grain and graininess was underlined in the Digital Statement, and it was announced that a "forensic reproduction" of microscopic grains was neither possible nor wanted.[132] Tacitly, this view finally rejects the idea of grain being the photochemical equivalent to pixel.

Now, I raise one question: does graininess need to be represented digitally? Historically, the answer to this question has not remained constant. As I explained in the first two chapters of

[130] For instance, Kodak T-Grains are larger in surface (but flat) and they yield a considerably less grainy image compared to smaller (but not flat) grains.
[131] FIAF Technical Commission, 'The Digital Statement. Part I', October 2018, 18.
[132] FIAF Technical Commission, 'The Digital Statement. Part II: Preservation Scans'.

this thesis, film manufacturers and archivists alike had often tried to reduce graininess in photochemical (re)productions. The quest for authenticity in digital reproductions, however, seemed to have reinstated graininess as an integral part of the image, an important aspect of its look, a sign of its authenticity, which also needed to be preserved. But the dilemma visibly still persists, and there is no definitive answer to it.

In sum, FIAF discourses sought to implement authenticity in technical applications by defining a comparative framework including both film and digital images. The photochemical source image on film was the reference to which the digital image needed to resemble. But an identical reproduction, which satisfied technical authenticity, seemed to be very complicated to achieve and the results of tests and studies did not give conclusive results. Considering the characteristics of scanning, the question is if such a reproduction can be technically feasible?

Authentic Reproduction?

Could an entirely transparent imaging system exist in the future for reproduction of photochemical film? Resorting again to the Model Theory,[133] which I presented in Chapter Two, I argue that it is highly unlikely. Any imaging system provides models of an original source image, where image information is mapped to new equivalents, whether for photochemical, video or digital reproduction. Several models may be created of the same image which corresponds to the needs and goals of the reproduction process (pragmatism). Finally, the models always represent a part of image information in the source element, which have been sampled according to the reproduction technologies and goals. The models, therefore, always include reductions. This can be explained through the technological framework within which a reproduction is conducted. These technological frameworks are composed of an assembly of different technologies, machines, pieces of equipment, etc., whether for photochemical, video, digital (re)production (or else). The physical machinery of capture and recording (film, optics, IC chips, magnetic tapes, sensors, etc.), primary in all these cases, is not limitless, and not all the factors always remain entirely controllable. Any tiny change or disturbance to it results in a different model. To make it all the more arbitrary, there is also a human factor as in the figure of the operator of these machines and technologies, as well as the reproduction choices for aesthetic or practical reasons. Reductions in the models become inevitable due to all these factors, despite the fact that they may become too small to be noticed. Thus, any reproduction is forced to select main attributes and leave the others out.

[133] Stachowiak, *Allgemeine Modelltheorie*.

Considering that the photochemical source image is not computational nor entirely numerical, it never allows a perfectly unambiguous reproduction: its continuity needs to be somehow sampled, regularly (via electronic or digital means) or irregularly (via photochemical means). A model is always a simplification, and there is, always, a good deal of estimations involved in reproductions as model-making processes.[134] These questions of selection and reduction do not seem to disappear within computational frameworks (i.e. in the electronic or digital realm or probable future systems). On the contrary, computational thinking is based on modelling, thus selection and reduction are integral parts of it. The machines, to which the work is delegated, need formal and computational models to function. Although it is difficult to predict where the world will lead to, cinema imaging systems tend to become more and more computational over time – not less. The image reproduction through future imaging systems could probably get very close to the source image, but it seems highly unlikely to ever achieve a total authenticity. To conclude, a reproduced image may look like the source image, but its reproduction has been achieved within a different technological framework, whether going from photochemical image to photochemical or electronic or digital. Each technological framework has its own specificities, as well as a whole history of practices and culture, which shape its images. In the next subchapter, through concrete examples, I will investigate how, precisely, this phenomenon is manifested in the visual aspect of an image.

2.4 The Technical Side of the Image in Transition from Photochemical to Digital[135]

As argued above, technically and theoretically, a reproduced image can but mimic the visual characteristics of its source. In this subchapter I turn to the technical side of the transition of an image from a photochemical to a digital carrier (meaning the source image and its direct clone out of the scanner), in order to critically analyse the influence of the technologies on the look of the images. Indeed, reproduction depends not only on the scanning characteristics (pixel

[134] The simple act of copying digital data from one location to another is not considered as reproduction here, contrary to transcoding, which potentially changes the image. I will come back to these concepts later in this chapter. Here, I am mainly considering the reproduction of photochemical source images.

[135] This subject has been theoretically discussed by scholars from different point of views. For a discussion of film as "performance" and an aesthetical approach regarding nostalgia of film materiality, see: Barbara Flueckiger, 'Material Properties of Historical Film in the Digital Age', *NECSUS. European Journal of Media Studies* 1, no. 2 (November 2012): 135–53. For media archaeological approaches and the concepts of remediation and transition, see: Cavallotti, 'From Grain to Pixel? Notes on the Technical Dialectics in the Small Gauge Film Archive'; Lundemo, 'Conversion, Convergence, Conflation: Archival Networks in the Digital Turn'. Here, I approach it from an intertwined technical-discursive point of view close to Fossati's *From Grain to Pixel*, and I use the term "transition" only in referring to the actual reproduction of a source image into a duplicated image.

count, sensors, optics, etc. of the scanner), but also on the characteristics of the film element being scanned and specifically, how this image had been formed (and survived) prior to its reproduction. I claim that it is crucial to know the history of the image and how it has been created in order to reproduce it digitally. This helps to nuance better the term authenticity in practice. The restoration examples which will be discussed here are *Charles mort ou vif*, *Grauzone* as well as *Romeo und Julia auf dem Dorfe*,[136] which present three different case studies due to their production and digitisation workflows.

2.4.1 The Photochemical Workflows and their Traces on the Image

The photochemical workflow depends on the production modes, [137] which are in turn influenced by artistic choices, cultural reasons[138] as well as technical and economic constraints of the production context. In its simplest form, the workflow consisted of a camera negative printed subsequently on a film print:

Later, two intermediate steps were added, constructing the following workflow, which was most commonly used for Hollywood and bigger European productions, where all elements were 35mm:

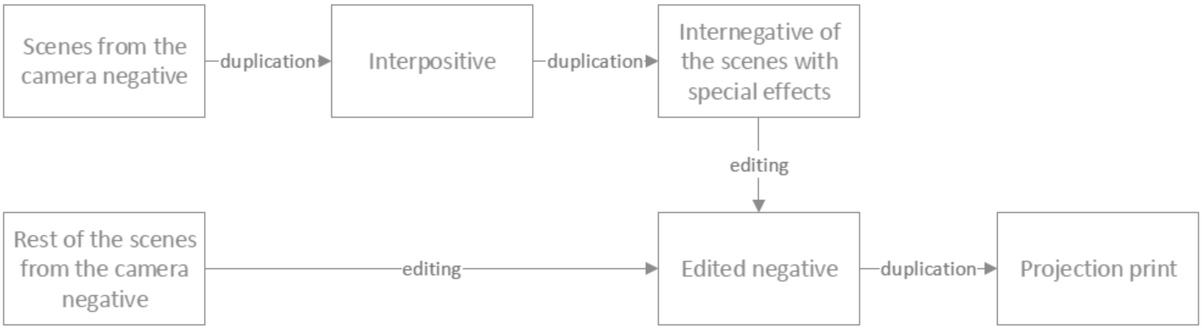
The intermediate positive (also called interpositive or duplicate positive) is a low-contrast, fine-grain duplication element which is supposed to reproduce most image details. Then, this

[136] Some projects in which I have been in charge of restoration at the Cinémathèque suisse, from 2017 to 2021:
Charles mort ou vif (Alain Tanner, Switzerland, 1969). Restoration by Cinémathèque suisse, 2017-2018, laboratory Immagine Ritrovata, Bologna.
Grauzone (Fredi M. Murer, Switzerland, 1979). Restoration by Cinémathèque suisse, 2018-2019, laboratory Cinegrell Zurich.
Romeo und Julia auf dem Dorfe (Hans Trommer and Valérian Schmidely, Switzerland, 1941). Restoration by Cinémathèque suisse, 2017-2022, laboratory Immagine Ritrovata, Bologna.

[137] For photochemical post-production methods, see: For digital post-production see: Leon Silverman, 'The New Post Production Workflow: Today and Tomorrow', in *Understanding Digital Cinema*, ed. Charles Swartz (Burlington/Oxford: Focal Press/Elsevier, 2005), 15–56. For the archival context, see: Cherchi Usai, *Silent Cinema: An Introduction*, 44–71.

[138] The cultural habits and preferences, in different countries, regions, even labs, shape an important factor in the establishment of the practical landscapes.

element is reproduced on an internegative which is the source of the subsequent prints. In reality, the workflow camera negative → projection print was also a simplified version of this, as the process contained almost always more complex steps at least for some scenes (for instance for grading and special effects). These scenes would be first duplicated into interpositive, then into internegative and then edited into the full camera negative. That would look more like the following diagram:



The 1941 film *Romeo und Julia auf dem Dorfe* followed this workflow. The prints thus contained scenes which were duplicated two times before figuring in the edited negative, while others were directly reproduced from the original camera negative. Because of the multiple reproduction steps, the image quality throughout the whole final print was not homogeneous. This production route was common for films from the 1930s and 1940s in many countries. The effect of different image qualities in different successive shots remains visible to the trained eye, for example, when an editing effect such as dissolve has been optically printed.

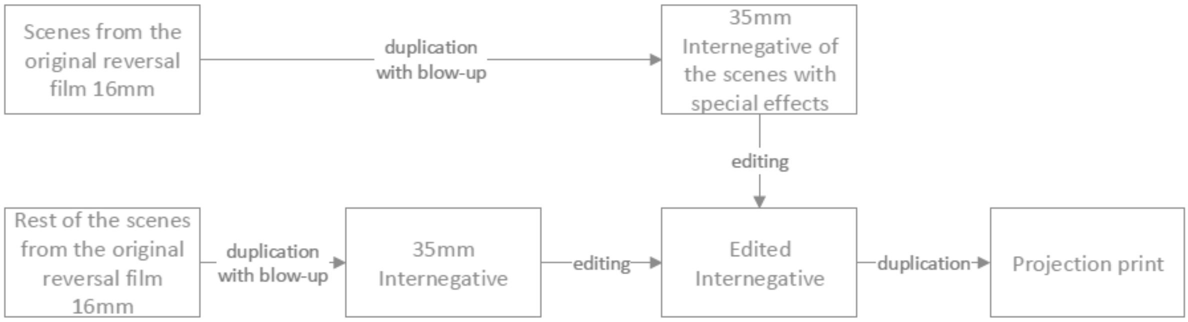
Generally (but not always), photochemical reproduction includes a negative-to-positive inversion or vice-versa. There are types of films which can be duplicated directly from negative to negative (CRI – colour reversal intermediate negative) or positive to positive (reversal film).[139] The reversal film could be used as the carrier inside the film camera; in this it can be assimilated to polaroid photographic film. The process of duplication can be done by different methods: contact printing or optical printing, on step or continuous printers.[140] The gauge of the elements (35mm, 16mm, or sometimes more rare formats such as 28mm or 9.5mm) can be changed in routine production routes thanks to optical printing. The standard projection format for a commercial release in mainstream cinemas was 35mm,[141] but for many smaller

[139] In fact, the transformation from negative to positive in the reversal film takes place during the development process.

[140] For a historical manual of photochemical film duplication, see: Raymond Spottiswoode, *Film and Its Techniques* (Berkeley: University of California Press, 1951), Chapter 8.

[141] For a short history of the standardisation of 35mm, see: Paul C. Spehr, 'Unaltered to Date : Developing 35mm Film', in *Moving Images : From Edison to the Webcam (Stockholm Studies in Cinema)*, ed. John Fullerton and Astrid Söderbergh Widding (Sydney, John Libbey, 2000), 3–28.

productions, it was quite common to shoot on 16mm before blowing-up to 35mm for theatrical distribution.[142] In the Swiss film industry of the 1960s and 1970s, 16mm-shooting (on reversal or negative film) was indeed very common. The filmed element was then prepared for 35mm-release. This was the case for *Charles mort ou vif* and *Grauzone*, which were both filmed on 16mm (reversal) film, sharing a similar production route:



At each step, the photochemical imaging system samples the existing image and records it onto a new film. The existing image is already a mix of image information and grain, out of which a selection of information is carried out (via sampling by light) and recorded on a new carrier. A new grainy texture is also added to it which is related to the new carrier's chemical characteristics, exposure and treatment. This process also introduces imprecisions: first, there could be small errors, notably when the emulsion does not absorb all the light that it should; second, the type of film stock is not the same (changing notably the graininess); third, printing machines and light sources may change from case to case. What's more, at each step, the element should be developed. This also increases the risk of small, arbitrary changes to the image – which cannot be quantified nor prevented. The authenticity is thus technically challenged at each step in the case of photochemical reproduction, and it is impossible to produce the exact same-looking elements: each element has its own look or aspect. The amount of details on the first-generation image is higher compared to later generations, that is why it is claimed that each duplicated element suffers loss compared to the generation before. Again, here I am only talking about the technological act of image reproduction at each step, from one image recorded on an element such as negative, to another image recorded on a positive, for instance. These images are not directly seen on the screen, but they are intermediate products that exist on physical film artefacts. What's more, photochemical elements are subject to

[142] Many films could also circulate solely on 16mm.

chemical,[143] mechanical[144] and biological[145] degradations, which may be more or less according to the film's type and the conditions of its storage during its lifetime.

From what I have covered here, it becomes clear that a photochemical image, which will be subject to digitisation, carries already a whole history of different practices (production, duplication, special effects, conservation, etc.) which influences its technical quality as recorded on film. Therefore, it might be insufficient to identify it solely with its generic technical system (such as Technicolor) or even its generation. The uniqueness of images on film, as well as the diversity of aesthetic or technical choices in reproduction, make it difficult, I daresay impossible, to find one best practice in digitisation and apply it to everything in search of an authentic reproduction.

2.4.2 The Transition of the Image

From the discussion above, I argue that when an image is digitised (in an uncompressed form), its technical quality depends not only on how the digitisation is done practically (pixel count, bit depth, light, sensors and other technologies), but also on the source image, which as explained, is quite diverse even for one film. First of all, there is the question of choosing the source element, as there are several candidates for that. However, most often, many of these materials are not at the disposal of film archives, or when they are, they sometimes do not gather all the necessary prerequisites to be used in reproductions, as they may be incomplete or too damaged. Any element that is chosen to serve as the source of digitisation, will impose its own authenticity requirements as it has its own look. The choice of a source image implicates thus different reproductions, as each digital image looks like its own photochemical source, and not necessarily any other. Of course, the goal of the reproduction is also an important factor, whether the digitised image is destined for access or preservation. Here, I focus only on uncompressed digitisation in the technological sense without taking into consideration any external reference (such as an answer print); so, I investigate the tendency to reproduce the visual characteristics of the photochemical source digitally.

In the case of *Charles mort ou vif*, the original reversal 16mm film was almost complete (apart from three shots) and in good condition, so it could be selected as the source image for digitisation in 4K. The three missing shots were digitised from the 35mm internegative (still in 4K), and inevitably, they presented different image qualities in the digitised version of the

[143] Such as nitrate decomposition or vinegar syndrome.
[144] Wear and tear problems, such as scratches, broken perforations, shrinkage, etc.
[145] Such as mold attacks.

film.[146] The digital reproduction conserves thus the photochemical generation loss, as well as the visual trace of the historical damages on the film (in the case of *Charles* line scratches can be seen on the images coming from the internegative). The grainy texture reproduced on each digital image also resembles that of its own source element. As a result, the technical image quality differences of the source elements, digitised both in 4K and on the same machines, do not disappear in the transition. These differences remain visible after grading, but might not be noticed by an untrained eye.[147]

The same production route had been employed in the making of *Grauzone*, but it could not undergo the same digitisation decisions, as the 16mm reversal film in this case was considerably less complete. Hence, the 35mm internegative film served as the digitisation source (also in 4K). This element had lost a lot of image details at the photochemical blow-up stage at the time, maybe in part because of its dominant dark lights. The 4K digitisation, in this case, has also entirely recorded the grainy texture of the internegative (which made it look less sharp compared to its 16mm original reversal film). Naturally, the digitised images of the two films do not reproduce the same look, the amount of details and the sharpness being considerably inferior in the case of *Grauzone* than for *Charles*, despite the fact that they share the same original production route. In order to observe better the dependence of the quality difference of the digitised image on its source, a part of the 16mm reversal film of *Grauzone* has also been digitised at 4K and compared with the 35mm internegative (Figure 47). It can be seen that more details are visible in the second image, notably in the dark parts in the middle of the image. This example gives an idea of the generation loss induced by photochemical optical printing. If the 16mm reversal film had been chosen as the digitisation source of *Grauzone*, more details would have been preserved on the digital version, which were never seen in the original prints of the 1970s. In this way, with regards to the first-generation image, the digital reproduction seems technically to be more authentic (i.e. presents less loss) compared to the photochemical reproduction; while theoretically, it diverges from the original film as seen by spectators in 1979.

---

[146] I have prepared a short video of the film's ending, which presents a transition between digitised shots of 16mm reversal film and 35mm internegative. The last shot with the proverb is taken from the latter, while the preceding shots are from the former. The difference in image quality is seen better on a bigger screen. See: https://youtu.be/Enqq8_xkmko.

[147] This case study has been discussed at Master-level course of Film Studies at the University of Lausanne, and most of the students did not notice the difference before being told.

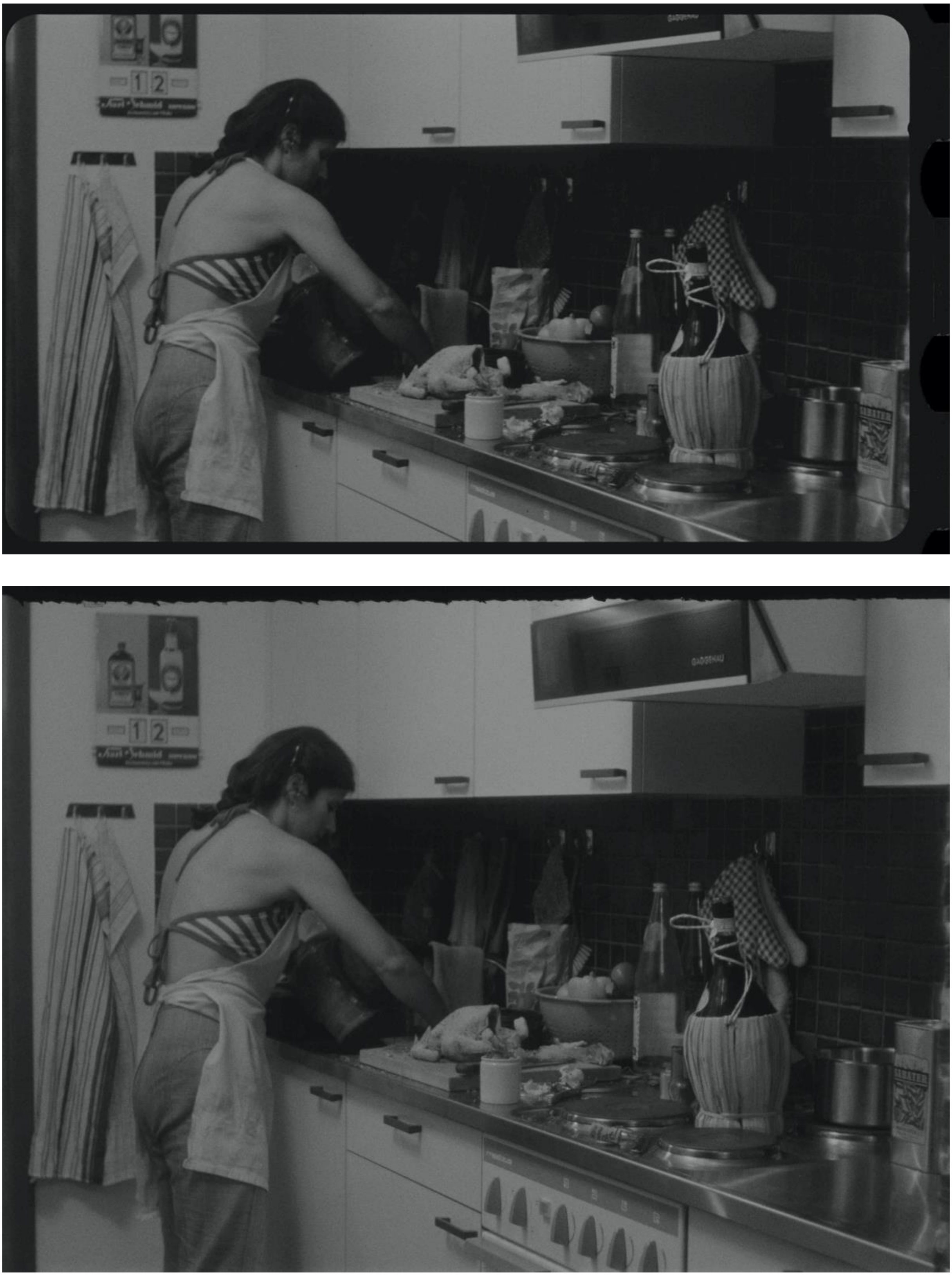


Figure 47 A digitised frame of *Grauzone* (Fredi M. Murer, Switzerland, 1979). The image on top is a 4K digitisation from 35mm internegative (2nd generation), and the image on the bottom is a 4K digitsation from the 16mm reversal film (1st generation). Courtesy of Cinémathèque suisse, thanks to Nicolas Ricordel for his help to prepare this example.

A more complex example is *Romeo und Julia auf dem Dorfe*, for which only projection prints with different visual characteristics (in terms of lighting, grain, sharpness, amount of details, etc.) have survived. As these are all incomplete and very damaged, a reconstruction needed to be conducted which mixed 4K digitised images of different sources (several 35mm nitrate prints and a 16mm internegative) together in the same edit. Moreover, the prints already had shots coming from an internegative, which did not have the same quality as the shots coming from the original camera negative directly. The dissolves were carried out in the middle of the shots, in a way where a considerable difference was introduced in the lighting (Figure 48). The final version of the digitised film was a patchwork of shots from different sources, carrying different technological signs (whether digital or photochemical). Without specifically touching the grain nor other inherent image qualities (such as sharpness), the film was graded in a way where the quality differences were minimised visually as was possible, and the tear and wear marks related to prints were digitally removed where possible (such as projection marks which looked different on every print, for instance in Figure 49). One of the prints had holes on the right side of the image on one whole reel, which could not be removed without creating digital artefacts. The images from this reel of this print can be recognised even in the final restored version of the film. Every shot on this digitised film has characteristics that bear witness to its technological history, be it during its production, projection, archival life or digital restoration.

Figure 48 These two images, having different quality and lighting, are digitised frames coming one after the other in the film *Romeo und Julia auf dem Dorfe*. The second has gone through an optical printing to create a dissolve with the following shot. The transition remains quite visible. Courtesy of Cinémathèque suisse.

In sum, it is the image (re)production processes that create the visual difference in images. The carrier, while intrinsically related to the image, can be detached from it: images may transition from a carrier to another, each carrier imposing its own quality restrictions, but the traces of the old carrier remain on the new ones. The (sometimes subtle) differences of look introduced by carriers are not solely related to the digital technologies and also carry visual traces of photochemical film processes and other optical interventions.

Figure 49 An example of a projection mark on a frame of a print of *Romeo und Julia auf Dem Dorfe*. Courtesy of Cinémathèque suisse.

2.4.3 Photochemically-shot Digital Cinema

The persistence of the so-called photochemical look is not uniquely evident in archival reproductions, but is also common in current film production, as there is a considerable number of films which are still shot on photochemical film but distributed digitally, in Europe as well as elsewhere.[148] This tendency is closely followed (and promoted) by film archives. In 2015, the roundtable "Future of film" during Il Cinema Ritrovato (mentioned in the previous chapter), included a part dedicated to filmmakers, notably Pietro Marcello whose 2015 film, *Bella et perduta*, was shot on 16mm before being distributed on DCP. Marcello's previous film, *La Boca del lupo* (2009) was shot on digital Betacam video (although it also included archive footage originally shot on 8mm, Super8, 9.5mm and 35mm). However, in Bologna he announced that now that he has known film, he would prefer it always to digital filmmaking.[149] Similarly, during Il Cinema Ritrovato 2016, at a discussion on "Importance of film… in a digital world" with Davide Pozzi, Kodak sales director Christian Richter evoked the "analog renaissance" as a motive for shooting on film which would guarantee "the ONLY true, unique

[148] There is also a film mode on many digital cameras, which tries to simulate the photochemical look digitally.
[149] Payne et al., 'Il Futuro della pellicola/The Future of Film', accessed 24 December 2020. Indeed, Marcello's following film, *Martin Eden* (2019) was shot again on 16mm.

and organic 'Film Look'", and allowed to "differentiate [a] project from the 'digital' rest".[150] Although photochemically-shot films were digitised and distributed on DCP, they did retain their original, sought-after film look. As explained in Chapter Three, DCP was designed technologically in a way that it acted as an almost transparent container, thus not interfering much with the visual characteristics of the original digitised image that it compressed.

What Kodak (and some filmmakers and cinematographers) appreciated in film shooting in a digital workflow was that the digital image did not look the same as a digitised image (in the same pixel count and bit depth). Shooting on film is indeed a choice that achieves a specific image look. A brief look at a few recent European examples will shed light on how the use of photochemical film and its specific look contributes to the overall construction of a film and its narration modes in many aspects. *Paradise* (Andrei Konchalovsky, Russia, 2016), a film about the Second World War, was shot on 16mm and 35mm. In this film, the grain contributes to the narration, which includes pseudo-documentary interviews supposed to date back to the 1940s. The same goes for the Cannes prize winner, *Son of Saul* (László Nemes, Hungary, 2015), filmed on 35mm and also dealing with the Second World War. *Son of Saul* has a distinctive aesthetic sign, which is the sharp foreground in a blurry background: most of the shots follow the principal character in close-up while the background images (the horrors of war and the atrocities of a concentration camp) are blurred (leaving the sound to represent them). This was obtained through a particular way of shooting with a film camera:

> "The cinematographer was also the camera operator and shot handheld. He used a 40 mm lens which focused precisely on the image at hand at the same [time] it made for a very shallow depth of field."[151]

Shooting on film, according to Nemes, "was the only way to maintain a certain instability in the images, and thus be able to film this world organically. The challenge was to strike an emotional chord in the audience — something that digital doesn't allow for".[152] Nemes claimed that a film shot on film was different compared to the "digital hoax", as the moving grain of the

[150] Christian Richter, 'The Importance of Film' (Il Cinema Ritrovato, Bologna, 29 June 2016). Emphasis in the original powerpoint slides.
[151] Jack Egan, 'Director László Nemes Goes Inside Auschwitz in Son of Saul', Below the Line, 7 December 2015, https://www.btlnews.com/awards/director-laszlo-nemes-goes-inside-auschwitz-in-son-of-saul/, accessed 26 June 2021.
[152] Bryant Frazer, 'Shot on 35: Why Film Matters for Son of Saul', Studio daily, 25 February 2016, https://www.studiodaily.com/2016/02/shot-on-35-why-film-matters-for-son-of-saul/, accessed 26 June 2021.

film from one image to another was “alive”, while the pixels were “dead”.[153] *Son of Saul* was distributed both on 35mm and DCP (mostly the second).

A different example of a film shot on film and then digitised for distribution was *Lazzaro felice* (Alice Rohrwacher, Italy, 2018). *Lazzaro* was filmed on 35mm, and when digitised, its frame also included the borders of the film image (with its distinctive signs related to film, even camera hair). This way, the Italian film seems to have a frame inside of its digital frame, reinforcing its fable aspect where a young man dies and comes back to life (based on Lazarus of Bethany’s biblical narrative). The director Alice Rohrwacher, who has a habit of shooting on film, also participated in a round table on “film and digital: between past, present and future” at Il Cinema Ritrovato film festival in Bologna in 2014. The last example I will evoke here is *Bait* (Mark Jenkin, 2019, UK), which was filmed on 16mm with a vintage Bolex camera and processed and developed in a traditional handmade way, and finally distributed on DCP. The film portrays the clash between the traditions of a fishing community in a Cornish village, and the city people who bring gentrification to the area. In this case, the artisanal mode of production, visible in the look of its images, contributed to the creation of the atmosphere of the village, hostile to these unwanted intrusions from outside. On the other hand, the artistic choices may also privilege digital shooting, such as Hong Sang-soo’s prolific career where films intentionally have a digital, fixed, flat look corresponding to the banality and universality of the stories of his characters, capturing “slices of life”.[154]

By 2022, the aesthetics of different photochemical (16mm, 35mm, etc.), electronic, digital and mixed looks (photochemical in digital, or juxtapositions) continue to co-exist, visible to a trained eye, or consciously made so. At a conference during the festival Toute la mémoire du monde in 2016, Martin Roux went beyond the dichotomy of photochemical vs. digital and presented them as choices in the creation of an aesthetically-pleasing image, and how that was arbitrated by psychophysics.[155] This point was already raised by Jean-Pierre Beauviala at the 2011 *Et si le cinéma perdait la mémoire?*, where he talked about cinema’s march towards hybridity.[156]

---

[153] Interview with László Nemes, BBC: Francine Stock, ‘Son of Saul, The Sound Barrier, 1916 v 2016’, *The Film Programme* (BBC, 28 April 2016), https://www.bbc.co.uk/sounds/play/b0783ln2, accessed 24 December 2020.

[154] Recurring term in discussions of Hong Sang-soo’s cinema; see for example: http://www.movingimage.us/programs/2016/06/03/detail/tales-of-cinema-the-films-of-hong-sang-soo/, accessed 24 December 2020.

[155] Roux, ‘Image numérique et image argentique, quelles différences perceptives ?’

[156] ‘Vers un cinéma hybride? Dialogue avec Jean-Pierre Beauviala’ (Révolution numérique: et si le cinéma perdait la mémoire?, Cinémathèque française, Paris, October 2011), https://www.canal-

In sum, images are intrinsically related to their original materiality which imposes a certain look on the image; the “effet-pellicule”.[157] Then, when going through a transition, visual traces of this materiality are left on the reproduced image, while it also accepts further influence from the new carrier to which it has been transferred (for instance, the digital’s structured grid of pixels). My technical study in this part demonstrates the impossibility of (visual) authenticity in image reproduction, and the inevitability of hybridity. On the contrary, multiple images may exist, with diverse looks. As long as cinema collections with their diverse technologies exist in film archives, the hybridity will be there, whether in the image itself or in archival practices.

3 Conservation : Images and Digital Archivability

Similar to how digitisation was studied within archives with regards to its authenticity, digital conservation was mostly referred to in consideration of its archivability; both of these concepts rising from a more general tendency to keep the film images as they are. What I mean here by digital conservation is the safeguarding of films in a digital form. In the more general context of digital archiving, the term digital preservation is more common, owing to diverse studies on the management, activities and practices of safeguarding digital data (of any kind).[158] In the film archival community, however, digital preservation includes also digitisation, which I have covered in the previous subchapter. In this part, in a more limited and precise manner, I use the word conservation in order to make analogies with the traditional archival practice of conservation of films, and I will only focus on how digital-born or digitised films can be conserved. Digital conservation was not a new concept by the early 2010s, and had been evoked and studied since at least the early 2000s, while technically it remained scarce, if not non-existent, within the archival community by this time. The main archival discussions on the subject and the move to a more pragmatic view occurred during the latter part of the 2010s. I will briefly go back to the older discourses in order to illustrate how archives perceived digital conservation before.

What the archival discourse network had observed and retained from digital conservation in the beginning, was its numerous problems which outweighed its claimed advantages. As the FIRST

u.tv/video/cinematheque_francaise/vers_un_cinema_hybride_dialogue_avec_jean_pierre_beauviala.7767, accessed 26 November 2021.

[157] Habib, ‘Rayures, poussière, grain. “L’effet-pellicule” au temps du numérique, ou la survivance simulée de l’involontaire (un essai de reconnaissance)’.

[158] See for instance one of the earliest studies on the subject: Task Force on Archiving of Digital Information et al., ‘Preserving Digital Information: Report of the Task Force on Archiving of Digital Information’ (Commission on Preservation and Access, 1996).

project had summarised back in 2004,[159] digital conservation technologies were not considered technically satisfactory by that time: they required a considerable infrastructure, continuous management and the data was not thought as being safely secured considering the problems of longevity, reliability, migration, obsolescence and possibility of loss. This view contradicted that of television and audio archives, when these mingled during the Joint Technical Symposium in 2004. There, digital conservation was presented as the solution for conserving audiovisual content,[160] and it was even proposed to "abando[n] analog".[161] Indeed, the materialities conserved by television and audio archives (magnetic tape and discs, notably) seemed to have a shorter lifespan than what was imagined for digital at the time, in contrast to that of film, which was believed to be more robust. During this knowledge exchange, it seemed therefore that film archives were alienating themselves from other types of audiovisual archives on theoretical and technical grounds.

Similarly, the report *Digital Dilemma*, published in 2007, enumerated the economic, technical and human threats to digital conservation, before attesting that "there [was] no digital archival master format or process with longevity characteristics equivalent to that of film",[162] although it did not rule out the necessity of digital conservation. At the Joint Technical Symposium in 2007, the subject was omnipresent, but it was mostly presented by tech providers or consultants, not by film archivists. These discussions were particularly concerned with the necessity of building digital archives which would facilitate film distribution and access, and remedy the problems of film conservation. It was stated that digital archiving could potentially keep films "without degradation" and "forever".[163] This was based on the conception that digital bits could be conserved with no degradation, but the actual technologies to ensure that were diverse, not standardised, complicated, and not always efficient.[164] European film archives, on their side, teamed up with tech companies and research institutes within the aforementioned project EDCINE in order to tackle the problem of digital conservation following the standardisation of digital cinema in 2007. This project did not propose technological implementations for digital

[159] FIRST, 'European Film Heritage on the Threshold of the Digital Era. Full Report (Part One).', 19–23.
[160] For example: Daniel Teruggi, 'PrestoSpace: Preservation Toward Storage and Access Standardised Practices for Audiovisual Contents in Europe' (JTS 2004: Preserving the Audiovisual Heritage – Transition and Access, Toronto, June 2004).
[161] Robert Heiber, 'Abandoning Analog: The Case for Digital Audio Archiving' (JTS 2004: Preserving the Audiovisual Heritage – Transition and Access, Toronto, June 2004).
[162] Academy of Motion Picture Arts and Sciences, *Digital Dilemma*, 51.
[163] Dave Cavena, 'Archiving Movies in a Digital World' (JTS 2007: Audiovisual Heritage and the Digital Universe, Toronto, 28 June 2007).
[164] Cavena.

carriers, but it did focus on possible image format technologies and the general structure of a digital archive, most importantly to encounter the upcoming challenge of digital conservation which was to be considerably intensified with the arrival of digital-born material at archives. I will come back to this project later.

The archival theoretical view seemed to be formed partly in reaction to technophilic discourses, which lacked concrete technological solutions usable in archives, and reinforced by archives' own studies and (limited) practical experience. In fact, digital conservation remained a scarcely-practised archival activity. By the early 2000s, the few archives which were engaged in digital restoration activities had wondered how to archive the intermediate files created during the process. A solution to this problem, adopted notably by CNC,[165] was to conserve the data on DTF (Digital Tape Format), a proprietary digital magnetic tape by Sony, but that was done in view of further manipulation of the images, not with conservation in mind. A few years later, in 2006, the Dutch project Images for the Future imagined a technical infrastructure for distribution which would be the digital storage necessary to keep the films digitised for access. Later in the course of the project, when films were being digitised in higher resolutions and beyond the immediate access finality, the question of digital conservation also became more present and more pressing. As the main part of archival deposits up to the digital roll-out remained photochemical film, not much had been done in order to include digital conservation practically despite the fact that it was sometimes evoked and discussed. Theoretically, it remained inferior to film in archival imaginaries.

In what follows, I will investigate how film archives reacted to digital conservation technologies, and how they came to accept digital conservation as an archival activity, despite the slowly-advancing technological landscape which had remained rather static since its early developments in the 1990s. I will argue how the archival imaginary underwent substantial theoretical and technical changes; from an initial position where the archives rejected the archivability potential of digital technologies altogether, to where they adapted the existing digital conservation technologies to their use. In this process, the theoretical discourses and the technological realities seemed to meet halfway, and the search for an archival format was rethought through the prism of technological hybridity

[165] According to Nicolas Ricordel (personal discussion). The two generations of DTF were released in 1994 and 1999 respectively.

3.1 The Many Faces of Film vs. Digital Conservation

The archival inertia in the face of digital conservation needed to be overcome after the roll-out, when the challenge was formulated in three directions:

- Can photochemical films be conserved digitally (through their digital replicate)?
- Should digital-born material be conserved also on film?
- Should film-born material be conserved on film and digital-born material digitally?

These questions, and the viewpoints which endorsed or refuted them, reunited theoretical and technical discourses together, and functioned within an already-established framework of film conservation. There seemed to be a constant comparison between film and digital technologies for conservation, which resisted the acceptance of digital conservation as an archival activity. Several patterns could be extracted from these questions, which generally oppose film to digital: which one is better for conservation?

Film on Digital?

The first case was theoretically countered through archival discourses. "Digitisation does not equal preservation"[166] was a popular theoretical-archival viewpoint which had been formed and nurtured in the early 2000s, partly because of the insufficiency of technological solutions for digital conservation and the impossibility of a total digitisation scheme, but also, owing greatly of course to the intensification of museological discourses within the archival community. Digital was simply not accepted as an "archival format".[167] Inevitably, this view needed to be adapted in cases where a large amount of digitised material had been produced and now needed to be conserved somehow, insofar as this did not mean that the original photochemical elements were to be discarded and did not interfere with photochemical conservation activities. Despite some theoretical resistance, practically, solutions needed to be sought for digitised films.

Digital on Film?

The second standpoint had also been imagined much earlier, at least in 2006, as explained by Alfonso Del Amo:

> "The archives feel pressure to adapt to the digital reality. We are asked to conserve films digitally because it is simpler and less costly. But we know that this is very far from real

[166] FIAF Programming and Access to Collections Commission, 'PACC Report to the FIAF General Assembly'.
[167] See for instance: 'Self-Preservation', FlandersToday, 30 March 2011, https://web.archive.org/web/20210101045234/http://www.flanderstoday.eu/arts/self-preservation, accessed 25 December 2020.

> conservation. The reality is, today, that films produced in digital have no assurance of survival. On the contrary, to assure their conservation, it is necessary to reproduce them on photochemical film."[168]

Despite having stated that, Del Amo believed that this could not go on forever if film industry decided to abandon film totally. But such a solution was discursively popular. It was privileged and implemented in France by 2011, when the photochemical deposit of digital-born films was made mandatory by law. According to this law, film producers received extra funding to record back digital works on film for legal deposit. The decision, regarded as a "transient solution", followed studies that judged digital conservation as insufficient.[169] The same was required of the films which benefited from digitisation funding (explained in the previous subchapter). In the meantime, external cinema laboratories such as Éclair and Orfeo converted partly into digital conservation spaces, while French film archives lacked infrastructure and strategies to archive digital films digitally. This political decision to conserve film on digital did not satisfy film professionals in France, the matter was taken to court, but in 2013 the law was maintained.[170] However, very few films were in effect recorded back to film, and in 2019, CNC quietly stopped this practice. The digital-on-film conservation approach, in its early conception, refuted entirely digital conservation as an archival practice. However, later, it was considered as one possibility among others when selective digital-on-film conservation schemes were conceived. Such is the on-going project at Cinémathèque suisse, at the initiative of the Swiss Federal Office for Culture, which, since 2020, has funded the shooting back to film of a handful of new digital productions per year.

Film on Film, Digital on Digital?

The third case also had a history dating back at least to 2002 when David Francis imagined a future where films were produced and distributed digitally. According to him, if archives did not want to turn into retrospective collection holders, they needed to accept and conserve digital

[168] Alfonso Del Amo García, 'Archivios in tiempos de cambio. 62o Congreso de la FIAF, São Paulo, 24 y 25 de abril de 2006', *Journal of Film Preservation*, no. 71 (July 2006): 17.
[169] René Broca and Etienne Traisnel, 'Collecter et conserver les films du dépôt légal fournis sur support numérique' (CST, June 2011); 'CST - RT – 026 – C - 2012 – v1.0 : Support Maître d'archivage pour conservation' (CST, 4 April 2012). In this regard, it is interesting also to mention the radio discussion with a few French film and archives professionals in 2013, which conveys well the dominant views on digital and film conservation at the time: 'La restauration des films', *Projection privé* (France Culture, 20 July 2013), https://www.franceculture.fr/emissions/projection-privee/la-restauration-des-films.(In French).
[170] Guillaume Champeau, 'Les fims numériques doivent être fournis sur pellicule au CNC', Numerama, 15 July 2013, https://www.numerama.com/magazine/26514-les-films-numeriques-doivent-etre-fournis-sur-pellicule-au-cnc.html, accessed 26 December 2020.

films as well.[171] This view was reiterated by the affluence of digital-born material after the roll-out. The DAEFH report in 2011 concluded the inevitability of digital conservation:

> "As all films are now produced digitally, they must be preserved digitally (any other alternative is short-lived and not practical)."[172]

A year later, ACE's position paper "A Digital Agenda for Archives" also underlined this fact:

> "Films are being made in a new way and they will have to be archived in a new way. Active film archives will have to go digital. There is no choice to be made, no alternative. Digital film has to be archived digitally."[173]

This could not wait, as "Digital film is here *now* – we must be able to archive it *now*".[174] The EU report on the recommendations for film heritage in the digital era evoked as well the responsibility of archives towards digital cinema productions: "the switch to digital cinema means that FHI are evolving towards hybrid archives taking care of both analogue and digital collections".[175] This viewpoint considered film technologies and digital technologies as forming two big categories whose conservation had to be ensured separately and not with the same technological means. This discourse somewhat elevated the status of digital film to a museological object deserving conservation in its original technologies.

3.2 Is Digital Conservation an Archival Practice?

As evoked above, theoretically, digital conservation had an unclear, generally unfavourable status within the archival community. In order to better nuance how the archival imaginary of the time reacted to digital conservation, I will explore the actual practices of archives faced with this challenge through the examples of two national film archives.

Coming out of the seven-year project Images for the Future in 2014, the Eye Filmmuseum needed to address the problem of digital conservation for its mass of digitised material:

> "Another obstacle - one that has yet to be fully overcome - is long-term storage for the digitised material now that the Images for the Future project has drawn to a close. A digital infrastructure requires structural management and maintenance, which costs

[171] Francis, 'Challenges of Film Archiving in the 21st Century'.
[172] Nicola Mazzanti, ed., *Digital Agenda for the European Film Heritage: Challenges of the Digital Era for Film Heritage Institutions* (Brussels: European Union, 2011), 10.
[173] Christensen and Kuutti, 'A Digital Agenda for Film Archives'.
[174] Mikko Kuutti, 'A Digital Agenda for Film Archives' (ACE Workshop Management Strategies for Film Archives in the Digital Era, Il Cinema Ritrovato, Bologna, 28 June 2012).
[175] European Commission, 'Film Heritage in the EU', 11.

money. These activities were funded by Images for the Future while the project was on-going, but no structural solution has been found yet for the subsequent period."[176]

During the project, Eye had outsourced its digital conservation, while their project partner, the television archive Sound & Vision had acquired a magnetic tape library for in-house conservation. In 2012, a contract was signed between the two partners to centralise conservation in Sound & Vision. This, however, did not last long, and by 2016 Eye repatriated its digital collections inside its own walls by also acquiring a tape library. A financial study[177] in September 2016 by the consulting group BCG,[178] which underlined the necessity to support digital conservation, led to the allocation of a further 1 million euros to Eye for this task since 2017, integrated in the national funding the archive received annually.[179] Indeed, while in the beginning Eye did not consider digital conservation as an archival practice, by 2017, the task was reclaimed by the archive,[180] which recognised its need to be continuously maintained and managed – contrary to photochemical film's (seemingly) passive conservation.[181] This approach did not discard photochemical conservation, but it envisaged both digital and photochemical conservation for film-born material. Eye's digital conservation system was not limited to digitised material, although it departed from it, and also included the conservation of digital-born films, whose technical challenge resembled that of digitised films.

The next example, that of Cinémathèque suisse, is different from Eye in the fact that the Cinémathèque did not have a large amount of digital material prior to 2011. By the time that digital elements started to be deposited after the roll-out, digital conservation was an entirely new field for the archivists at the Cinémathèque, and, for a lack of adequate equipment, they stored the received hard disks in film cans (Figure 50). But there had already been one internal study on the subject in 2010, which was complemented by an external study in 2015, paving the way for the setting up of a digital conservation system. The internal study, conducted by the

[176] 'Images of the Past. 7 Years of Images for the Future'.
[177] BCG, 'Financieel onderzoek EYE', End Report (Dutch Ministry of Education, Culture and Science/Eye Filmmuseum, September 2016).
[178] Boston Consulting Group, an international management consulting company.
[179] For more information about the Dutch political incentive for digital storage of films at Eye, see the official letter by Minister for Culture to the Dutch Parliament in this regard: M. Bussemaker, 'Brief van de Minister van Onderwijs, Cultuur en Wetenschap', Structuurversterking filmindustrie, Tweede Kamer, 25434, no. 47, Vergaderjaar2015 2016.
[180] See also: 'Eye Collection Policy 2014-2017' (Eye Filmmuseum, 2014); 'Eye Collection Policy 2017-2020' (Eye Filmmuseum, 2017).
[181] Photochemical conservation, while largely claimed as passive, could indeed include active, large-scale plans of safeguarding: for instance, the Nitrate plan in the Netherlands. See: Bregt Lameris, 'Early Passive and Active Preservation at the Netherlands Filmmuseum, 1956-1984', *Journal of Film Preservation*, no. 87 (October 2012): 51–56.

staff of the film department in 2010, addressed the upcoming urgency of digital-born film conservation and considered three possibilities: shooting back to film, hard disk storage, Linear Tape Open (LTO) storage. As the second option was judged not archival, a comparison was carried out between shoot-back and LTO storage from financial and technical points of view, which was not conclusive considering the high costs of both and the technical problems of digital formats and carriers in any case. The report proposed thus, firstly, to study the possibility of a tape library while improving the disk-based temporary storage, and secondly, to develop several strategies regarding the nature of the deposited films, if it has a patrimonial value or not.[182]

Figure 50 Hard disks stored in film cans. Photo by Maryline Monnerat, Cinémathèque suisse.

The second study, conducted by AWK consulting group in 2015 as per the demand of Swiss Federal Office for Culture, examined the feasibility of digital long-term archiving at the Cinémathèque, which now had a few years of painstaking experience with digital-born films. In-house (LTO tape robot or SSD) and external (cloud-based) conservation solutions were

[182] Caroline Fournier and Caroline Neeser, ‘Le numérique à la Cinémathèque suisse’, Unpublished Restricted Document (Cinémathèque suisse, 2010).

compared, and a mixed architecture (Figure 51) was proposed as the best solution.[183] The study allowed the Cinémathèque to acquire a tape library and a DAM system to automate ingest and backup tasks. Technically maintained by the computer department of the Cinémathèque, the film department gradually became more involved in digital conservation tasks from 2018, when it was reorganised around the definition of one film collection (on different carriers: film, LTO, disk, video, etc.), strategies and specifications were defined and a role of digital conserver was created. Through a different way in comparison to Eye, Cinémathèque suisse also accepted digital conservation as an archival task, although the question of film vs. digital conservation remained open within the archive in Switzerland, similar to many other countries in Europe.

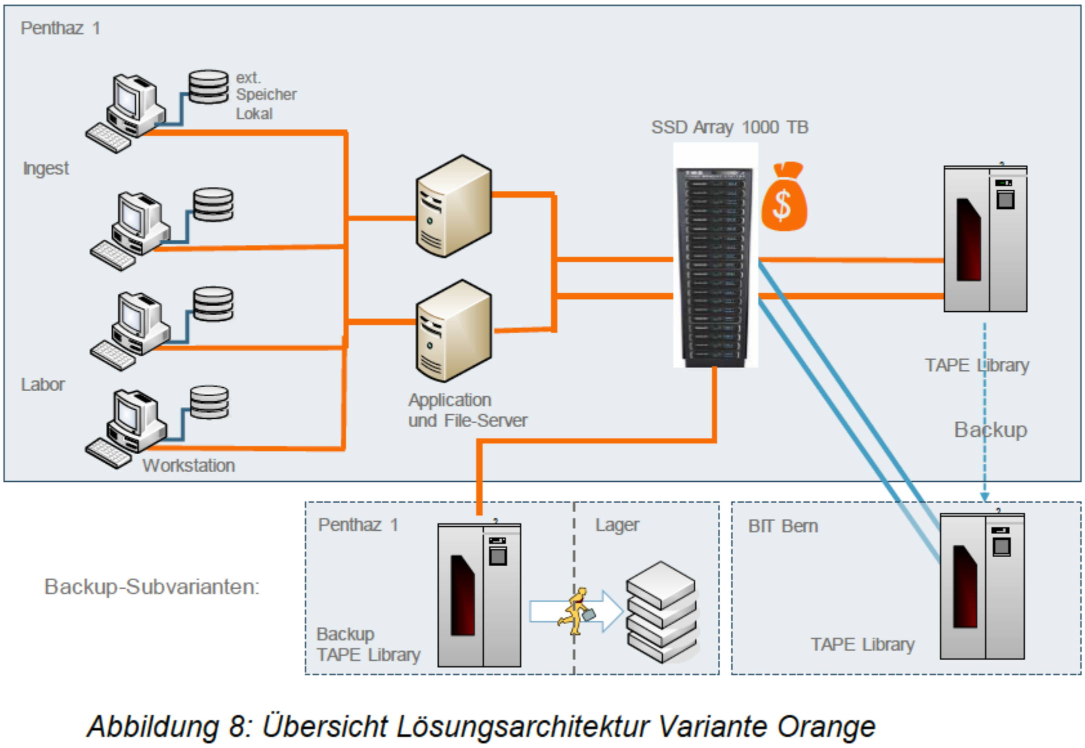


Figure 51 The architecture proposed by AWK for a digital conservation infrastructure at Cinémathèque suisse. It imagines a mixed SSD-LTO Tape Robot architecture.[184] The high costs of SSD storage have been indicated with the $ symbol, and indeed, this part of the proposal was never implemented.

While practically some national film archives did accept digital conservation as an archival activity, the question of film vs. digital conservation remained far from resolved – whether technically or theoretically. Digital conservation needed to penetrate into the archival framework of conservation (which had been formed through photochemical practices up to then). Through this process, the digital archivability would regularly come under scrutiny: how could digital be considered as an "archival format"?

[183] Dimitri Tombros (AWK), 'Machbarkeitsstudie Digitale Langzeitarchivierung der Cinémathèque Suisse', End Report (Cinémathèque suisse/Office fédéral de la culture, 16 December 2015).
[184] Tombros (AWK), 23.

3.3 An Archival Format?

After the roll-out, when the place of digital conservation in the archival imaginary was theoretically and practically getting established, one of the main arguments which (mostly) favoured film over digital conservation, seemed to be its archivability. While the term archivability is not often used in film archival discourses, the concept is omnipresent through discussions on archival format, and as such, it designates the "long term stability of motion picture media".[185] How was an archival format imagined, and what was expected from it? The quest for an archival format went back to the earliest presence of digital technologies in archives, when the need for a "practical" format for all archival use cases was pronounced at the JTS 1990.[186] In this part, I intend to extract the characteristics of an archival format by a historical review of related discourses.

In general terms, to quote scholars Axel Volmar, Marek Jancovic and Alexandra Schneider, the term format "seems to refer to certain material characteristics of media objects, such as shape and dimension, but can also describe structural or programmatic relationships between individual elements and their organizational logic".[187] Before the digital era, the term was used within the archival community (and the film industry) in the first definition proposed here, where it could either define the film gauge (16mm, 35mm, etc.) or the image aspect ratio.[188] By the 1980s and 1990s, the term became more regularly associated with video technologies. A video conservation concern being "the sheer quantity of incompatible formats that have been used over the years to record pictures on magnetic tape",[189] it can be understood why archives tended to look for an archival format from the early stages of digital technologies. The problems of video conservation in the context of upcoming digital technologies were mentioned by Michael Friend, who underlined that "none of the past or contemporary electronic formats, from magnetic tape to optical disc media, can be considered 'archival'".[190] During the 1990s, therefore, the discussions benefited from a closeness with video formats and video conservation

---

[185] Bev Pasterczyk, 'Image Is Everything - Protect It! - Kodak Update' (The Reel Thing XXIX, Hollywood, California, 23 August 2012).

[186] William Storm, 'The Archivist's Requirement of a Format', in *Archiving the Audiovisual Heritage. Third Joint Technical Symposium*, Proceedings of the 3rd JTS in Ottawa on May 3-5, 1990 (Rushden: Stanley L Hunt (Printers), 1992), 176–80.

[187] Axel Volmar, Marek Jancovic, and Alexandra Schneider, 'Format Matters: An Introduction to Format Studies', in *Format Matters*, ed. Marek Jancovic, Axel Volmar, and Alexandra Schneider (Lüneburg: Meson press, 2020), 9.

[188] And, of course, different sound formats before digital, but that goes beyond the scope of this thesis.

[189] 'Guide to a Basic Technical Equipment Required by Audio, Film and Television Archives', *Bulletin FIAF*, no. 43 (1991): 35.

[190] Friend, 'Film/Digital/Film', 42.

challenges; but, simultaneously, the archival imaginary was also formed by their decades of experience in film conservation. Paul Read declared in 2004:

> "What is needed is a long life digital preservation format, that can sit on a shelf, costing only its space, and be ready, and easy to open, whenever it is wanted. So we will need digital archival formats… and there isn't one."[191]

Read mentioned a few criteria, inspired by film conservation, which would be desired for a digital archival format. As he observed, there was not any format which corresponded to the archival needs. Indeed, whether before or after the roll-out, there was a fair amount of unresolved uncertainties and fears about digital conservation technologies which prevented them from being considered an archival format: their longevity was questioned,[192] their obsolescence was feared, digital conservation required constant migration, digital loss was considered total,[193] carriers and formats were multiple,[194] etc. These were mostly expressed through comparison with film conservation.[195] Here, I am going to explore the three notions which often appear in archival discourses: longevity, obsolescence and migration, and in the next parts, I will come back to the questions of loss and format multiplicity. But before that, I will make a detour to film conservation, in order to theoretically embed these notions in the existing archival imaginaries.

Since the beginning of the archival movement in the 1930s, conservation was an archival activity, which transcended different technological frameworks. Throughout the decades, concepts had been developed which defined the archivability of films based on the specificities of film technologies. In reality, film conservation also presented a certain number of problems,[196] especially some film formats and technologies (such as the inflammable nitrate film, or the vinegar syndrome), but also with regards to the availability of cold storage as an optimal conservation strategy (which, historically, could not be guaranteed by many archives until the 2000s).[197] Since the 1970s, film archives were very well aware of the problems of film

---

191 Read, 'Archiving Digital Media', 152.

192 Christensen, 'Report of the Technical Commission'.

193 As explained by Stewart Brand, "digital files do not degrade gracefully like analog [media]. When they fail, they fail utterly": Stewart Brand, 'Written on the Wind', *Civilization*, November 1998, https://longnow.org/essays/written-wind/.

194 The problem of multi-formats was presented notably by Leon Silverman, 'Opening Remarks' (JTS 2004: Preserving the Audiovisual Heritage – Transition and Access, Toronto, June 2004).

195 For more information, see: Charlotte Crofts, 'Digital Decay', *The Moving Image* 8, no. 2 (2008): 13–35.

196 See for example: Nicolas Ricordel, 'l'Ere numérique, la morphine des films?', *KinéTraces Editions*, no. 2 (2017): 145–55.

197 Thomas Christensen, 'Passive Preservation & Active Access – Long Term and Short Term Obligations of a Film Archive' (FIAF Restoration Summer School, Il Cinema Ritrovato, Bologna, June 2014).

conservation, and hoped for alternatives which would free them from the burdens of film conservation.[198] But the fact is that, over time, they had learnt to conserve films, had developed methods to counter its obsolescence and refined their practices to carry out a migration when the conservation of an element was not possible anymore due to unstoppable damages. When the archival community faced digital conservation first, the problem was that the same concepts and visions needed to be adapted to new technologies; meaning that they were to be redefined. Indeed, the whole conservation strategies needed to be rethought as the digital technologies required a completely different framework: instead of a passive conservation in climate-controlled spaces, with punctual interventions on elements that needed to be migrated, a new and continuous conservation plan needed to be devised.

The most discussed characteristic of an archival format was its longevity.[199] Film archives expected a technology that could be left on shelves, and remain intact for decades with little to no maintenance. Since the earliest discourses, comparisons were conducted between film and digital material in order to determine how long they might last. While it was generally stated that photochemical elements could be conserved for more than 100 years, digital carriers, in the best case, were not expected to go beyond some 30 years.[200] Film was presented as the "GOLD Standard of Archiving", with "100+ years of demonstrated archival life", facing no "technological obsolescence".[201] When longevity was considered, film conservation focused on the film carrier as an artefact or an object, whose survival throughout the years ensured the persistence of the image recorded on it. With digital technologies, this would be more complicated: Was it about carriers, formats, playback software, or the zero-and-one bit sequences themselves? Of course, these are all intrinsically related to one another as I intend to show with my technical discussion further in this chapter, but their intertwined nature makes it difficult to amount for a longevity estimation in years.

The endpoint for longevity could be either destruction or obsolescence. Indeed, the latter was another point which was largely discussed within the archival community, primarily in relation to digital conservation:

---

[198] 'UNESCO Document: Possible International Instrument Concerning the Preservation of Moving Images', FIAF 1978 Brighton Congress Report (Brussels: FIAF, 1978).

[199] Howard Besser's 1999 article "Digital Longevity", which includes all digital information and not only film, is an interesting read in this regard, as it enumerates the possible factors which threaten longevity. Howard Besser, *Digital Longevity*, ed. Maxine Sitts (Andover, MA: Northeast Document Conservation Center, 2000), http://besser.tsoa.nyu.edu/howard/Papers/sfs-longevity.html.

[200] For example : FIRST, 'European Film Heritage on the Threshold of the Digital Era. Full Report (Part One).', 19.

[201] Ogden, 'A Future for Film'.

> "Digital and electronic media are prone to several types of obsolescence. Besides the carrier decay and carrier format obsolescence known from analogue media, there are also hardware, software, file format and runtime environment obsolescence to take into account."[202]

Archives worried that by simply keeping digital films as they kept photochemical films, these might be hit with fast obsolescence after a short time, and thus lost. This is incontestably true that digital obsolescence affects (more or less rapidly) formats, carriers, and/or digital environments. In general terms, because of the "fast-moving computer technology", obsolescence can make digital information disappear, as if they had been "written on the wind".[203] Digital obsolescence, in some practical cases, can be overcome, in the sense that information can be retrieved from obsolete digital media.[204] But its complexity (owing to the newly-structured interconnections between carriers, formats and environments) can make data retrieval very difficult. Historically, obsolescence was not a new concept within archival imaginaries, as it was also a threat to photochemical film collections, with the diverse formats and types of film technologies (despite the fact that standards existed). In this case, it did not directly concern the film element as a physical entity, but as a technology. Archives indeed conserved many film technologies which had gone obsolete: short-lived film formats, gauges, or machines. These technologies could sometimes be reanimated, simulated and thus safeguarded through other technologies and under special circumstances. For instance, it was common practice within archives to reproduce uncommon formats such as 28mm on 35mm, or silent films in new formats and frame rates. This existing understanding of obsolescence, and the devised archival solutions to counter it up to then, did not necessarily correspond to the new challenges introduced by digital technologies, which could hit the film data much faster and in a variety of ways.

The third characteristic of archivability, closely related to the two before, was migration. The principle of passive conservation stipulated that the less migration needed, the better the archivability. However, digital information needs to be constantly migrated in order to counter obsolescence, inaccessibility and loss. It does require the deployment of financial and technical resources, as well as a constant verification and management of the digital conservation system.

---

[202] Christensen and Kuutti, 'A Digital Agenda for Film Archives'.

[203] Brand, 'Written on the Wind'.

[204] For a famous example, refer to the BBC's restoration of an early British computer project, Domesday: Jeffrey Darlington, Andy Finney, and Adrian Pearce, 'Domesday Redux: The Rescue of the BBC Domesday Project Videodiscs', *Microfilm and Imaging Review* 32, no. 4 (January 2003).

Migration, of course, did not start with digital technologies either: any (photochemical) duplication could be considered a migration. When film technologies were threatened by obsolescence, or when films were endangered by biological and chemical decay or mechanical problems, they needed to be migrated onto newer carriers. These two cases correspond to migration because of format and carrier obsolescence respectively. More or less the same concept applies to digital technologies, where either file formats or carriers might face obsolescence and need migration. However, the frequency of digital carrier migration (estimated at 5-10 years) is considerably higher compared to photochemical ones; and the digital format migration, which inevitably goes through transcoding, might induce data loss. Both of these clashed with the archival understanding of conservation, as the latter was supposed to remain a passive task, with the films intact on shelves in cold storages, not subject to loss.

When faced with digital conservation technologies, on the one hand there were the promises and potentials as presented by tech providers in archival conferences, and on the other the requirements of archives with regards to their vision of conservation. The archival habits, experiences and existing practices had been crucial in the construction of the concept of an archival format in the digital realm. Overcoming the existing views seemed to be an obstacle in the archival acceptance of digital conservation, and, although technological possibilities such as digital magnetic tapes and disks were already available from the late 1990s, they were not largely adopted by archives at the time. As the concept of archival format did not correspond to the available digital technologies and could not be directly reprised, it seemed that archives needed to widen their views and adapt their definition of it to the technical realities of digital technologies in order to be able to accept digital conservation. In the next two subchapters, I strive to deconstruct the concept of archival format, and the archivability requirements that go with it, via a socio-technical study of the conservation technologies. In order to do so, I will first address the subject through the study of carriers, then formats.[205]

3.3.1 The Materiality of Digital Image: Carriers

> "I don't know so please relate
> If digital is all that great
> Where's the master for my vaults

[205] In this thesis, I focus on image technologies and will therefore not go into the details of digital preservation strategies and management, shared between all different industries that need to preserve digital data, and standardised through frameworks such as Open Archival Information System (OAIS).

When my film's just ones and noughts?" [206]

Contrary to what this poem (distributed at the FIAF Congress 2000 in London) ironically implies, an image carrier always exists physically whether photochemical, analogue or digital. The photochemical image, born on a specific film carrier, can be duplicated onto other carriers (inevitably with loss – which is part of its natural process). The zeroes and ones of the digital image need to exist on some material in a digital carrier as well, but can move from a carrier to another with no loss, if no transcoding is involved. Through the links that they hold with the images that they carry, the carriers, I will argue, have an effect on their existence and visual aspects, and, therefore are an intrinsic part of the archivability concerns. In this part, I will go through different possible carriers for digital images, before analysing how, precisely, the material link binds the physical technologies and the virtual images together.

The early digital image carriers, such as D1, D2, digibeta, or other tapes from the 1980s and the early 1990s, were very similar to analogue video tapes, as their image formats were closely related to their carrier. Thus, they resembled film or video artefacts in terms of archivability, where the longevity and stability of a carrier determined that of the images. But gradually, the link between the digital images and their carriers was weakened, becoming almost invisible in (archival) theoretical imaginaries:

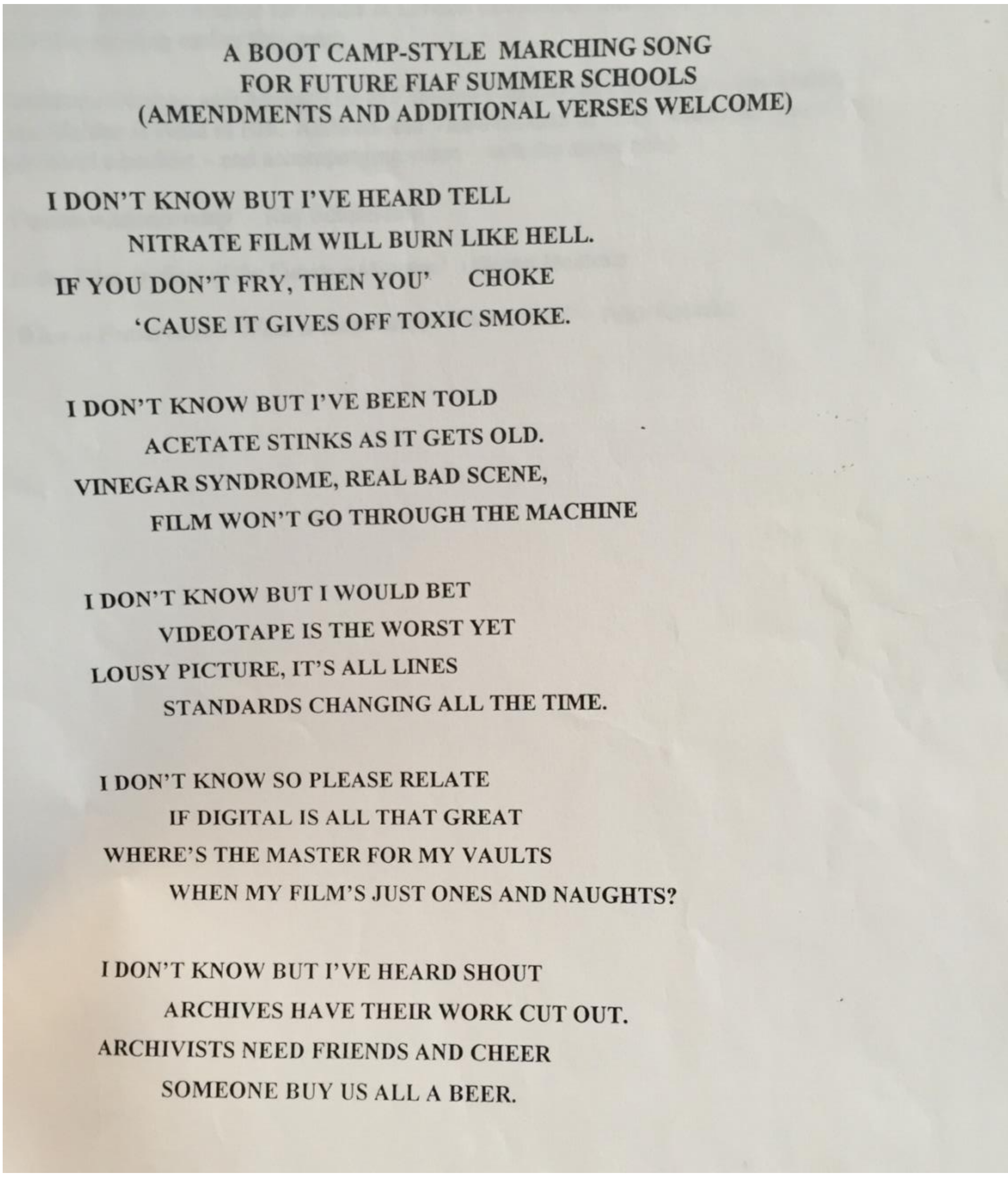
> "Preserving digital film is completely different from preserving analogue film: In the analogue world, taking care of the physical carrier equals taking care of the content. Digital archiving is about preserving the content, regardless of the carrier."[207]

The problem of longevity here had to be transformed: the question could not anymore be only how long the carriers would last, but also how long the data would persist in constant migration from a carrier to another. This means that the evolution of carriers would have to be taken into account as well when considering the longevity. Undeniably, digital films do not hold the same connection with their carrier as photochemical films, but they still need to be conserved on some carrier. Contrary to the early digital tapes, later digital carriers were not specifically created for the film industry or the film archives, or even for images, but had their own contexts of scientific development and adoption within the much larger field of digital data (of any type). In the scientific understanding, images were simply (immaterial) data, and inscribed as such on general digital carriers. The archives needed to circulate within the world of digital data

[206] See for the complete version in Figure 52.

[207] 'Commission Staff Working Document on the Implementation of the Recommendation of the European Parliament and Council of 16 November 2005 on Film Heritage and the Competitiveness of Related Industrial Activities', 11.

preservation to find carriers which suited most their practices, and adapt to them. Since the early 2000s, two main technical possibilities have existed, which remain valid as of yet.



A BOOT CAMP-STYLE MARCHING SONG
FOR FUTURE FIAF SUMMER SCHOOLS
(AMENDMENTS AND ADDITIONAL VERSES WELCOME)

I DON'T KNOW BUT I'VE HEARD TELL
NITRATE FILM WILL BURN LIKE HELL.
IF YOU DON'T FRY, THEN YOU' CHOKE
'CAUSE IT GIVES OFF TOXIC SMOKE.

I DON'T KNOW BUT I'VE BEEN TOLD
ACETATE STINKS AS IT GETS OLD.
VINEGAR SYNDROME, REAL BAD SCENE,
FILM WON'T GO THROUGH THE MACHINE

I DON'T KNOW BUT I WOULD BET
VIDEOTAPE IS THE WORST YET
LOUSY PICTURE, IT'S ALL LINES
STANDARDS CHANGING ALL THE TIME.

I DON'T KNOW SO PLEASE RELATE
IF DIGITAL IS ALL THAT GREAT
WHERE'S THE MASTER FOR MY VAULTS
WHEN MY FILM'S JUST ONES AND NAUGHTS?

I DON'T KNOW BUT I'VE HEARD SHOUT
ARCHIVES HAVE THEIR WORK CUT OUT.
ARCHIVISTS NEED FRIENDS AND CHEER
SOMEONE BUY US ALL A BEER.

Figure 52 Distributed at the FIAF Congress 2000. Found in the folder dedicated to FIAF Congress 2000 at the archives of FIAF, Brussels.

The first possibility was digital magnetic tape storage, such as Sony's proprietary DTF;[208] or an open version, LTO (Linear Tape Open), designed by a consortium of manufacturers (HP,

[208] See for example: ECMA, '12,65 mm Wide Magnetic Tape Cassette for Information Interchange - Helical Scan Recording - DTF-2', Standard ECMA-315, December 2000.

IBM and Seagate) in 1997.[209] It was promoted by its manufacturers as "very robust, with features supporting reliability, high data integrity, scalability, and interchangeability".[210] This type of carrier uses a magnetic tape, on which digital data are inscribed. The tape storage needs an external drive and the corresponding firmware to communicate with the computer. It has generations, i.e. newer versions coming every few years with more capacity and faster read and write speed. The new generations come with different firmware and hardware which are not necessarily compatible with older generations. While the magnetic tape was a familiar artefact for archives, the question of generations complicated the matter, as migrations needed to be organised in order to counter the obsolescence of the carriers.

The second widespread technology was disk storage. In use in standard computers, these systems "use a rotational magnetic plate (disk) with single or multi-platter, operating in a vacuum-sealed environment, watertight to dust and humidity"[211] and can have different configurations. A newer type of disk storage, called solid-state (SSD), also exists which holds data only on electronic chips with no mechanical parts. While technically promising, the SSD has not been adopted widely because of its high costs.[212] Disk storage itself has thus different technological implementations inside, but it can communicate directly with a computer through an I/O cable such as USB, mechanisms that are also prone to obsolescence.[213]

Of course, these two technical possibilities have not been the only proposed digital conservation technologies. In the 1990s and 2000s, the popularity of optical media (such as CD or DVD) for access favoured their possible use also as a storage carrier. During the Joint Technical Symposium in 2000, a few interventions addressed the "permanence", i.e., archivability, of optical media.[214] If the original carrier of digital information or images were optical media, one

---

209 https://web.archive.org/web/20061113034635/http://www.ultrium.com/newsite/html/news_11_04_97.html, accessed 30 December 2020.

210 G. A. Jaquette, 'LTO: A Better Format for Mid-Range Tape', *IBM Journal of Research and Development* 47, no. 4 (July 2003): 429.

211 FIRST, 'State of the Art Report', 194.

212 In the Figure 51, the expensive library recommended for the Cinémathèque suisse (which was not implemented) is of this type.

213 While many film archives use disks and disk-based servers for their digital films, I am not aware of any European national archives which use a disk library for their digital conservation. But an example is the Montreux Jazz Digital Project, conducted by EPFL in Switzerland, which has a hard disk library, in addition to LTO libraries. See https://www.epfl.ch/innovation/domains/cultural-heritage-and-innovation-center/montreux-jazz-digital-project-2/, accessed 14 June 2022.

214 Léon Bavi-Vilmont, 'The Effects of Atmospheric Pollutants SO2 and NO2 on CD-Rom and CD-R' (Poster Presentation, JTS 2000: Image and Sound Archiving and Access. The Challenges of the 3rd Millennium, Paris, 20 January 2000); Jean-Marc Fontaine, 'Eléments de caractérisation de la qualité initiale et du vieilissement des disques CD-R', in *Image and Sound Archiving and Access: The Challenges of the 3rd Millennium. Proceedings of the (Fifth) Joint Technical Symposium*, ed. Michèle Aubert and Richard Billaud, Proceedings of the 5th JTS in

tendency would be to conserve them as they were, on their original optical carriers.[215] In this sense, the digital image and its carrier were considered as forming one object, similar to how film image and its carrier were linked, and they needed to be conserved together. Optical media have also been considered as alternatives for mass digital storage, and continue to be studied and promoted within the larger audiovisual archiving community, without being adopted up to now.[216] Technically, it is difficult to estimate the lifespan of optical media, as it varyingly depends on the details of their construction. Optical media may survive a long time according to their manufacturers (which estimate their lifespan even to 100+ years), but they can have a considerable error rate (around 2%), which means that they may fail anytime in their archival life, thus creating data loss.[217]

During the mid-1990s, another carrier type was under research for some time which sparked much hope and interest within film archives. It was declared by the FIRST project in 2004 that the so-called optical-magnetic tapes, “if carefully selected and widely used by film stock holders, could be a future solution for long term Digital Film Storage”.[218] Kodak was involved in research on these carrier types through a two-year project, in 1995-1997, entitled LOTS (Laser Optical Tape Storage).[219] Simply put, this project intended to use a magnetic tape in cartridges on which digital data could be inscribed optically with laser beams. The idea was that an Eastman Kodak-produced tape could be used to this end. Although the technical goals of the research were claimed to be achieved, the move to commercialisation did not happen by

---

Paris on January 20-22, 2000 (Paris: CNC, 2000), 113–27; Jacob Trock, ‘Permanence of CD-R Media’, in *Image and Sound Archiving and Access: The Challenges of the 3rd Millennium. Proceedings of the (Fifth) Joint Technical Symposium*, ed. Michèle Aubert and Richard Billaud, Proceedings of the 5th JTS in Paris on January 20-22, 2000 (Paris: CNC, 2000), 104–12.

[215] See Alain Carou, ‘Twenty Years After: Degradation Survey of a Large Collection of Optical Discs’ (JTS 2004: Preserving the Audiovisual Heritage – Transition and Access, Toronto, June 2004).However, for European film archives this was rarely a reality, as professional cinema films did not originate on optical media.

[216] Morgan David and Yuji Sekiguchi, ‘The Role of Optical Storage Technologies in Future Digital Archives’, in *Sustainable Audiovisual Collections Through Collaboration: Proceedings of the 2016 Joint Technical Symposium*, ed. Rachael Stoeltje et al., Proceedings of JTS 2016 in Singapore on March 7-9, 2016 (Bloomington: Indiana University Press, 2017), 170–76.

[217] Joe Iraci, ‘Longevity of Optical Disc Media: Accelerated Ageing Predictions and Natural Ageing Data’, *Restaurator. International Journal for the Preservation of Library and Archival Material* 38, no. 3 (1 September 2017): 273–98. The error rate estimate comes from: Barry M. Lunt, Douglas Hansen, and Matthew Linford, ‘Optical Disc Life Expectancy: A Field Report’, in *Nonlinear Optics* (Joint International Symposium on Optical Memory and Optical Data Storage, Kauai, Hawaii: Optical Society of America, 2011). See also: ‘CD / CD-R and DVD-R RW Longevity’, Library of Congress, accessed 28 November 2021, https://www.loc.gov/preservation/scientists/projects/cd-r_dvd-r_rw_longevity.html.

[218] FIRST, ‘State of the Art Report’, 194.

[219] See ‘Status Report 95-03-0023’, https://web.archive.org/web/20060929204403/http://statusreports.atp.nist.gov/reports/95-03-0023.htm, accessed 30 December 2020.

the end of the project. The research and implementation of optical-magnetic tapes has continued since, but it has not yet become a viable option.[220] The perspective of this technology could satisfy the archival criteria of longevity: “thanks to the support used, long term storage time of more than 100 years is expected”.[221]

With the optical-magnetic technology, digital conservation would move towards film conservation, as the tape used in it was produced by Eastman Kodak and had long been in use in the field of cinema. The optical reading and writing were also familiar for archives. This represented, in fact, an adaptation of already-existing technologies for the digital conservation of images. Storage on tape was already the case with LTO, but the reading and writing was done in contact with a head in the drive (similar to video drives), and the question of generations compromised the longevity. The technological remediation has also been the driving force behind other digital carrier projects and research since the early 2000s. For example, in 1999, a research project from the University of Basel and ETH Zürich, “One Long Image”,[222] suggested digital data be printed back on film, and the concept was implemented a few years later by the same lab in Basel, under the supervision of Peter Fornaro and Rudolf Gschwind.[223] Similar ideas have been devised and implemented by others as well.[224]

In sum, digital images went from being considered tied to their carriers to a more independent configuration where they could be transferred between diverse carriers, while inevitably in need of a material part to exist. This materiality could resemble technologically what archives knew before (digital data on magnetic tape or film) or adhere to more conventional digital carriers such as disks. All of these conservation technologies receive digital data as input and conserve them; whether on magnetic tapes, film, mechanical disks, silicon-based material, plastic optical

[220] Several US patents have been made about it from 1994 to 2017. See: Daniel Scott Rosen, Digital Optical Tape Storage System, US Patent 9,640,214 B2, issued 2 May 2017, https://patentimages.storage.googleapis.com/9b/c5/bd/60abdbb68c103d/US9640214.pdf, accessed 30 December 2020.

[221] FIRST, ‘State of the Art Report’, 194.

[222] Armin Wittmann, ‘One Long Image. A New Approach to the Creation and Archiving of Digital Motion Picture Data’ (PhD Thesis, Zürich, Switzerland, ETH, 1999).

[223] See: Peter Fornaro and Rudolf Gschwind, ‘Monolith. Migration-Less Long Term Digital Storage for Archives’ (JTS 2010: Digital Challenges and Digital Opportunities in Audiovisual Archiving, Oslo, 3 May 2010).

[224] For example, “Bits on film” research project, see: C. Voges and J. Fröhlich, ‘Applications of Data Storage on Cinematographic Film for Long-Term Preservation of Digital Productions’, *SMPTE Motion Imaging Journal* 121, no. 1 (February 2012): 39–42. Alternative conservation methods, such as PIQL and DOTS, try to market their products by focusing on the two aspects of longevity and human-readability. Both these methods were presented at Il Cinema Ritrovato in 2018. See: Andrew Warner, ‘DOTS—Long-Term, Human-Readable Archival Data Storage’, *The Long Now* (blog), 27 December 2015, https://blog.longnow.org/02015/12/27/dots-long-term-human-readable-archival-data-storage/, accessed 30 December 2020. PIQL, ‘Physically Present – Future Preserved’, n.d., https://piql.prod.simpleness.no/content/uploads/Brochure-Piql-Preservation-Services.pdf, accessed 30 December 2020.

disks, etc., recorded electronically, optically or digitally. Despite the promising research, the only practical options for film archives remained digital magnetic tape storage and disk storage. These technologies could serve as the material part of digital images. Their technical characteristics and construction details influenced the longevity of images, despite the relative independence between them.

Material Link and Digital Damages on Image[225]

The material, technological part of digital carriers remains largely invisible to users (and among them, archivists). Image data is of course stored on a material carrier, but access to the images needs to be ensured through a virtual structure visualised by a computer. This structure is a user interface, which enables the interaction between the user and the image (Figure 53). This supplementary step erases the immediate link between the image and its carrier voluntarily, as it moves towards a seemingly all-virtual access to the images, while the hardware part remains in control of the machine. The virtual aspect is maximum in the case of external (cloud) digital storage, as the hardware part is implemented in an opaque way in another place, maintained by another company, entirely out of reach. The contemporary digital culture functions primarily in this way, by masking the link with an existing materiality, while creating new virtual spaces (such as VR – Virtual Reality experience).

Does the carrier invisibility mean that the image is detached from its materiality? In order to answer this question, I resort to the theoretical concept of "digital materialism".[226] According to theories constructed within different frameworks of digital materialism, "digital stuff is composed of material entities",[227] which are all based on the fact that digital materiality is composed of material bits; with the key argument that "there is no 'pure information': code is inscribed; bits are written".[228] Similarly, digital has been defined by sociologist Dominique Boullier as a "logical materiality" and is broken down into two parts of logic and materiality, which in turn represent algorithms and circuits respectively.[229] Indeed, digital technologies consist of a logical, conceptual part, which needs to be implemented materially. These two are two sides of a coin, whether visible or not, they always go together. The digital image, as

[225] In 2019, I presented a similar study of the material link between images and their carriers: Maral Mohsenin, 'Description of Material Defects: From Analog to Digital Film' (Resisting Matter: Describing Archival Objects, Lausanne, 3 April 2019).
[226] Nathalie Casemajor, 'Digital Materialisms: Frameworks for Digital Media Studies', *Westminster Papers in Culture and Communication* 10, no. 1 (15 September 2015): 4–17.
[227] Casemajor, 4.
[228] Casemajor, 6.
[229] Boullier, *Sociologie du numérique*, 32.

visualised by a computer, is inherently related to its implementation; similar to a photochemical moving image which appears on a cinema screen when a film projector is running.

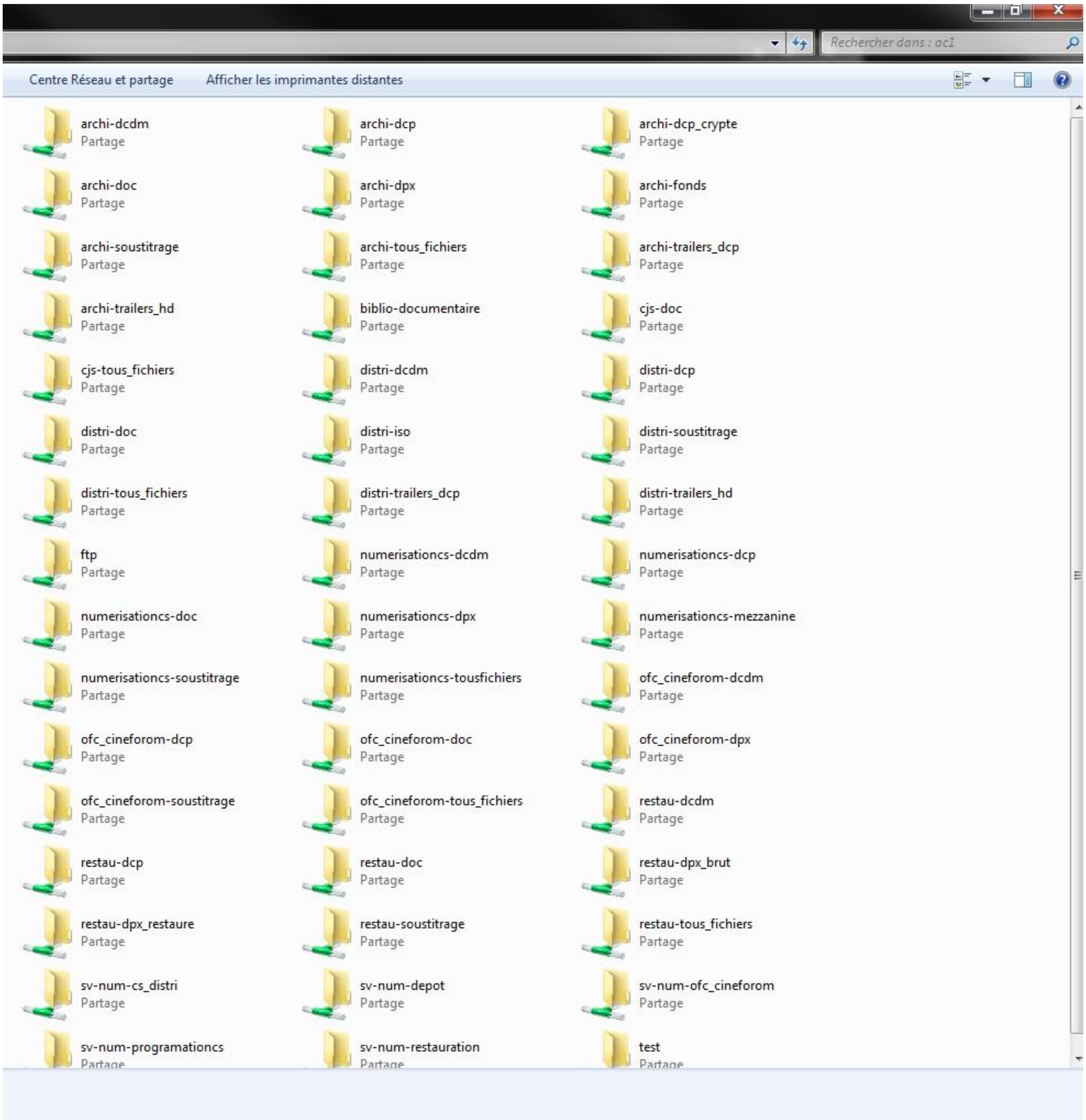


Figure 53 The virtual structure of a digital archive. Courtesy of Cinémathèque suisse. These folders do not hold a physical link to the LTO tapes in the tape library, but they exist on a purely virtual level for an easier interaction between users and machines.

What is most important for my study, is that the relation between conceptual and material parts of the image influences its archivability. Indeed, a material failure may entail the loss of the image, revealed in its visual aspect. In that, digital carriers function in a somehow similar manner to electronic or photochemical carriers. A small fluctuation in light intensity (for photochemical film) or in the electrical signal (for analogue video) due to different carriers has a direct consequence on the images. In comparison, digital implementation, which is not based on precise numbers but on combinations of 0s and 1s, is very resistant to small fluctuations in a way that these will not always show in the image visually. But when an error occurs in the material part of a digital image, it may reveal itself visually (like on the photochemical film) or it may, simply, prevent the bit streams from being read by the computer (what can be described as damage to image integrity, or loss of digital image). In the same way that photochemical carriers are subject to decay (chemical, biological or mechanical), digital carriers are also prone to it, because their physical part (regrouping tapes, mechanical parts, circuits, etc.) can degrade or malfunction. For instance, an LTO tape is degraded every time data on it is accessed, because the read/write head physically touches the tape. After some 20,000 contacts of this type, the tape might wear out. This also shows why an optical reading/writing of magnetic tape was to revolutionise the longevity of the carrier: it would function with light instead of direct contact, minimising the damages imposed on the magnetic tape.

It has been stated that analogue media "age gracefully",[230] contrary to digital media. David Walsh compared, with a touch of satire, how photochemical and digital damages can affect the visual aspect of the image in projection:

> "There is one sure way of telling projected film from digital images: if you look carefully enough you will soon see those telltale transient marks from the specks of dust which inevitably settle on film in even the cleanest projection booth. So are we perhaps in love with all those comforting spots and scratches which tell us that the image derives from some flawed, but somehow natural, process? It is certainly hard to develop any affection for digital projection defects; when things go wrong in this domain, we are likely to be presented with a fuzzy green image, or an image with curious stripes across it, or, most likely, no image at all."[231]

Digital damages[232] do not only appear in projection, but in any process that digital images might go through. They may be related specifically to the digital carriers themselves, or to processes (which also have a material existence) such as transfer, visualisation, ingest or projection. For

[230] The term comes from Brand, 'Written on the Wind'. See 193 .

[231] Walsh, 'Do We Need Film?', 5.

[232] Digital damages were studied in some projects conducted by television archives, such as PrestoPRIME but more specifically in project DAVID (Digital AV Media Damage Prevention and Repair, 2012-2015), whose results were presented at the Joint Technical Symposium in 2016: Peter Schallauer and Franz Hoeller, 'Digital Video Damage in Archives: Detect, Repair, and Prevent—Results from the DAVID Project', in *Sustainable Audiovisual Collections Through Collaboration: Proceedings of the 2016 Joint Technical Symposium*, ed. Rachael Stoeltje et al., Proceedings of JTS 2016 in Singapore on March 7-9, 2016 (Bloomington: Indiana University Press, 2017), 123–30. It has also been subject to study by National Film and Sound Archive of Australia: Mick Newham et al., 'Digital Disaster Recovery for Audiovisual Collections' (UNESCO Memory of the World in the Digital Age Conference, Vancouver, 26 September 2012), http://www.unesco.org/new/fileadmin/MULTIMEDIA/HQ/CI/CI/pdf/mow/VC_Newnham_28_B_1150.pdf, accessed 3 February 2019.

conservation, damage is considered as everything that may go wrong during the processes that a digital film goes through during its archival life:

> "Digital damage is any degradation of the value of the AV content with respect to its intended use by a designated community that arises from the process of ingesting, storing, migrating, transferring or accessing the content."[233]

Figure 54 This digitised frame of *Charles mort ou vif* was corrupted during the transfer to LTO tapes. Courtesy of Cinémathèque suisse.

Figure 55 A digitised frame of a chromolithographic loop, which has been degraded during the scanning process. Original film courtesy of Cinémathèque suisse.

Figure 54 and Figure 55 show two examples of digital damages visible on the images which have appeared during the process of transferring (from digital to digital, and from photochemical to digital, respectively). For the first image, while it is difficult to say which part

[233] M. Hall-May et al., 'Deliverable D3.1', Public Deliverable, DAVID, November 2013, 12.

of the physical materiality of the technological systems and processes involved in the transfer has failed leading to this damage, its computational pixelated structure reveals its dependence on its digital materiality. The second image, which has been created by a digital scanner, presents a damage of a more mixed look, computational indeed, but also optical, revealing the three-strip light technology of the scanner.

This consideration of the material link demonstrates that digital image carriers, similar to their photochemical or analogue counterparts, have physical limits in their archivability. Due to their inevitable materiality, they are bound to face degradations or errors, which will leave traces on the visual aspect of the image or lead to loss. This observation does not mean that no archival format can ever exist, but it suggests rethinking the very definition of an archival format by including it in a larger context of conservation strategies and processes.

Carrier Adoption within Archives

Faced with the flux of digital material during the 2010s – either digital-born or digitised material – many European national archives had to stop waiting for a digital carrier that would fulfil their expectations of archivability, and adapted to the existing, common ways of digital conservation (often LTO libraries). Indeed, many archives accepted digital conservation as a new set of practices, which needed to be realised if the archival goal of safeguarding (digital) film heritage were to be achieved. These practices came gradually to apprehend the concepts of obsolescence, decay and migration in the case of digital technologies, and the necessity to envisage solutions to counter or manage them. In the next subchapter dedicated to formats, I will specify how archival discourses devised strategies and policies in order to improve their digital conservation practices.

This consensus in accepting digital conservation as an archival practice and including its characteristics in archival planning was not shared by all archives. From a theoretical point of view, the division between a digital image and its carrier, which was imagined in the case of mass digital storage on LTO libraries, did not please everybody. For some, the two levels of digital carrier and content continued to be considered as forming one unique archival object. As a museological object, a specific digital content would be related exclusively to its own carrier, and it could not move freely to a new carrier. The Filmmuseum Austria, for instance, did not adapt to the dominant tendencies in the archival community in order to secure digital images, but since 2017, it has developed another strategy that corresponds closely to their museological position: they have accepted and archived LTOs as unique archival objects, not merely as carriers containing image data. The artists (experimental filmmakers) can deposit their films on LTO, and the archive will clone these (without altering or verifying the files on it whatsoever) and keep them as "original" artefacts.[234]

3.3.2 "In the Jungle of Formats" … or Not?

For digital image technologies, the format (which is the same word used for any computer file) denotes the way digital image information is described.[235] In this case, format does not necessarily relate to the digital carrier, but to an intermediate version of a digital image, which is its zeroes-and-ones sequence: according to the format specificity, the computer translates the sequence to a visualised image. In a considerably-amplified manner compared to video formats, digital formats are numerous, may be incompatible with some digital environments (i.e., computer operating systems or software may be unable to translate them into a visual image), and may die out quickly. Nicola Mazzanti referred to these problems when stating "format stability is a very serious issue" in 2012.[236] Format multiplicity for digital image perpetuated the same risk as video for film archives and it remained a widely-discussed subject from the 2000s on.

The adoption of formats reveals the socio-cultural forces behind archival practices. Scholar Jonathan Sterne has proposed to shift the focus from demarcations between media to demarcations between formats in order to better demonstrate the technologies, economics and culture behind practices.[237] The term "format cultures", proposed by Volmar et al., also references the "specific communities of practice, which can form around one or a series of interrelated formats".[238] The two-way relation between formats and practices is indeed important for a digital image, notably from an archival perspective. Different image formats have different use cases, characteristics, histories and practices.[239] On the other hand, their practical use may also influence their technical specifications. This point has been evoked by David Walsh:

---

[234] Kevin Lutz, 'Keynote' (Digital Preservation Winter School, The Netherlands Institute for Sound & Vision, Hilversum, January 2019), https://vimeo.com/311233890, accessed 30 December 2020. It should be noted that the legal deposit in Austria entrusts films to Austrian Film Archive, and politically, Austrian Film Museum does not face the same pressure as national film archives in charge of legal deposit.

[235] The omnipresence of formats in the field of media has launched also the "format studies". See notably: Marek Jancovic, Axel Volmar, and Alexandra Schneider, eds., *Format Matters* (Lüneburg: Meson press, 2020).

[236] Mazzanti, 'Digital Cinema Technologies from the Archive's Perspective. Part 2', 4.

[237] Sterne, *MP3: The Meaning of a Format*, Introduction.

[238] Volmar, Jancovic, and Schneider, 'Format Matters: An Introduction to Format Studies', 11.

[239] See also: Bruce Bennett and Marc Furstenau, 'Formats', in *Cinema and Technology: Cultures, Theories, Practices*, ed. Bruce Bennett, Marc Furstenau, and Adrian Mackenzie (London: Palgrave Macmillan, 2008), 19–21.

> "Just as a negative and a print have entirely different characteristics and purposes, so do a digital preservation master and whatever medium is chosen for presentation."[240]

As previously explained, a digital image, in its most basic form, is a sequence of 1s and 0s, visualised as a matrix, where every pixel holds a value indicating the luminosity (or colour information).[241] In reality, the digital image does not always remain in its basic, uncompressed form. For instance, when it is to be included in a DCP and projected in a cinema, it is encoded as JPEG 2000.[242] When it is to be put online, it needs to be compressed more. And when it is to be archived for posteriority, it is hoped to be "archival": "store and ignore"![243]

What were the archivability characteristics that an image format had to have? As said before, this was determined in comparison with film, which was considered "archival" by default, and it was advertised as such, most notably by Kodak:

> "With film, there is no compression, no format obscurity, no corruption of media, no third part server, no hacking. There it is, as it was and as it will be. Analog is Archival. Use film."[244]

Characteristics contributing to the "archival" character of photochemical film as imagined by the archival community, in comparison with digital formats, are being lossless (no image detail can be omitted as it would through a compression), resistant against time (therefore no obsolescence) and stable (always yielding the same image, incorruptible). The status of film as archival was attributed to it in a late stage and while keeping digital technologies in mind. Through this, I claim that the existing practices of film archives, and their knowledge of previous technologies, were crucial in drawing the digital format landscape needed for digital conservation within film archives. In what follows, I will show how the practices evolved with regards to archival imaginaries of the time. Indeed, my analysis below will reveal how film archives, which were faced at first with the question of what format to conserve, redirected their concern towards how to conserve different formats.

From Photochemical to Digital: What Format to Archive?

In 2010, the FIAF Technical Commission prepared a document regarding the archiving of the upcoming digital deposits:

---

[240] Walsh, 'Slow Disasters: How Neglect Continues to Destroy Our Film Heritage', 28.
[241] See Chapter One, Figure 12.
[242] See Chapter Three, 2.1.
[243] Academy of Motion Picture Arts and Sciences, *Digital Dilemma*, 16.
[244] Kodak, *Journal of Film Preservation*, no. 101 (October 2019): 33.

"1. Only a DCDM or an unencrypted DCP are acceptable formats for the long-term preservation of a cinema work. Archives must be aware that a DCDM will be considerably larger than a DCP.

2. A DSM can also be accepted, but not in place of a DCDM or DCP." [245]

Joggling between DCDM's uncompressed image and DCP's reduced size but compressed JPEG-2000, the TC deemed both as acceptable archival elements, without further detailing the image formats inside these packages. The DCP corresponded to what was seen in the cinemas by the spectators, while the DCDM was the master source that created the viewing copies. The recommendation concerned the existing archival challenge of acquisition, and was rooted in practices and discourses established with regards to photochemical deposits, preceding the omnipresence of digital film elements. Indeed, in many European countries, films that have been financed nationally are required to deposit a print at the national film archive.[246] This needed to be updated to englobe the technical realities of digital cinema, but, on the way, some theoretical and technical obstacles existed.

The deposit requirement for photochemical elements was generally a newly-struck unused film print in most European countries. In Switzerland, similar to many other countries with smaller cinema industries, the film prints deposited at the archive were sometimes failed prints, in order to reduce production costs.[247] Of course, film prints are the elements that were seen in projection by the public at the time of their release, but archival practices of preservation and restoration mostly privileged the use of earlier-generation material, such as original negatives (when available). Indeed, the latter have the most details and sharpest images in the photochemical chain, and it is often this element which serves to create new prints within archives. For years, the mandatory deposit of a film print was common practice in archives, while intermediate elements such as negatives were not deposited through the official deposit schemes, and arrived

---

[245] FIAF Technical Commission, 'FIAF Technical Commission Recommendation: the Deposit and Acquisition of D-Cinema Elements for Long-term Preservation and Access', Version 1.0, Digital Technology Guidance Papers (FIAF, 2 September 2010), https://www.fiafnet.org/images/tinyUpload/E-Resources/Commission-And-PIP-Resources/TC_resources/D-Cinema%20deposit%20specifications%20v1%200%202010-09-02%20final%201.pdf, accessed 18 February 2021.

[246] In some, such as France, any national film is required by law to be deposited at the national film archive. The contractual/legal deposit of films was widely discussed, notably from a legal point of view. See for example: 'Legal Deposit/Dépôt Légal/Depósito Legal', *Journal of Film Preservation*, no. 73 (April 2007): 52–67; 'Legal Deposit/Dépôt Légal/Depósito Legal', *Journal of Film Preservation*, no. 74–75 (November 2007): 83–88.

[247] As an example, the print of *La Paloma* (Daniel Schmid, Switzerland, 1974), deposited in 1974 at the Cinémathèque suisse conformed to the requirements of OFC, has desynchronised sound for a part of film, which lasts around 5 minutes.

later mostly through voluntary deposit. That was to change gradually with digital conservation requirements.

With digital elements, in the beginning, often the same procedures and workflows applied. At the Cinémathèque suisse, a document was prepared in 2010 which detailed the workflow of contractual deposit regardless of their carrier. Whether 35mm, DCP or for instance HDCAM and Digibeta, the same process of visual verification, cataloguing and archiving in climate-controlled vaults applied. Then, in 2011, another list was published (revised in 2013) which enumerated various formats of analogue and digital video as acceptable deposit formats, as well as "DI, DCDM and DCP" for Digital Cinema. At this time, the Cinémathèque refused proprietary formats such as ProRes. A new document was published in 2016 which omitted this limit, and required digital elements in their "original format", whatever that might be, or their distribution format (mostly DCP but not limited to that). The recommendation, modified again in 2017, requested the deposit of the film "in the best possible format", but practically any available file would have sufficed.[248]

The DCP as the "equivalent" to photochemical print was considered acceptable during the mid-2010s almost everywhere in Europe because it "[represented] the work exactly as presented to the audience", nevertheless it was qualified as "a lossily compressed format, and therefore not an absolute ideal for long term archival preservation".[249] The tendency seemed to head towards determining a better lossless element that went beyond the minimum requirements for photochemical deposits, and consequently beyond the idea of requesting for conservation only the element which is actually shown in cinemas.

From 2015 on, "delivery specifications" for legal or contractual deposit were published by several film archives, for instance in Sweden in October 2015, in the Netherlands in January 2016 and in Switzerland in May 2019. These national documents originated all in the FIAF's 2010 recommendation by stating that "the film elements required are an uncompressed master and an unencrypted distribution copy",[250] with the main difference that they included more precise details about formats to be deposited. For uncompressed images, DPX and TIFF, with specific bit depths[251] and in specific colour space were preconised, while compressed masters

---

[248] See Appendix 3. The work on current recommendations started in 2018, and the document was published in May 2019.

[249] FIAF Technical Commission, 'FIAF Technical Commission Recommendation: the Deposit and Acquisition of D-Cinema Elements for Long-term Preservation and Access'.

[250] Swedish Film Institute, 'Technical specifications for contractual deposit of digital film elements', October 2015.

[251] Less than 10 was generally not accepted. This was fixed despite the fact that, for some, a bit depth of less than 14 was not representative, for instance according to Ned Price, Shawn Belston, and Grover Crisp,

(digital video formats such as ProRes) and unencrypted DCPs were also required. This was "to conserve a version of the film in the best possible quality and in a format compatible for archiving".[252] By this time, film archives had considerable experience in film restoration (where intermediate elements such as negatives were actively sought-after) and had developed a consciousness of the multiplicity of the film image, which underlaid their understanding and treatment of the digital image. They had also been gaining experience with digital images for diverse reasons (projection, restoration or distribution). The archival efforts to define archivable digital formats derived from these epistemic fields.

From an Archival Format to Format Plurality

As noted before, from the 2000s, there was a tendency within film archives to look for an archival format, which, in the beginning, was thought to be unique. Attempting to introduce a unique archival format, the EDCINE project (2006-2009) had proposed to use JPEG 2000 images with an MXF container, inspired by the D-Cinema standard. EDCINE's choice regarded a lossless profile of JPEG 2000 rather than the one used by D-Cinema standard, but there was a willingness to archive the digital cinema images as close as possible to their representation on a cinema screen.[253] This approach, which favoured the design and implementation of one archival format, went further with growing discussions on open-source formats and format standardisation, while another view appeared which proposed to simply follow the film industry's practices and keep all formats. The *No Time to Wait* conference series, launched in 2016, was a major drive in the larger field of audiovisual archiving, which, similar to JTS, regrouped archivists and technology developers:

> "The symposium was designed to bring together audiovisual archivists and audiovisual format designers with a focus on the standardization of a preservation-grade audiovisual file format combination package."[254]

The R&D approach promoted by *No Time To Wait*, from people close to audiovisual archives (mostly television and video), intended to develop an open format, responding to different

'Comparing Digital Restoration and Original on Film' (Lezioni di Cinema, Il Cinema Ritrovato, Bologna, June 2014). Price's estimation seemed to be based more on personal observation, considering the impossibility of a technically-accurate comparison between a photochemical image and its digitally-sampled clone.

[252] Cinémathèque suisse, 'Spécifications techniques pour le dépôt obligatoire d'éléments de films numériques' (Cinémathèque suisse/OFC, May 2019). My translation.

[253] Nowak et al., 'D6.5 Definition of Detailed Workflow and Format Specifications for T6.3', 15.

[254] MediaAreda, 'No Time to Wait: Standardizing FFV1 and Matroska for Preservation', Report from the No Time to Wait Conference (Berlin: Deutsche Kinemathek, Zuse Institute Berlin, MediaArea, 2016), https://mediaarea.net/blog/2016/07/26/No-Time-To-Wait-Preservation-FFV1-Matroska-Symposium.

criteria such as data accessibility and losslessness, but also entailing a uniformisation of practices.[255] There are some technical advantages if only one format is archived; for instance, automated operations (such as quality control, ingest, format migration, etc.) can be considerably simplified. The open formats could fulfil the archivability criteria of longevity, as they can in principle remain manageable and maintainable for a long time through the changing digital environments, thanks to the availability of their codes. The most durable suggestion of this type has been FFV1, which has been adopted by archives such as Cinémathèque française and the Irish Film Institute, while others have been more reluctant to adopt it.

FFV1 is an open-source video format, with the open-source container Matroska, which was developed first in 2003 by Michael Niedermayer, and is maintained by the FFmpeg project (to which different developers can contribute).[256] FFV1 is advocated as a losslessly-compressed "archival" format,[257] and technically it can recreate the files it compresses in an identical manner.[258] It is presented as a format suitable for archiving, and does not belong originally to the technological culture of the film industry. As such, it modifies the digital elements originally received in archives, which have a much larger existence in the cinematographic landscape: cinema is produced, post-produced, projected and distributed in those formats. This signifies that archives need to transcode systematically all digital deposits, which potentially could also introduce loss into their conservation processes. Walter Arrighetti (a cinema technology expert) evoked this point in the *Journal of Film Preservation* in 2019:

> "The choice of archival file formats should be driven by organisational, cultural, technical, and economic criteria that help in both future-proofing content and increasing its value and usability within the industry value chain."[259]

---

[255] For example: Reto Kromer, 'Matroska and FFV1: One File Format for Film and Video Archiving?', *Journal of Film Preservation*, no. 96 (April 2017): 41–46; Yvonne Ng et al., 'Open Source Tools for Open Source Preservation' (FIAF 2018 Prague Symposium, Prague, April 2018).

[256] See: Peter Bubestinger-Steindl, 'Review and Comparison of FFV1 versus Other Lossless Video Codecs for Long-Term Preservation', in *Sustainable Audiovisual Collections Through Collaboration: Proceedings of the 2016 Joint Technical Symposium*, ed. Rachael Stoeltje et al., Proceedings of JTS 2016 in Singapore on March 7-9, 2016 (Bloomington: Indiana University Press, 2017), 153–59.

[257] For a critical scholarly study of FFV1 and its discursive, cultural and practical relation to "loss", see: Marek Jancovic, 'Lossless Compression and the Future of Memory', *Interactions: Studies in Communication & Culture* 8, no. 1 (2017): 45–61. For the study of its standardisation efforts in relation with other formats, see: Jimi Jones, 'So Many Standards, So Little Time: A History and Analysis of Four Digital Video Standards' (PhD Thesis, University of Illinois at Urbana-Champaign, 2019).

[258] Based on tests done at the Cinémathèque suisse (in 2021), a dpx image, for instance, can indeed be reconstructed in an identical manner, but not its metadata header cannot be recovered losslessly.

[259] Walter Arrighetti, 'The Interoperable Master Format (IMF) in Film Preservation', *Journal of Film Preservation*, no. 101 (October 2019): 35.

This statement raises an interesting point in technological adoption which concerns the necessity of formats' adaptation to a diverse range of criteria, going beyond only technical requirements. Indeed, theoretical and cultural views and practices are also crucial factors that contribute to the adoption or rejection of formats. What makes these processes more complex, is the fact that, through conferences and exchanges such as *No Time to Wait*, the archivists could also make their voices heard in the development of formats such as FFV1. However, initially, most of these exchanges were between technologists and video archivists, and responded to the challenge of video archiving with its numerous incompatible proprietary formats. In national film archives, where deposited digital films generally arrive in (*de facto*) industry standards, the problem of proprietary video formats was less pressing, and the main desire was to find suitable digital conservation strategies in compliance with production pipelines (as also argued by Arrighetti).

Indeed, this situation of a "jungle of formats"[260], which impacted television and video archives particularly, did not seem to be of equal concern in national film archives, as the formats in use in cinema (and archives) proved over time to remain quite stable.[261] Part V of FIAF TC's Digital Statement underlined the dominance of the same formats (DPX, TIFF, ProRes, etc.) in cinema and archival applications, and the technical specifications of different countries also essentially required the same formats. The DPX and TIFF formats date back to the early 1990s, and since then, they have been standardised and remained in use in archival and industrial applications. ProRes, a proprietary format by Apple, is also a common format in post-production since its introduction in the mid-2000s. While a jungle of formats was certainly a reality for (digital) video, during the (late) 2010s it seemed to have been reduced to a handful of formats in the case of the film industry and national film archives.

In his article, Arrighetti proposed IMF (Interoperable Master Format) for archiving purposes. IMF is a modular structure that can be modified for five applications, respectively: uncompressed image data, UltraHD 4K JPEG2000-based video, HDCAM-SR video, DCP, and ACES (colour standard). Technically speaking, IMF is not a simple file format, but an organised package in the same way as a DCP, which includes metadata files and wrapped image and audio essences. The technical description of IMF (where the images are wrapped in MXF) did not limit the image formats other than stating that "image essence shall consist of image frames,

[260] Reto Kromer, 'Archivage de l'audiovisuel Dans la jungle des formats de fichier' (Toute la mémoire du monde, Cinémathèque française, Paris, March 2019).
[261] Thomas Christensen, 'Preservation and Digitising for Now and the Future, the Model of the Danish Film Institute' (Budapest Classics Film Marathon, Budapest, September 2019).

each a rectangular pixel array",[262] and "may be of one of a selection of encodings and compression families".[263] The IMF structure, which can encompass many image formats, is a step towards the acceptance of a variety of image formats used in cinema applications. This is more inclined towards the second approach in digital conservation: to privilege multi-format archiving.

In 2018, a European standardisation group started a four-year project to define standards for digital film preservation. Coordinated by Fraunhofer Institute, the technical committee CEN TC457 gathered together technology developers and archive specialists. Many European national film archives (Sweden, France, Germany, Switzerland, the Netherlands, Finland, Spain, etc.) took part in defining a unified structure through which digital elements could be conserved.[264] Rather than defining a suitable archival format, which had been an early goal of the project, the committee endeavoured subsequently to propose a solution to keep and arrange the files in any format. In the proposed structure, every film element (image sequence, DCP, video, etc.) could find its place (Figure 56).[265] The work in this committee followed earlier work by Fraunhofer Institute, in the framework of EDCINE and its subsequent efforts, which had resulted in the creation of Archive Curator Suite (2011). The latter is a system that prepares JPEG 2000-based Archival Master Packages. The move from Curator Suite to the CEN Preservation Package illustrates a change from a format-based towards a structure-based imaginary, where the emphasis is not anymore on finding one archival format, but on how to conserve multiple formats, in use in the cinema industry and film archives. Time will tell if this standard will be efficiently adopted within archives, but the multi-format system already resembles what many archives have been doing, and I believe that it underlines that the archival imaginary, at least partly, is willing to recognise the multiplicity of digital formats within the technological realm of cinema.

The question of which format(s) to conserve gave way to discussions on how to conserve any chosen format. The best practice was not anymore about the choice of the best image technology, but the diversity of digital image technologies (crystallised by different formats) was somehow accepted by film archives. The multi-format model considers many formats worthy of conservation, contrary to the one-format preservation approach (implemented in

[262] 'Interoperable Master Format — Application #2E', SMPTE Standard, 2020, 5.
[263] 'Interoperable Master Format — Essence Component', SMPTE Standard, 2020, 8.
[264] ACE was not directly involved in the project but followed it through its members. Towards the end, it became an observer in the process.
[265] This standard will be published in 2022: CEN/TC 457, 'A Framework for Digital Preservation of Cinematographic Works - The Cinema Preservation Package', European Standard EN17650, 2022.

many TV and video archives).[266] As a result, format archivability becomes a multiple choice, which considers the context of formats in use, their technical specifications, their place in the cultural sphere of the film industry, as well as the goal of their preservation.

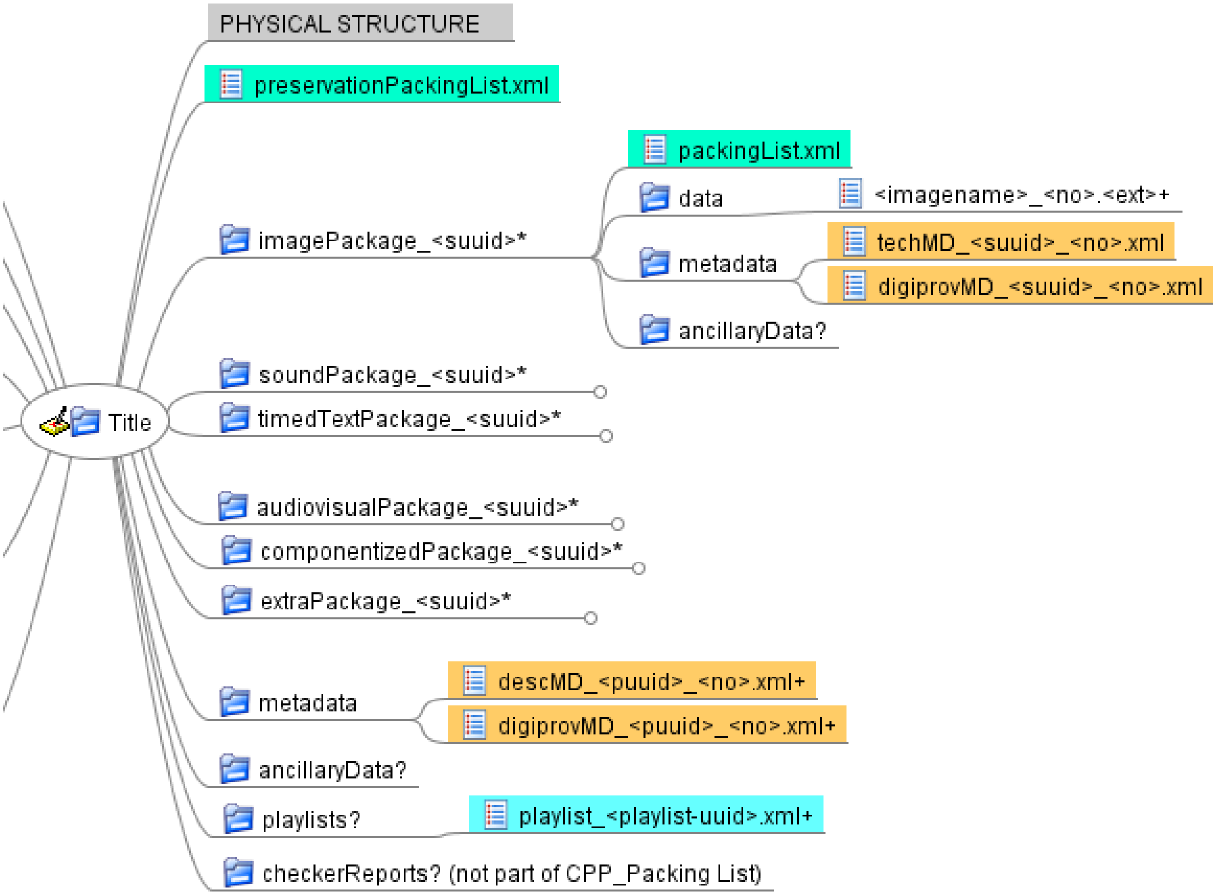


Figure 56 The structure proposed by CEN/TC 457 as a package englobing different formats and representations, called the Cinema Preservation Package, in the framework of the EN 17650 standard.[267]

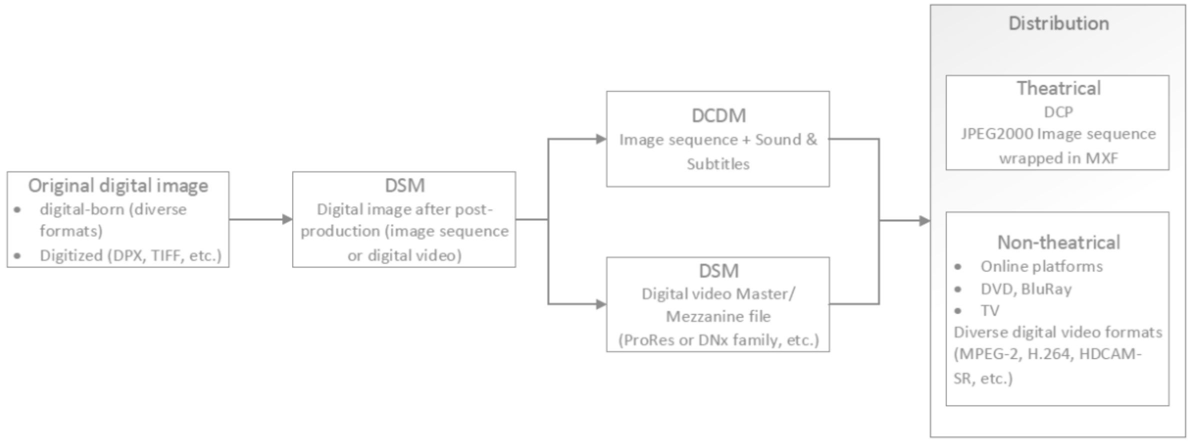
Digital Formats and the Question of Loss

Now that I have underlined the possibility of format plurality within the digital conservation practices of national film archives, it is important to revisit the existence and transition of the digital image between different formats, as it can clarify the questions of loss and compression in conservation, from technical and theoretical aspects.

The digital (or digitised) image can be transformed (or, in technical terms, transcoded) several times during its lifetime, from its production to its conservation; similar to a photochemical image that was, for instance, formed first on a negative, then transferred onto intermediate

[266] See: A. de Jong, 'Digital Preservation Sound and Vision: Policy, Standards and Procedures', Policy Document (Netherlands Institute for Sound and Vision, 2016).
[267] CEN/TC 457, 'Technical Report - Guideline for Implementing the Cinema Preservation Package', Technical Report, European Standard EN17650, 2022.

elements and finally onto a projection print. Similar to what I explained for photochemical workflows, many digital image workflows may also exist in the film industry and archives: images are created in different ways, and they undergo different transitions, before being transcoded into DCP for theatrical distribution or prepared in other compressed formats for other platforms (online, home entertainment, TV diffusion, etc). Below, a simplified workflow shows some steps the digital image may go through:



Generally speaking, images can either be presented in an (uncompressed) image sequence, or wrapped in a container as a digital video (sometimes individually, and sometimes with temporal compression). Separate images create movement when passing at a certain speed, while in the video system with a temporal compression, the movement is already encoded into the video where individual images are presented together. It should be reminded that DSM, DCDM and DCP are not formats, but packages (structures), which can be more or less rigidly defined. For DCP, as explained, the image format is the MXF-wrapped JPEG-2000; for DCDM, the image format is defined by DCI to be TIFF; but for DSM, there is no required or recommended format, and any image format could do (such as DPX, TIFF, or any digital video format, according to the production or restoration workflows). The transition from one step to another, when it entails a transition from one format to another, changes the code-stream of the digital image. This is defined as digital generation loss. However, if an image is simply copied from one place to another, from one computer to another, with no changes in the format, it does not get altered and does not suffer any loss (of course, if the transfer does not go wrong). Contrary to the photochemical case, where each duplication was unique, all the copied digital elements are identical. This embodies the losslessness characteristic that digital technologies claim. As explained, losslessness is therefore quite rare, as most operations on digital images may induce loss, whether inevitable because of transcoding between image formats or sometimes involuntarily because of possible transfer errors.

From an archival-theoretical perspective, where an imaginary of eliminating or reducing loss in preservation has been dominant, DCP being a lossily-compressed element was problematic, although it was indeed the distribution element for digital films much like photochemical print. As a result, in addition to DCP, other elements from earlier steps of production workflows were also to be conserved. As advocated by FIAF in 2010, DCDM (or equivalent) would be an "archival master".[268] In reality, DCDM often did not exist for smaller European film industries, or if it did, it did not necessarily follow the DCI recommendations (which gave it its name). The "master" file (source of distribution copies) could be a digital video file (called mezzanine), or an image sequence in DPX or TIFF. According to their hands-on experience, most European national film archives have been of the same opinion that an uncompressed image sequence, in TIFF or DPX format, is the closest to an archival master, as the digital frames were kept intact, and no lossy compression has been imposed on the elements (yet) at this step. The image sequence had also been a turning point in digital filming in the early 2000s, as I explained in Chapter Two about 24p cameras, which were considered more adapted to cinema.

The choice of image sequence format was not evident from the beginning. Several formats were in use in the industry, especially for capture, mostly proprietary such as the raw formats from Red or Arri. Some non-proprietary formats were used in post-production as well, such as OpenEXR from George Lucas's company Industrial Light and Magic (ILM), whose high bit depth offered a better manipulation possibility. DPX and TIFF, both in use since the 1990s, seem to be the most common image sequence formats by 2022. While the DPX format was created directly for cinema, the TIFF format, which had in fact been a source of inspiration for DPX, was developed to describe image data for computers in the mid to late 1980s. It aimed to "incorporate scanned images into [computer] publishing"[269] and facilitate image exchange between different computer applications. DPX was supposed to be as rigid as possible in order to be able to mimic the original characteristics of film faithfully; but TIFF was supposed to be flexible in order to offer different editing functionalities to users, while "not tied to specific scanners, printers, or computer display hardware".[270] TIFF's sixth revision (TIFF6.0) was released in 1992 and has not been modified since then. In cinema, since the 1990s, the uncompressed TIFF image sequence was used for VFX, and by 2007, it was selected as the recommended image format in DCDM by the DCI. TIFF and DPX remain most frequent

[268] FIAF Technical Commission, 'FIAF Technical Commission Recommendation: the Deposit and Acquisition of D-Cinema Elements for Long-term Preservation and Access'.
[269] https://www.fileformat.info/format/tiff/corion.htm, accessed 29 December 2020.
[270] Adobe Developers Association, 'TIFF Revision 6.0', 3 June 1992, 5.

formats in archival deposits of new digital productions and digitisations. Beyond the technical characteristics of image sequence formats, the formats' adoption in archives depends not only on their use in the film industry but also on how a format embodies the theoretical needs of archives. Their status as "archival masters" relied primarily on the fact that these elements were not compressed, so they did not entail any technical loss, although they remained intermediate elements in digital workflows.

The digital production workflows may also be video-based, before the step where a DCP is fabricated for distribution. Some digital video formats[271] of ProRes and DNx families have encountered a wide industrial adoption thanks to their corresponding software (respectively Apple Final Cut Pro and Avid). Although not standardised, neither open formats, nor uncompressed,[272] these video formats often figure among the elements deposited at archives, which, following the industry, may indeed choose to accept them (and even use them in their own production workflows). In what follows, I intend to clarify how the concept of compression communicates with the understanding of loss in digital conservation via different digital formats. When a film is shot in a digital video format and post-produced on the same format, it has no uncompressed form technically and has always uniquely existed as a lossy element. This is not a digital generation loss, but a loss that is inherent to the mode of production. This could be likened to the anamorphic image on a film, which is optically compressed: an (unquantifiable) loss is included already into this image which would not be recovered at any further duplication. This is only a technical loss, and perceived as such in the understanding of a computer, but theoretically, it may be misleading to call it loss as it omits details which have never existed since image capture. Similarly, when a film is shot on uncompressed image sequence and post-produced on a video format, it has no uncompressed finished form either, and the only way to archive its "master" format is to accept the compressed video. This would resemble the example of a super 35mm negative, where a normal image is compressed into an anamorphic form after duplication and post-produced as such.[273] When the loss is incorporated into the (digital) film's production workflow, it is impossible to eliminate it or to recover the lost image information, even if the lossy format is transcoded into an uncompressed format. It

[271] A digital video file is comprised of two parts of codec and container. Here, when using the term format, I am referring to the codec.

[272] Video formats may be uncompressed as well, but these common industrial formats are indeed compressed (and with loss). It is however difficult to clearly determine how much loss is generated through a ProRes transcoding for instance. What's more, ProRes, as stated, is a family of formats which have very different compression levels. For some information on this, see 'Apple ProRes White Paper', January 2020, https://www.apple.com/final-cut-pro/docs/Apple_ProRes_White_Paper.pdf, accessed 29 December 2020.

[273] See for example: https://www.widescreen.org/aspect_ratios.shtml, accessed 29 December 2020.

is obvious that archival transcoding shall not introduce further loss, but the actual losslessness of the image depends on the way it has been produced.

The adoption or rejection of formats in film archives is therefore influenced by cultural habits and industrial adoptions as much as on archival decisions and imaginaries. The concepts of losslessness, standard and open, as constructed in archival imaginaries for years, contribute to the understanding and adoption of formats which are themselves impregnated by previous technologies and other fields and applications. The choice of formats and the various workflows which digital images go through shape not only their look, but also their archival implications. Considering this technological multiplicity, it would be difficult to find one unique way which can be applied to the conservation of all digital films.

3.4 Hybridity of Conservation Technologies?

The discursive position of "film is a better archival material", which was by the mid-2010s the dominant archival tendency, [274] has still remained present within the archival community. What changed slightly the tone (without ever really eliminating this view), was the impracticality of conserving digital-born or digitised material on film: many film labs had closed, film technological knowledge was scarce and recording on film was expensive.[275] The combination of political and theoretical discourses with real technical implementations seems to have contributed to a slight shift of the archival imaginary from a film vs. digital conservation to a film and digital conservation approach, where not only both have been included in archival practices, but each of the categories have included a number of different technologies and methods.

Indeed, many archives have come to the understanding that conservation is an activity to safeguard film heritage in both its conceptual and material existence as far as possible, and it may need to employ photochemical, digital or other means. Emblematic of this technological diversity acceptance is part V of FIAF TC's Digital Statement, which instead of fixing technical recommendations for digital conservation, intended "to provide an overview of the different practices of digital preservation […] [and] to draw a landscape of digital preservation in

[274] Apart from FIRST and Digital Dilemma and other sources cited, See also: Laurent Cormier et al., 'Roundtable. Pour une conservation numérique du cinéma?' (Toute la mémoire du monde, Cinémathèque française, Paris, 2013), https://www.canal-u.tv/video/cinematheque_francaise/pour_une_conservation_numerique_du_cinema_table_ronde.14685.

[275] For digitised film, naturally, it was regarded as best practice that original film materials were to be conserved by archives, and according to many archivists, conservation prevailed on preservation. See for example: Walsh, 'Slow Disasters: How Neglect Continues to Destroy Our Film Heritage'. While this may sound obvious now, this had historically not been the case in all archives: in the past, sometimes when nitrate films were preserved on safety material, the originals were then disposed of.

different locations" according to the results of the survey conducted by the TC. The Statement underlined the differences, but it also aimed to provide "a sense of the standards that have been applied" by film archives, recognising that "some choices [seemed] to be predominant".[276] It seems to me that such indications show how film and digital conservation approach is gaining more ground within the archival community, but still, many archives opt for external digital conservation, and many film archivists do not consider digital conservation as their task. There does not seem to be a wholly-dominant imaginary and it is too early to talk of a definitive shift in the archival imaginary.

Digital conservation, already discussed years before the digital roll-out, became a pressing necessity a few years afterwards. My analysis in this subchapter demonstrates how the already-accepted criteria of archivability within film archives were put to the test with regards to available digital technologies and how in the process they redefined different notions of conservation such as longevity and loss. It becomes evident that the existence of an archival format that would remain on shelves for years without suffering any loss and with little to no maintenance was quasi-impossible. This realisation tampered archival imaginaries and resulted in a diversification of conservation practices and concepts, based on state-of-the-art technological possibilities. But will there be other methods in the future which will achieve that? Will a carrier exist one day which knows no decay, no loss, no end? As of 2022, there seems to be a rising hype around DNA archiving (still in its early steps of development), which would offer unlimited longevity, as the DNA molecules are forever. DNA archiving, in fact, is conceptually not much different from digital archiving: instead of describing images with 0s and 1s, it encodes them via its four nucleobases (A, C, G, T).[277] Of course, biologically the DNA molecules remain forever (if conserved correctly), but their encoding, synthesis, deconstruction, retrieval, etc., are all modelled and conducted through different scientific methods, and, much like everything else in science, their implementation may introduce errors and imprecisions. DNA archiving, or other methods which may appear in the future, might surpass current conservation technologies, but considering the archival collections, theories and imaginaries, which go beyond the mere technological constraints and advantages, hybrid

[276] Céline Ruivo and Anne Gant, 'Digital Statement. Part V', Resources of the Technical Commission (FIAF, April 2019), https://www.fiafnet.org/images/tinyUpload/2019/04/Preservation_Digital_Statement_Final.pdf, accessed 24 December 2020.

[277] Marc Antonini et al., 'DNA-Based Media Storage: State-of-the-Art, Challenges, Use Cases and Requirements Version 3.0', Public Report, JPEG DNA Exploration, January 2021.
For more documents, see: https://jpeg.org/jpegdna/documentation.html, accessed 15 April 2021.

conservation schemes seem to remain more suited. The technological transition is constant, and so have been archival adoption and adaptations.

4 Chapter Conclusions

During the second half of the 2010s, the main question within the archival discourse network was not anymore if images could and should be digitised or digitally conserved, but how those needed to be done. This shift in the archival imaginary followed, on the one hand, the political discourses which pushed towards an acceptance of digital technologies in archival practices, and, on the other, the technical necessity following the digital roll-out which entailed several archival projects and initiatives in response to the new challenges. Throughout this chapter, I have argued that, while the political discourses drew a potential future archival landscape of the next few years, the theoretical and technical discussions and practices shaped and refined it over the years.

European national archives had been digitising films since the late 1990s (in different quantities, qualities and for different reasons), but digitisation became the main buzzword a few years after the roll-out. By this time, attention was drawn to the technological act of digitisation and several archival studies and tests were conducted in order to reach a sort of authenticity in reproduction. Film archives were looking for methods and technologies which would enable the creation of a digital element from a photochemical one, in a way that the image details and characteristics (such as sharpness) would be preserved and the deviations from the source would be minimised. As I have investigated in this chapter, however, this proved technically to be complicated, as the technological frameworks within which the photochemical and digital image existed were different. Theoretically, as well, the archives recognised the impossibility of authentic reproduction, as a change of carrier would inevitably reduce it to simulation. For some, only digital reproduction was considered as a simulation, while others considered any type of reproduction as simulation. The evolving discourses reached a point where the image multiplicity was accepted. Indeed, as my technical study shows, the look of an image is influenced not only by digitisation (and its technical details), but depends also on the production modes and the industrial and archival life that the image has gone through. All these leave their traces on the image, and contribute to its multiplicity.

In conservation, archivability criteria, which had been fixed by archives based on their years of experience in the field, as well as their needs and desires, underwent changes too. In the beginning, the search was on for an archival format which would fulfil several criteria, such as longevity and losslessness. Later, faced with the realities of digital conservation technologies with regards to carriers and formats, the very notions of longevity and loss came under scrutiny, and a more hybrid view was formed which considered many digital or photochemical elements as worthy of being conserved and redefined the strategies of conservation with respect to several factors such as cultural practices, technological possibilities, theoretical understandings, production constraints and archival needs. Digital conservation remains a highly debated matter, whether theoretically or technologically, and needs to be monitored and studied further in the coming years.

These two research directions lead me to claim the multiplicity of the image. A frame of a film has a different look on a specific negative, positive, intermediate photochemical element, videotape, DCP or in another digital format, according to how it has been (re)produced, processed and conserved. This difference will always persist, through any technological system, because of two main reasons:

- Images are always models of something, and therefore, they entail always a sort of sampling, which makes reductions inevitable.
- Images always have a materiality in one way or another. Their link to it is conceived differently but the material carrier exists anyhow and needs to be considered by archives; whether it is film, magnetic tape, digital disk, or even DNA molecules.

In this chapter, I have argued that the multiplicity and hybridity have been, somehow tacitly, acknowledged within the archival community, not only on a technical level, but also on a more strategic level. There is not one way in which all archives function. The archival practices go beyond technological and economic modalities; they are constructed upon histories, cultures and visions (manifested through discourses) which modify the adoption and use of technologies. This on-going shift in the archival imaginary has been most visible at the 2019 FIAF Congress in Lausanne, where the past and future of archives were confronted in an attempt to valorise their differences: different histories, different geo-political situations, different goals followed by archives. Instead of disputing whose approach to archiving is the best (as had been incarnated via Langlois-Lindgren debate for years within FIAF), a multitude of approaches could potentially cohabit. Corresponding to this view, multiple image technologies, whether digital or photochemical, continue to be in use in film archives. While the move towards hybridity and plurality seems to be underway, it is as of yet far from being entirely accomplished.

Conclusion

> "The 1995 Los Angeles Congress introduced many of us to the possibilities of the digital world with its symposium sessions on 'New Technologies for Preservation' and 'High Speed Networking and Interactive Access' […] Twenty-five years later, such activities are commonplace."[1]

Writing in 2021, in the midst of a new crisis triggered by the COVID-19 pandemic, Elaine Burrows, formerly a film archivist at the BFI and current editor of the *Journal of Film Preservation*, recognised the years-long history of archives' confrontation with digital technologies, underlining: "Archives must always be adaptable and try – however slowly – to adopt some new methodologies and technologies".[2] Indeed, in this dissertation, I have demonstrated how diverse digital image technologies were adopted and adapted to archival practices, in interaction with the archival discourses, through processes which permanently modified the archival episteme. In the early years, the technologies in question were those which allowed for image manipulation (Chapter One). Gradually, other technologies were also introduced, developed and adopted that enabled archives to widen alternative access to film heritage through different channels (Chapter Two), to project films digitally (Chapter Three), or to digitise and conserve them in various formats and on different carriers (Chapter Four). Throughout this history, there has not been simply one single digital technology, but several technologies of different types (digital, mechanical, optical, photochemical, etc). As I have argued in my work, the multiplicity and diversity of technologies go against the dichotomy of film vs. digital, and redraw the technologically-diverse cinematographic landscape within which archives function.

The technological history of film archives that I have proposed in this dissertation reveals that the archival understanding of digital technologies, and consequently their reaction to them, were in constant mutation. Furthermore, the technologies themselves have also been conceived and developed within a rich socio-cultural and historical context. Crossing the history of archives with that of technologies sheds a new light on the digital transition era in film archives by nuancing the processes of technological adoption and adaptation in a dynamic socio-cultural context. My methodology, based on an archaeological study of the interrelations between techne and episteme, has enabled me to extract the mutual influences and communications

[1] Elaine Burrows, 'Editorial', *Journal of Film Preservation*, no. 104 (April 2021): 5.
[2] Burrows, 6.

between technological and archival domains, and identify historical periods with dominant socio-technical discursive and practical patterns. The archaeological approach is particularly apt in this situation, not only because of its emphasis on discourse analyses, but also because of its non-linearity. Indeed, it has allowed me to go back and forth in time, sometimes only a few years and sometimes decades, in order to portray a richer, more nuanced picture of the intertwined discursive and technological landscapes.

The links that I have drawn between different aspects of the analysis are not linear, nor following a cause-and-effect logic, but polysemic, and historically and socio-culturally charged. There is no evolution of technologies from point A to point B. Each technology is conceived and adopted or adapted in its own way, and within its own boundaries. This methodology not only allows for a thorough study of the durable technological additions but also excavates those whose short-term existence has marked, at least partly, the imaginaries; and vice-versa, they have been formed by the archival imaginaries at a specific point in time. The archaeological approach in my research stresses the historical crossing of the pieces of scientific and technological details with archival discourses (before, during and after their encounters with technologies), and in this way, it helps integrate the socio-technical histories into the archival imaginaries.

Techne, in my work, is understood not only as cinema technologies themselves but also as the sciences behind them. Studying the diverse scientific (mathematical, mechanical or photochemical) bases of the technologies in this dissertation has revealed precious information regarding their conception, and illustrated how they operate, what they can and cannot do, how they interact with archival imaginaries and how they correspond to archival concepts; or, on the other hand, how these concepts have been translated into a possible scientific language – whether of numbers, codes, equations, physical or chemical theories, etc. Even if the scientific aspect generally remains hidden and lesser-debated in archival discourses, its influence, as well as its characteristics, are felt in the processes of technological adoption. Underlining the subjectivity, estimation and approximations involved in all scientific processes, their encounter with equally subjective archival discourses becomes an auspicious terrain where both are nourished and modified (to different degrees). In my dissertation, I claim that the scientific basis is precisely the link which relates archives (and their episteme) to the technologies (and the thinking behind them). It is the collision of these two sources of knowledge, consciously or not, closely or remotely, which paves the way for technological definition, conception, development, experimentation, refinement, adoption, adaptation or rejection.

It might be that the digital technologies seemed complicated to archives by the 1990s because of their "black box" status. Indeed, contrary to the mechanics, chemistry and optics which had become familiar subjects to many archivists throughout their several years of experience with film technologies, the codes and algorithms, or the tiny microchips of the digital technologies, escaped from the archival understanding, creating the "black box" uncertainty when archives first faced different digital technologies. During the subsequent periods, there have been different needs and desires within archives to unlock the digital box and interact more or less with scientists and technology developers – leading therefore to the formation of specific imaginaries and theoretical positions with regards to digital technologies. Despite the fact that the scientist-archivist interrelations did not always go deep, I have argued in my dissertation that the socio-cultural influences of sciences and technologies, manifested in different ways, have always met the archival imaginaries directly or indirectly.

While the archival community has been considered as a united entity in this dissertation, I have not hesitated to call into question its homogeneity. Indeed, while national film archives in Europe share many common goals and practices, as well as similar economic and political frameworks, the archivists do not all adhere to the same ideas, and through the confrontation of their different viewpoints, archival notions, concepts and practices are challenged regularly. While at one point, it was believed within FIAF that a unique view must prevail in archives and the decisions stemming from this view should be applied by all members, in reality archives have always functioned and evolved differently; attesting to that is the eternal Langlois-Lindgren debate: whether archives needed to focus primarily on the presentation or the preservation of film heritage. The different voices, which had always existed and continue to exist, are amplified when faced with digital technologies because of the multiplication of possibilities. Rather tacitly, it seems that the archival community moves towards a recognition of the differences, which paves the way to accept the co-existence of several methodologies, visions, and technologies. The archival discourses have come to embrace their differences, in view of different missions attributed to them, joining thus the technological terrain where diversity and multiplicity already reigned, be it digital or photochemical (or other). Just as several new digital image technologies have been explored, discussed and tested by archives, there has been a tendency to uncover, discuss and valorise the past technologies of cinema in all their diversity. An interesting on-going project in line with the current imaginary is *Tales* *from the Vaults,* jointly conducted by FIAF and TECHNES, aiming to provide an "illustrated history of film technology".[3]

I can now go back to the three intertwined questions that I raised in the introduction of my study: the conditions of technological adoption, the question of technological co-existence, and the socio-culturally evolutive patterns of archival imaginaries. First of all, my dissertation illustrates how the conception and adoption of technologies have taken place in a historically-charged socio-cultural context, and in interaction with existing archival imaginaries. The patterns and processes involved are not linear, nor definitive. Therefore, the integration of digital technologies can hardly be considered as a determinist attack on archival structures. Rather, it attests to a dynamic socio-technical construction. I have highlighted how certain technologies have been integrated into archival practices through many steps of discussion and adaptation, while others, although potentially interesting, have not lasted long (such as François Helt's DUST system) or have been relegated to marginal activities (such as E-Cinema).

Secondly, digital is not one single technology, but enables a series of plural technologies implemented in diverse ways. In the case of film archives, digital technologies did not generate a disruption in archival practices, but they were added to what existed before. This way, a dynamic landscape is constructed within film archives (and industry), where several technologies co-exist, each with their own applications, goals, particularities, estimations, approximations and losses. Through the study of scientific imaginaries, and their collision with archival imaginaries, a series of interrelations between old and new technologies come to light which go beyond simple imitation or confrontation, and represent different forms of remediation. The technological history of archives that I have recounted in this dissertation favours the view of cinema history and its technologies as forming a continuous archival collection, rather than a disrupted one into two film and digital categories.

Thirdly, through the processes of technological adoption, the archival imaginaries underwent many modifications. In the 1990s, the archives viewed digital technologies as an intermediate – hidden – step to restore images; then, their growing presence created existential concerns for archives and questioned their very *raison d'être*, leading them to fight for the survival of traditional technologies; and finally, they (generally) settled for coming to terms with digital technologies as part of the technological landscape of cinema, while they adapted the technologies to their own use and needs. Following the encounters with techne, some archival

[3] See: https://www.fiafnet.org/talesfromthevaults, accessed 12 April 2021. Christophe Dupin, 'Partnership with Technès: Tales from the Vaults', *FIAF Bulletin Online*, no. 18 (December 2019): 33.

notions needed to be (re)defined, such as authenticity, archivability, manipulation, reproduction, quality, projection, etc. As I have depicted, the archival imaginary during the past thirty years has known a material turn, which accompanied the digital turn; this was crystallised in the reinforcement of a museological approach around film technologies, running parallel to the adoption of digital technologies.

1 Expanding the Scope of the Study

The methodological model that I propose here could be used to study similar subjects, which have inevitably been left out of this dissertation. Firstly, I have focused on image technologies; but an archaeological study of episteme and techne within the socio-cultural context of archives could also apply to other cinema technologies, most importantly sound. Film sound preservation has already been subject to some scholarly studies, for instance by Sonia Campanini, who addressed the questions of preservation and presentation of film sound in her 2014 PhD thesis. According to Campanini, studies on cinema have generally been driven by a "hegemony of the visual, since the image and visual component of film has predominance over the sound component".[4] Similarly, sound has been less discussed within film archives. In Paul Read and Mark-Paul Meyer's *Restoration of Motion Picture Film*, sound is furtively mentioned, while the authors concede that "sound restoration is another area that certainly warrants its own publication".[5] There are, of course, exceptions to this side-lining of sound: different aspects of film sound with regards to restoration or presentation were presented in some archival conferences,[6] and a few articles were published on sound restoration.[7] Moreover, during the Joint Technical Symposiums, archives have also communicated with sound archives. There are specialised sound restoration labs, such as Cinevolution in Belgium, founded by Jean-Pierre Verscheure, which treats sound in a similar manner to image from theoretical and ethical points of view.[8] One part of FIAF TC's Digital Statement will also be dedicated to sound.[9]

---

[4] Sonia Campanini, 'Film Sound in Preservation and Presentation' (PhD Thesis, University of Udine, University of Amsterdam, 2014), 3.
[5] Read and Meyer, *Restoration of Motion Picture Film*, Editor's preface.
[6] For example: Gilles Barberis and Lorenzo Rattini, 'Acoustics for Small Rooms' (The Reel Thing, Eye International Conference, Amsterdam, 29 May 2017).
[7] See for example: Jean-Pierre Verscheure, 'The Challenge of Sound Restoration from 1927 to Digital', *Film History* 7, no. 3 (Autumn 1995): 264–76; Robert Gitt, 'Bringing Vitaphone Back to Life', *Film History* 5, no. 3 (1993): 262–74. Part III of the FIAF TC's Digital Statement, to be published probably in 2022, will also tackle the question of sound preservation.
[8] https://www.cinevolution.be/, accessed 11 April 2021.
[9] The 4th part, which is not published yet as of June 2022.

Sound technologies, from an archival perspective, are historically and culturally different compared to image technologies, and that is why they need to be studied separately.[10] Technically, as well, they differ from image technologies, be it for their recording, reproduction or presentation. Sound signals are continuous one-dimensional functions of time and, unlike images, they are not decomposed into frames. Their visual representation, in the case of photographic sound (optical sound on film), is indecipherable to the ear, and absolutely needs to be translated back into sound for that. This characteristic goes against photochemical images, which are visible to the naked eye, but resembles digital files which also need to be translated into a perceivable version for the eye. Historically, sound technologies have been quite diverse and the transition between different formats has been more frequent, albeit less controversial, compared to images. For instance, since the 1960s, it had become common practice to record sound on magnetic tapes, before reproducing it as optical sound on film. Moreover, during the period that is the subject of my study here, sound was already digital. For example, DAT (Digital Audio Tape) was released in 1987 for sound recording, and was widely adopted within the industry (and archives) in production and restoration. The development and adoption of digital sound technologies followed a different timeline, responded to different technical challenges, and sparked different discourses within the archival community. Of course, the adoption processes of digital image and sound technologies do meet at certain points, as I have mentioned in the case of Gamma Group in Chapter One; but the different cultural circumstances and technical details of sound would make it worthwhile to devote thorough research to it.

Secondly, the dissertation considers only the case of European national film archives, excluding many other types of archives. Firstly, this concerns specialised film archives: regional or thematic ones. While in the 1990s FIAF affiliates were wondering if they should open up to include these archives, today these archives are an important part of not only FIAF, but also the larger audiovisual archiving landscape.[11] At the FIAF 2019 Congress in Lausanne, specialised archives were present via a panel, and their work, which manifests several particularities, was valorised and celebrated as distinct and valid archival practices.[12] Among these I would like to mention university archives (Cinémathèque universitaire in Paris), regional archives

[10] See: *Photographic Sound Technology* (London: British Kinematograph, Sound and Television Society, 1980); John K. Hilliard, 'SMPTE Historical Note: Basic Sound Recording and Reproducing Practices between 1927 and 1940', *SMPTE Journal* 92, no. 2 (February 1983): 207–10. Elisabeth Weis and John Belton, eds., *Film Sound: Theory and Practice* (New York: Columbia University Press, 1985).

[11] See for example the work conducted by association INEDITS on amateur films: http://www.inedits-europe.org/, accessed 12 April 2021.

[12] Lydia Pappas et al., 'Session 4: Specialized Archives' (FIAF 2019 Lausanne Symposium, Lausanne, April 2019).

(Cinémathèque de Bourgogne, Lichtspiel Kinemathek Bern), amateur film archives (Home Movies, Bologna), ethnical or socio-political movement archives (Archivio Nazionale Cinematografico della Resistenza in Turin, Ciné-Archives in Paris), etc. The case of these archives, in terms of technological adoptions and the evolution of their practices, their political and financial frameworks, as well as their position within the larger film industry, does not necessarily correspond to the established models of national film archives and needs to be studied in their own socio-technical context, despite the many similar practices, technical challenges and objects that they share with national archives. For instance, these archives might not have been expected politically to accept digital films for conservation, but they still needed to acknowledge digital technologies in restoration and projection if they wanted to continue giving access to their collections. I believe that many discussions in my dissertation can also apply to their case, and have mentioned them briefly in my analysis if their discourses coincided with those of national archives.

Secondly, further studies should be carried out on Global South film archives, meaning those in Asia, Africa and Latin America (and to some extent, Eastern Europe). These also present their own challenges, timelines, visions as well as geo-political, socio-cultural and historical frameworks within which they exist and function. Their relation to technologies, and their processes of technological adoption, adaptation or rejection do not necessarily follow the same routes as archives in Western European countries (that I have covered in this thesis), in North America or Australia. This inclusion is a pressing matter, since the technological divide between European countries and other parts of the globe may lead to the invisibility and even loss of a large part of global film heritage. Within the archival community, this direction was highlighted at the FIAF 2019 Congress in Lausanne,[13] and had already figured in a small number of archival collaborative projects,[14] publications,[15] and congresses.[16] It has also been explored for certain areas of the world in scholarly work by Aboubakar Sanogo (Carleton

[13] Maral Mohsenin et al., 'Socio-Political Diversity of Film Archives: Transitions from the Past to the Future' (Roundtable with the Central State's Film Archive of Albania, the Azerbaijan State Film Fund and the Cinematheque of Macedonia, FIAF 2019 Lausanne Symposium, Lausanne, April 2019).

[14] Such as FIAF's "The Film Archives in Africa Project (2010-2015)" (https://www.fiafnet.org/pages/Training/About-Film-Archives-in-Africa.html, accessed 12 April 2021); Film Preservation and Restoration Workshop in India (https://www.fiafnet.org/pages/Training/2019-Film-Preservation-Restoration-Workshop-India.html, accessed 12 April 2021).

[15] 'Maghreb and Middle East / Maghreb et Moyen-Orient / Maghreb y Oriente Medio', *Journal of Film Preservation*, no. 77–78 (October 2008): 13–37.'Afrique', *Journal of Film Preservation*, no. 76 (April 2008): 13–37.

[16] For example, the FIAF 2001 Rabat Symposium was focused on "Colonial Cinema: A Borrowed Film Heritage".

University, for Africa)[17] and Juana Suarez (New York University, for Latin America)[18]; and more researchers are currently underlining its importance.[19]

Recently, there seems to be a rise in interest in the archives of the Global South. In May 2022, the three-day Eye International Conference was entirely dedicated to the subject, where the floor was given to representatives and experts from these archives, leading to an outpour of many insights and research directions. Indeed, this kind of events prove crucial in efforts to (re)integrate these archives – side-lined within the discourses – into the international community of archives. The FIAF community, despite some initiatives such as the Training and Outreach programme, remains still primarily populated by European and American discourses. The cultural and language barriers might lead to a lesser visibility of some archives. More importantly, I signal out their financial and political infrastructures, which are radically different compared to European national archives studied here: political instability, lack of systematic regulation and (severe) underfunding. Moreover, the very notion of national film heritage needs a global re-definition, since it is not always clear considering the colonial histories[20] and specific collaboration patterns in many areas of the world[21].

I believe that my methodological model could indeed prove useful in the study of the archives in the Global South, as it allows for the inclusion of their specific socio-cultural context, their political frameworks, their historical specificities and, particularly, their technological (re)appropriation and remediation under these circumstances. Considering all of these differences, it is no wonder that the use, adaptation and adoption of industrial and archival technologies in non-European countries can present considerably different patterns as well as different timelines. As a follow-up to my analysis in Chapter Four, it would be interesting to research the technological histories of cinema in different regions of the world, and construct archival theories and practices which are specific to them.

---

[17] Aboubakar Sanogo, 'Africa in the World of Moving Image Archiving: Challenges and Opportunities in the 21st Century', *Journal of Film Preservation*, no. 99 (October 2018): 8–15.

[18] Juana Suarez, 'Audiovisual Archives, Cultural History and the Digital Turn in Latin America', Project (New York: New York University, n.d.); Pamela Vizner and Juana Suarez, 'Education Through International Collaboration: The Audiovisual Preservation Exchange (APEX) Program', *Synoptique* 6, no. 1 (2017): 102.

[19] Diego Cavallotti, Denis Lotti, and Andrea Mariani, 'Dalla Vaga Suggestione al Reperto Censito. Note per Una Storia Del Cinema e Dei Media Attraverso Gli Archivi', in *Scrivere La Storia, Costruire l'archivio. Note per Una Storiografia Del Cinema et Dei Media* (Milan: Meltemi, 2021), 22–26. Maral Mohsenin et al., 'Global Audiovisual Archiving: North-South Exchange in Knowledge and Practices' (Eye International Conference 2021, Amsterdam, June 2021). Giovanna Fossati, 'For a Global Approach to Audiovisual Heritage: A Plea for North/South Exchange in Research and Practice', *NECSUS. European Journal of Media Studies*, no. Autumn 2021_#Futures (13 December 2021), https://necsus-ejms.org/for-a-global-approach-to-audiovisual-heritage-a-plea-for-north-south-exchange-in-research-and-practice/.

[20] For Africa, understandably.

[21] For instance, between different Arab countries during the 1960s to 1980s, when pan-Arabism was common.

2 Where Do Film Archives Stand Now?

The on-going socio-technical transition of archives since 1990 has of course brought about some institutional and socio-cultural modifications. I have mentioned how the archival models of museum and library clashed, in what could be qualified as a new incarnation of the older discursive battle on preservation vs. presentation. The re-definition of some notions, such as access, contribute to the adherence of archives to one model or another, or to a mix of both. Most national film archives in Europe did modify their access policies and practices by including the question of digital access in it; a process that has also been accelerated during the COVID-19 crisis since 2020, when many archives started feeding their own (free) online platforms with digitised films from their collections. As I have argued in Chapter Four, by now there seem to be several accepted practices of specific archival tasks (restoration, conservation and access). Similarly, the terms archive, cinémathèque or film museum could harbour different meanings, embody different configurations and pursue different goals. I have also mentioned, in Chapter Two, how the reinforcement of museological tendencies brought archivists such as Jose Manuel Costa to identify a shift in the archival object of conservation; from being the history of cinema to also including the history of cinema technologies.

The level of interaction currently established between the technical and theoretical discourses within the archival community could potentially permit the archivists not only to work more efficiently with digital technologies, but also to identify what is missing and formulate the questions in an attempt to dialogue with technology developers – in a word, to assume an active role in the more general socio-technical landscape. I believe that the thirty years between 1990 and 2020 have culminated in an acceptance of different film and digital technologies (Chapter Four), where the archivists' agency, socio-cultural preferences and technical knowledge shape the decisions they make and the strategies they define. Of course, archivists could not always concretise their needs or desires with regards to technological development, as these are directly linked to the archives' financial and political status as well as the socio-cultural context within which they function.

From an ethical perspective, my dissertation diverts the centre of attention from the threats of digital technologies towards archival responsibilities.[22] Technologies have been and will always remain tools; it has been up to the archivists how they use them. As I have underlined throughout the thesis, digital technologies are not invading archives, imposing their own

[22] About the responsibilities, see: Fossati, *From Grain to Pixel: The Archival Life of Film in Transition*, 2018, 147–53.

agenda; rather, they are amplifying the field of possibilities in interaction with archival imaginaries. This new vision of ethics would allow for a multiplication of practices according to archival decisions: if the interventions are best carried out in the least invasive manner (towards a higher authenticity)[23] or if digital simulations of original production processes are to be undertaken;[24] if digital files are going to be conserved as they are, or if they are to be transcoded; how and where archive films are going to be accessible, etc. Needless to say, this approach reinforces the vision that ethics is best decided and applied on a case-to-case basis, through an intertwined study of technical possibilities as well as historical implications. The ethical discourses, which were already prevalent within the field before the digital technologies with regards to more conceptual decisions, are now also applied to the technical details of the images, as far as to the manipulation of every single pixel. Concepts such as "original", or choices such as the selection of a film element as the source of (digital) reproduction, are influenced by the new archival theories and ethics.

Do these institutional and socio-cultural changes owe entirely to digital technologies? Based on the research I have presented in my dissertation, I would argue that such an understanding is not precise: rather, they owe to the encounters between archives and technologies, based on archival histories and existing cultures, their rich episteme and their political recognition. Indeed, the ensemble of these aspects has contributed to the modified understanding and re-definition of archival ethics and concepts (for instance, restoration vs. digitisation), a re-hierarchisation of archival priorities and tasks (more funding allocated to digitisation of national film heritage), as well as some institutional and organisational restructuration within the national film archives (creation of digital departments or labs). Have archives achieved a stable state after the so-called digital transition? It is difficult to say, but I believe that, considering the dynamic nature of cinema's technological landscape as well as the constantly evolving socio-cultural context, archives will still go through changes. Finally, how will the technological situation of archives evolve in the future? Is there going to be a new form of technology which will outdo the digital? Such a possibility could, of course, not be ruled out entirely at this point. But according to the methodological model that I have developed throughout this work, when newer forms of technology come into existence that again modify archival practices, they will do so in interaction with archival imaginaries and the existing technological and socio-cultural

[23] For a recent discussion of this subject, see : Caroline Fournier and Jeanne Pommeau, 'Pour une relecture de l'éthique de la restauration et de la diffusion à l'aune du progrès technique', *Journal of Film Preservation*, no. 104 (April 2021): 13–24.

[24] See for example: Trumpy et al., 'Reconsidering Rigid Procedures of Color Film Digitization: Toning, Lenticular Processes, Chromogenic Stock, and Mroz-Farbenfilm'.

landscape of archives. The patterns of development, adoption, adaptation or rejection of technologies need to be taken into consideration also in the case of new future technologies.

Bibliography

1 Summary of Sources Consulted

Archival Organisations

FIAF:

- Congress Minutes, Reports, Programmes, Documents (conserved at the FIAF Office, Brussels), Symposia
- Journals: *Journal of Film Preservation* (1993 - Now), *FIAF Bulletin Online* (2011 -Now), *FIAF Information Bulletin* (1972-1985), *FIAF Bulletin* (1985-1993)
- Resources and Reports of FIAF Technical Commission and FIAF Programming Commission

ACE:

- Position papers, Studies and research
- Conferences of Cinema Heritage Subgroup of Cinema Expert Group (2008-2013)
- ACE Workshops since 2012, Bologna

CCAAA: Joint Technical Symposiums (1983 - Now)
UNESCO
National Projects and Studies in European Countries

Festivals

Il Cinema Ritrovato	Cineteca di Bologna	Bologna	1986 - Now
Giornate del cinema muto	Cineteca di Friuli	Pordenone	1982 - Now
Toute la mémoire du monde	Cinémathèque française	Paris	2012 - Now
Film (Re)Stored	Deutsche Kinemathek	Berlin	2016 - Now
Classic Film Marathon	Hungarian Film Archive	Budapest	2018 - Now

Archival Training Programmes

Archimedia	1997 - 2004
FIAF Restoration Summer School	2007 - Now
FIAF Programming Winter School	2017 - Now

Other events and publications (selective)

Journal of the Society of Motion Picture and Television Engineers
Transactions of the Society of Motion Picture Engineers
Image Technology, Journal of the British Kinematograph, Sound and Television Society (BKSTS)
Documents of the Commission Technique Supérieure (CST) in France
Documents of the European Digital Cinema Forum (EDCF)
Film manufacturers' documents and publications (such as Kodak)
The Moving Image by AMIA (Association of Moving Image Archivists), 2001 to Now
No Time to Wait conferences (2016 - Now)
Conservatoire des techniques, Cinémathèque française (2008 - Now)

Archival Conferences: see Appendix 1
European Projects: see Appendix 2

2 Documents and Publications from Archival Organisations

2.1 European, National and International Projects, Studies and Policy Documents

Almunia, Joaquin. Letter to Alain Juppé. 'Aide d'État SA.33489 (2011/N) – France. Plan de numérisation d'oeuvres cinématographiques de patrimoine', 21 March 2012.

Baroncini, Vittorio, Hank Mahler, Matthieu Sintas, and Theirry Delpit. 'Résolution du film 35mm en projection cinématographique'. [Abbreviated French version from original: ITU-R 6.149, 35mm Cinema Resolution], 20 September 2001.

BCG. 'Financieel onderzoek EYE'. End Report. Dutch Ministry of Education, Culture and Science/Eye Filmmuseum, September 2016.

Besserer, Bernard, and Cedric Thiré. 'Rapport d'activité - Actions effectuées dans le cadre de la convention de 2002 entre le CNC et le L3i, Université La Rochelle'. Paris: CNC, September 2003. http://retouche.free.fr/download/rec_rapport_cnc.pdf.

———. 'Traitement des rayures dans les images cinématographiques'. Paris: CNC, July 2002. http://www.service1.culture.gouv.fr/sdx/crcbc/pdf_export.xsp?id=etude_cnc0203&db=etude&app=fr.tech.sdx.crcbc.

Broca, René, and Etienne Traisnel. 'Collecter et conserver les films du dépôt légal fournis sur support numérique'. CST, June 2011.

Bussemaker, M. 'Brief van de Minister van Onderwijs, Cultuur en Wetenschap'. Structuurversterking filmindustrie, Tweede Kamer, 25434, no. 47, Vergaderjaar2015 2016.

Library of Congress. 'CD / CD-R and DVD-R RW Longevity'. Accessed 28 November 2021. https://www.loc.gov/preservation/scientists/projects/cd-r_dvd-r_rw_longevity.html.

'Celluloid and Pixels: Preservation and Collecting in the Filmmuseum'. Unpublished Policy Document. Nederlands Filmmuseum, 23 June 2000.

CEN/TC 457. 'A Framework for Digital Preservation of Cinematographic Works - The Cinema Preservation Package'. European Standard EN17650, 2022.

———. 'Technical Report - Guideline for Implementing the Cinema Preservation Package'. Technical Report. European Standard EN17650, 2022.

Christensen, Thomas, and Mikko Kuutti. 'A Digital Agenda for Film Archives'. ACE Position Paper, March 2012. https://ace-film.eu/wp-content/uploads/2012/03/A-Digital-Agenda-for-Film-Archives-2012.pdf.

Christensen, Thomas, and Julia Welter. 'Guidelines for Digitization, Digital Storage and Retrieval'. EFG Deliverable 4.3. European Film Gateway, 30 October 2009.

Cinémathèque suisse. 'Liste de formats', 2013.

———. 'Spécifications techniques pour le dépôt obligatoire d'éléments de films numériques'. Cinémathèque suisse/OFC, May 2019.

CNC. 'Dossier de presse. Présentation de la troisième session du plan de numérisation des films du patrimoine du CNC', 19 November 2012.

———. 'La Commission européenne autorise l'aide sélective du CNC à la numérisation du patrimoine cinématographique'. Press Release, 21 March 2012. https://www.cnc.fr/professionnels/communiques-de-presse/la-commission-europeenne-autorise-laide-selective-du-cnc-a-la-numerisation-du-patrimoine-cinematographique_113507.

———. 'Retour sur le "Plan nitrate"', 30 July 2019. https://www.cnc.fr/cinema/actualites/retour-sur-le-plan-nitrate_1027210.

'Commission Staff Working Document on the Implementation of the Recommendation of the European Parliament and Council of 16 November 2005 on Film Heritage and the Competitiveness of Related Industrial Activities'. Brussels, 4 August 2008. https://ec.europa.eu/archives/information_society/avpolicy/docs/reg/cinema/report/swp_en.pdf.

Commission supérieure technique de l'image et du son. 'Recommendation technique CST-RT-021 : Fichiers numériques d'échange et d'exploitation des œuvres numériques "dits Mezzanine"'. V1.0. Paris: CST, 15 July 2012.

Comte, Christian, and Nicolas Ricordel. ‘Compte rendu de Mission – Festival de Bologne 2001’. Unpublished Report. Paris: CNC, 2001.
Costa, Pedro. ‘D1.1 User Requirements and General Conditions’. Public Deliverable. EDCINE, 15 April 2007.
‘CST - RT – 026 – C - 2012 – v1.0 : Support Maître d’archivage pour conservation’. CST, 4 April 2012.
‘DIAMANT (Digital Film Manipulation System). Description of Scientific, Technological Objectives and Workplan’. Project Proposal - Part B. DIAMANT, 16 June 1999.
Digital Cinema Initiatives, LLC. ‘Digital Cinema System Specification’. V1.0, 20 July 2005.
———. ‘Digital Cinema System Specification’. V1.1, 12 April 2007.
———. ‘Digital Cinema System Specification’. V1.2 with Errata as of 30 August 2012 Incorporated, 10 October 2012.
———. ‘Digital Cinema System Specification’. V1.4, 20 July 2020.
Digital Cinema Initiatives, LLC, Digital Cinema System Specification, Version 1.1, 2007.
‘Digital Film Center’. Project Proposal, 1995.
‘Discours de Frédéric Mitterrand, ministre de la Culture et de la Communication, prononcé à l’occasion de la signature de l’accord sur la numérisation du patrimoine cinématographique’. Cannes, 15 May 2011.
‘Economies of the Commons 3. Sustainable Futures of Digital Archives.’ Conference presented at the Images for the Future, Amsterdam, October 2012. https://web.archive.org/web/20130706182500/http://ecommons.eu/.
EDCINE. ‘D6.7 System Architecture for Digital Archives with Support for Streaming Delivery’. Restricted Deliverable. EDCINE, 15 July 2008.
‘EDCINE/Archives. A Summary of the EDCine Project - Archival Applications’. Project Summary. EDCINE, March 2008.
European Commission. ‘Film Heritage in the EU’. 4th Report on the Implementation of the European Parliament and Council Recommendation on Film Heritage 2012-2013, 1 October 2014.
European Parliament and Council. ‘Recommendation of the European Parliament and of the Council of 16 November 2005 on Film Heritage and the Competitiveness of Related Industrial Activities’. *Official Journal of the European Union*, no. L 323 (16 November 2005): 57–61.
‘Eye Collection Policy 2014-2017’. Eye Filmmuseum, 2014.
‘Eye Collection Policy 2017-2020’. Eye Filmmuseum, 2017.
‘Film Forever: BFI Plan 2012-2017’. BFI, October 2012.
FIRST. ‘European Film Heritage on the Threshold of the Digital Era. Full Report (Part One).’ Project FIRST. Film Conservation and Restoration Strategies, June 2004.
———. ‘European Film Heritage on the Threshold of the Digital Era. Full Report (Part Two).’ Project FIRST. Film Conservation and Restoration Strategies, June 2004.
———. ‘State of the Art Report’. Project FIRST. Film Conservation and Restoration Strategies, June 2003.
Flueckiger, Barbara, David Pfluger, Giorgio Trumpy, Simone Croci, Tunç Aydın, and Aljoscha Smolic. ‘Investigation of Film Material–Scanner Interaction’. Version 1, 2018. https://www.zora.uzh.ch/id/eprint/151114/1/FlueckigerEtAl_InvestigationFilmMaterialScannerInteraction_2018_V_1-1c.pdf.
‘Förderungsansuchen 1995’. LIMELIGHT. Graz, Austria: Joanneum Research, 1995.
‘Förderungsansuchen 1996’. LIMELIGHT. Graz, Austria: Joanneum Research, 1996.
‘Förderungsansuchen 1997’. LIMELIGHT. Graz, Austria: Joanneum Research, 1997.
Fournier, Caroline, and Caroline Neeser. ‘Le numérique à la Cinémathèque suisse’. Unpublished Restricted Document. Cinémathèque suisse, 2010.
Goudineau, Daniel. ‘Adieu à la pellicule ? Les enjeux de la projection numérique’. Paris: CNC, August 2006.
Hall-May, M., G. Veres, J-H. Chenot, C. Bauer, and W. Bailer. ‘Deliverable D3.1’. Public Deliverable. DAVID, November 2013.
‘Images for the Future’. Project Plan. Eye Filmmuseum, Sound & Vision, National Archives, Kennisland, April 2006.
‘Images of the Past. 7 Years of Images for the Future’. Project End Report. Eye Filmmuseum, Sound

& Vision, National Archives, Kennisland, 2014.
ITU-R 6.149. ‘35mm Cinema Resolution Test Report’, 20 September 2001.
Jong, A. de. ‘Digital Preservation Sound and Vision: Policy, Standards and Procedures’. Policy Document. Netherlands Institute for Sound and Vision, 2016.
Kinematheksverbund. ‘Digitalisierung des Filmerbes: Die Position des Kinematheksverbundes’. Position Paper, December 2015. https://kvb.deutsche-kinemathek.de/wp-content/uploads/2015/05/Digitalisierung-des-Filmerbes-Die-Position-des-Kinematheksverbundes-20151.pdf.
———. ‘Digitalisierung des Filmerbes: Update zur Position des Kinematheksverbunds zum „Förderprogramm Filmerbe“ (2020)’. Position Paper, February 2020. https://kvb.deutsche-kinemathek.de/wp-content/uploads/2020/03/Update_Digitalisierung_Filmerbe_20200225_hq.pdf.
Kodak. ‘Capturing Information on Film’, May 2007. https://www.kodak.com/content/products-brochures/Film/Capturing-Information-on-Film.pdf.
———. ‘Eastman Professional Motion Picture Films: H-1’. Eastman Kodak, 2000. https://web.archive.org/web/20030709112201/http://kodak.com/US/en/motion/support/h1/index.shtml.
———. ‘Film Structure’. In *The Essential Reference Guide for Filmmakers*, 29–34. Kodak, 2007. https://www.kodak.com/content/products-brochures/Film/kodak-essential-reference-guide-for-filmmakers.pdf.
Kokaram, Anil C., Jean-Hugues Chenot, and Colin Smith. ‘BRAVA D12-Final Project Report’, 21 March 2003.
Kreines, Jeff. ‘A Few Notes on Affordable Non-Judgmental Preservation with the Kinetta Archival Scanner’, 2010. http://www.kinetta.com/download/files/KinettaNonJudgmentalPr1.pdf.
———. ‘The Kinetta Manifesto’. Version 2, 2008. http://www.kinetta.com/manifesto/KinettaManifesto2008v2.pdf.
Mabillot, David. ‘The Pandora’s Box of Dcinema’, March 2011. https://www.youscribe.com/BookReader/Index/546578/?documentId=517698.
Mazzanti, Nicola. ‘Challenges of the Digital Era for Film Heritage Institutions’. Executive Summary. DAEFH: Digital Agenda for the European Film Heritage. Brussels: European Union, 2011.
Nowak, Arne, J. Mohr, W. Spinnler, H. Thomas, Paul Read, and Nicola Mazzanti. ‘D6.5 Definition of Detailed Workflow and Format Specifications for T6.3’. Public Deliverable. EDCINE, 28 May 2007.
PIQL. ‘Physically Present – Future Preserved’, n.d. https://piql.prod.simpleness.no/content/uploads/Brochure-Piql-Preservation-Services.pdf.
‘Présentation du dispositif d’aide à la numérisation des films de patrimoine du CNC’. CNC, October 2014. https://www.cnc.fr/documents/36995/156986/pr%C3%A9sentation+du+dispositif+d%E2%80%99aide+%C3%A0+la+num%C3%A9risation+des+films+de+patrimoine+du+CNC.pdf/34ea822b-eec6-6771-3845-32b53f77002f?t=1532441816248.
‘Public Report on the Outcomes of the Project’. Public Report. European Film Gateway, 2011.
‘Public Report on Year 1 of the Project’. Public Report. European Film Gateway, 2009.
PwC. ‘Ermittlung des Finanzbedarfs zum Erhalt des Filmischen Erbes’. Berlin: Der Filmförderungsanstalt (FFA), 19 November 2015.
———. ‘Zusammenfassende Ergebnisdarstellung Kostenabschätzung zur digitalen Sicherung des Filmischen Erbes’. Berlin: FFA, 20 July 2015.
Raad voor cultuur (Council for Culture). Letter to Dutch Ministry of Education, Culture and Science. ‘advies filmconservering Deltaplan voor het Filmbehoud’, 1 August 2005.
Rehatschek, Karin, and Georg Thallinger. ‘Deliverable 27 - Final Public Report’. DIAMANT, 25 April 2002.
Ricordel, Nicolas. ‘Rencontre de Gamma Group dans le cadre du Festival Il Cinema ritrovato’. Unpublished Report. Paris: CNC, 4 July 2002.
‘Scanity Product Data Sheet’. Digital Film Technology (DFT), 2009. https://web.archive.org/web/20090731065416/http://www.dft-film.com/downloads/datasheets/DFT-SCANITY-Datasheet_04_09.pdf.

Schallauer, Peter, and Walter Plaschzug. ‘LIMELIGHT Software’. Year End Report. LIMELIGHT. Graz, Austria: Joanneum Research, March 1996.
———. ‘LIMELIGHT Software’. Year End Report. LIMELIGHT. Graz, Austria: Joanneum Research, March 1997.
———. ‘LIMELIGHT Software’. Year End Report. LIMELIGHT. Graz, Austria: Joanneum Research, March 1998.
Snell. ‘Archangel Ph. C-HD’, 2011. https://www.broadcaststore.com/pdf/model/814810/Archangel_PhC_HD.pdf,.
‘State Aid: Commission Approves France’s Plan to Digitise Its Film Heritage’. European Commission Press Release, 21 March 2012.
Swedish Film Institute. ‘Digitizing and Making the Swedish Film Heritage Available’. Report of the Digitization Project, January 2017.
———. ‘Policy of Digitization of Film Heritage’, June 2014.
———. ‘Technical specifications for contractual deposit of digital film elements’, October 2015.
‘Tech 3289. Preservation and Reuse of Film Material for Television’. European Broadcasting Union (EBU), May 2001.
Tombros (AWK), Dimitri. ‘Machbarkeitsstudie Digitale Langzeitarchivierung der Cinémathèque Suisse’. End Report. Cinémathèque suisse/Office fédéral de la culture, 16 December 2015.
Tweede Kamer. ‘Bedreigd Cultuurbezit [Endangered Cultural Property, Policy Document]’. Vergaderjaar 1991-1992, 21 965, no. 7. Tweede Kamer, n.d.
UNESCO. ‘Recommendation for the Safeguarding and Preservation of Moving Images’. Adopted by the General Conference at its twenty first session. Belgrade: UNESCO, 27 October 1980.
Warner, Andrew. ‘DOTS—Long-Term, Human-Readable Archival Data Storage’. *The Long Now* (blog), 27 December 2015. https://blog.longnow.org/02015/12/27/dots-long-term-human-readable-archival-data-storage/.

2.2 FIAF Journals

Abrusci, Concepción, Norman S. Allen, Alfonso Del Amo García, Michelle Edge, and Ana Martín-González. ‘Biodegradation of Motion Picture Film Stocks’. *Journal of Film Preservation*, no. 67 (June 2004): 37–54.
‘Afrique’. *Journal of Film Preservation*, no. 76 (April 2008): 13–37.
Alanen, Antti. ‘From Bologna to Sacile’. *Journal of Film Preservation*, no. 67 (June 2004): 55–61.
———. ‘Il Cinema Ritrovato/Le Giornate del Cinema Muto 2009’. *Journal of Film Preservation*, no. 82 (October 2010): 79–82.
———. ‘More Hal Roach Gravy’. *Journal of Film Preservation*, no. 85 (October 2011): 90–92.
Amsler, André. ‘One Long Image. A New Approach to Archiving Motion Picture Films’. *Journal of Film Preservation*, no. 64 (April 2002): 51–55.
Anonymous. ‘Charter of Film Restoration’. *Journal of Film Preservation*, no. 83 (2010): 37–39.
Arrighetti, Walter. ‘The Interoperable Master Format (IMF) in Film Preservation’. *Journal of Film Preservation*, no. 101 (October 2019): 35–46.
Aubert, Michèle. ‘News from the Affiliates. Archives Du Film Du Centre National de La Cinématographie’. *Journal of Film Preservation*, no. 47 (October 1993): 35–38.
———. ‘The Future of FIAF/L’Avenir de La FIAF’. *Journal of Film Preservation*, no. 51 (November 1995): 2.
Aubert, Michèle, and Richard Billaud. ‘Symposium Technique Mixte JTS, Paris 2000’. *Journal of Film Preservation*, no. 60–61 (July 2000): 20–35.
Auger, François. ‘Projectionniste dans une cinémathèque (la Cinémathèque québécoise)’. *Journal of Film Preservation*, no. 67 (June 2004): 10–14.
Bandy, Mary Lea, and Steven Ricci. ‘Video in Film Archives?’ *Bulletin FIAF*, no. 45 (October 1992): 26–35.
Burrows, Elaine. ‘Editorial’. *Journal of Film Preservation*, no. 104 (April 2021): 5–7.
Cherchi Usai, Paolo. ‘The Digital Future of Pre-Digital Collections’. *Journal of Film Preservation*, no. 88 (April 2013): 9–16.

———. ‘The Lindgren Manifesto: The Film Curator of the Future’. *Journal of Film Preservation*, no. 84 (April 2011): 4.
Christensen, Thomas. ‘Preserving Digital Film’. *Journal of Film Preservation*, no. 64 (April 2002): 38–40.
———. ‘The Historical Film as a Title or as a Collection of Physical Elements’. *Journal of Film Preservation*, no. 66 (October 2003): 22–24.
Comte, Christian, and Nicolas Ricordel. ‘SACHA : un scanner spécifique pour les films anciens aux Archives Françaises du Film’. *Journal of Film Preservation*, no. 68 (December 2004): 20–24.
Costa, Jose Manuel. ‘The Place of Analogue and the Double Life of Digital’. *Journal of Film Preservation*, no. 98 (April 2018): 17–24.
Costa, Jose Manuel, and Robert Daudelin. ‘De l’avenir des cinémathèques’. *Journal of Film Preservation*, no. 71 (July 2006): 4–15.
Couchman, Jeffrey. ‘The Night of “The Night of the Hunter”’. *Journal of Film Preservation*, no. 64 (April 2002): 4–8.
Da Costa, Joâo Bernard. ‘Activités de la Commission de Programmation’. *Bulletin FIAF*, no. 44 (March 1992): 14–15.
Da Costa, Joâo Bernard, and Jose Manuel Costa. ‘The Lisbon Congress (Symposium)’. *Bulletin FIAF*, no. 37 (September 1988): 15–18.
Daudelin, Robert. ‘Editorial: Spirit of the Times’. *Journal of Film Preservation*, no. 71 (July 2006): 2–3.
———. ‘Learning from the History of FIAF’. *Journal of Film Preservation*, no. 51 (November 1995): 22–29.
———. ‘Un chien andalou’. *Journal of Film Preservation*, no. 83 (November 2010): 86–87.
De Blois, Marco. ‘A Propos d’Alice: Neco z Alenky (Alice) de Jan Švankmajer’. *Journal of Film Preservation*, no. 85 (October 2011): 88–89.
———. ‘Lotte Reiniger : The Fairy Tale Films’. *Journal of Film Preservation*, no. 79–80 (April 2009): 128–29.
Dean, Tacita. ‘FILM’. *Journal of Film Preservation*, no. 86 (April 2012): 11–21.
Del Amo García, Alfonso. ‘Archivios in tiempos de cambio. 62o Congreso de la FIAF, São Paulo, 24 y 25 de abril de 2006’. *Journal of Film Preservation*, no. 71 (July 2006): 16–20.
Dimitriu, Christian. ‘The Leviathan and the Identikits – Global Figures for Everyday Use’. *Journal of Film Preservation*, no. 73 (April 2007): 6–18.
‘Don’t Throw Film Away! The FIAF 70th Anniversary Manifesto’. *Journal of Film Preservation*, no. 77–78 (October 2008): 5–6.
Dupin, Christophe. ‘Editorial’. *FIAF Bulletin Online*, no. 5 (June 2013): 2.
———. ‘First Tango in Paris: The Birth of FIAF, 1936-1938’. *Journal of Film Preservation*, no. 88 (April 2013): 43–57.
———. ‘Partnership with Technès: Tales from the Vaults’. *FIAF Bulletin Online*, no. 18 (December 2019): 33.
Edmondson, Ray. ‘Guest Editorial: Towards a Philosophy of Film Archiving’. *Bulletin FIAF*, no. 41–42 (January 1991): 6–7.
Erland, Jonathan. ‘The Digital Projection of Archival Films Project: Phase One’. *Journal of Film Preservation*, no. 91 (October 2014): 37–42.
Fairall, Charles. ‘FoFA: The Future of Film Archiving’. *Journal of Film Preservation*, no. 94 (April 2016): 9–15.
Farinelli, Gian Luca. ‘Film Archives after Film’. *Journal of Film Preservation*, no. 89 (November 2013): 13–14.
———. ‘Restauration sur le vieux continent’. *Journal of Film Preservation*, no. 52 (1996): 49–51.
FIAF Technical Commission. ‘Preservation Best Practice’. *Journal of Film Preservation*, no. 83 (November 2010): 34–36.
———. ‘The Digital Statement. Part I’. *Journal of Film Preservation*, no. 99 (October 2018): 17–22.
Fossati, Giovanna. ‘Notes on the 2004 Joint Technical Symposium. Preserving the AudioVisual Heritage – Transition and Access’. *Journal of Film Preservation*, no. 68 (December 2004): 25–31.
Fournier, Caroline, and Jeanne Pommeau. ‘Pour une relecture de l’éthique de la restauration et de la

diffusion à l'aune du progrès technique'. *Journal of Film Preservation*, no. 104 (April 2021): 13–24.
Francis, David. 'Challenges of Film Archiving in the 21st Century'. *Journal of Film Preservation,* no. 65 (October 2002): 18–23.
———. 'The Way Ahead'. *Journal of Film Preservation,* no. 82 (April 2010): 9–12.
Frappat, Marie. 'Histoire(s) de la restauration des films'. *Journal of Film Preservation,* no. 94 (April 2016): 42–52.
Friend, Michael. 'Film/Digital/Film'. *Journal of Film Preservation,* no. 50 (March 1995): 36–48.
———. 'Guest Editorial: An Introduction to the Fifty-First Congress of FIAF'. *Journal of Film Preservation,* no. 50 (March 1995): 2–5.
Giuliani, Luca. 'Film Heritage as Cultural Patrimony'. *Journal of Film Preservation,* no. 82 (April 2010): 6–8.
Guevara, Mari Sol Pérez. 'Challenges for European Film Heritage from the Analogue and the Digital Era'. *Journal of Film Preservation,* no. 88 (April 2013): 31–33.
'Guide to a Basic Technical Equipment Required by Audio, Film and Television Archives'. *Bulletin FIAF,* no. 43 (1991): 34–36.
Horak, Jan-Christopher. 'FIAF: The Traditionalists' View'. *Journal of Film Preservation,* no. 51 (November 1995): 13–17.
Horwath, Alexander. 'Persistence and Mimicry: The Digital Era and Film Collections'. *Journal of Film Preservation,* no. 86 (April 2012): 21–28.
———. 'The Market vs. The Museum'. *Journal of Film Preservation,* no. 70 (November 2005): 5–9.
———. 'The Old Life. Reframing Film "Restoration": Some Notes'. *Journal of Film Preservation,* no. 96 (April 2017): 27–34.
Jamieson, Krista. 'Ethical Film Restoration and Concepts of "Original"'. *Journal of Film Preservation,* no. 93 (October 2015): 9–14.
Jeavons, Clyde. 'Svenska Stumfilmsklassiker (Swedish Silent Film Classics)'. *Journal of Film Preservation,* no. 81 (November 2009): 79–81.
Jenkins, Brian. 'The Restoration of Archive Film Using Digital Techniques'. *Journal of Film Preservation,* no. 54 (April 1997): 35–39.
'Joint Preservation Project: Rochester-Bologna'. *Bulletin FIAF,* no. 45 (October 1992): 22.
Klaue, Wolfgang. 'Wolfgang Klaue on the UNESCO Recommendation for the Safeguarding and Preservation of Moving Images'. *Journal of Film Preservation,* no. 100 (April 2019): 41–42.
Klaue, Wolfgang, Roger Smither, Jan-Christopher Horak, Hoos Blotkamp, and Robert Daudelin. 'The Future of FIAF'. *Journal of Film Preservation,* no. 51 (November 1995): 2–28.
Klaue, Wolfgang, and Jerzy Toeplitz. 'A Dialogue Between Two Former FIAF Presidents'. *Journal of Film Preservation,* no. 48 (April 1994): 2–14.
Kodak. *Journal of Film Preservation,* no. 88 (April 2013): 2.
———. *Journal of Film Preservation,* no. 101 (October 2019): 33.
Konlechner, Peter. 'International Film Archive CD-Rom'. *Journal of Film Preservation,* no. 49 (October 1994): 15–17.
Kromer, Reto. 'Matroska and FFV1: One File Format for Film and Video Archiving?' *Journal of Film Preservation,* no. 96 (April 2017): 41–46.
Labrum, Meg. 'Editorial'. *Journal of Film Preservation,* no. 92 (April 2015): 3–5.
Lameris, Bregt. 'Early Passive and Active Preservation at the Netherlands Filmmuseum, 1956-1984'. *Journal of Film Preservation,* no. 87 (October 2012): 51–56.
Le Roy, Eric. 'La Bataille du rail'. *Journal of Film Preservation,* no. 83 (November 2010): 88–90.
———. 'L'édition DVD dans les archives du film'. *Journal of Film Preservation,* no. 79–80 (April 2009): 4–11.
———. 'Markens Grøde'. *Journal of Film Preservation,* no. 81 (November 2009): 87–88.
'Legal Deposit/Dépôt Légal/Depósito Legal'. *Journal of Film Preservation,* no. 73 (April 2007): 52–67.
'Legal Deposit/Dépôt Légal/Depósito Legal'. *Journal of Film Preservation,* no. 74–75 (November 2007): 83–88.
Lenk, Sabine. 'Manual for Access to the Collections'. *Journal of Film Preservation,* no. 55 (1997): 2–42.

Lipman, Ross. ‘Problems of Independent Film Preservation’. *Journal of Film Preservation*, no. 53 (November 1996): 49–58.
Loebenstein, Michael. ‘Editorial’. *Journal of Film Preservation*, no. 91 (October 2014): 3–5.
———. ‘Editorial: A Changing Landscape’. *Journal of Film Preservation*, no. 84 (April 2011): 2–3.
‘Maghreb and Middle East / Maghreb et Moyen-Orient / Maghreb y Oriente Medio’. *Journal of Film Preservation*, no. 77–78 (October 2008): 13–37.
Mazzanti, Nicola. ‘Access Going Digital - Some Technical Issues’. *Journal of Film Preservation*, no. 70 (November 2005): 58.
———. ‘Response to Alexander Horwath’. *Journal of Film Preservation*, no. 70 (November 2005): 10–14.
McKernan, Luke. ‘What Is Restoration? FOCAL International Conference Report’. *Journal of Film Preservation*, no. 89 (November 2013): 35–38.
McWilliams, Donald. ‘Shadows of Progress: Documentary Film in Post-War Britain 1951-1977’. *Journal of Film Preservation*, no. 84 (April 2011): 64–68.
Meacham, Brian. ‘Between the Archive and the Multiplex: 35mm Film Programming in the Post-Film Era’. *Journal of Film Preservation*, no. 97 (November 2017): 27–36.
Meyer, Mark-Paul. ‘Film Restoration Using Digital Technologies’. *Journal of Film Preservation*, no. 57 (December 1998): 33–36.
———. ‘Traditional Film Projection in a Digital Age’. *Journal of Film Preservation*, no. 70 (November 2005): 15–18.
Mohsenin, Maral. ‘Silent Film Speeds throughout Film History: Standards and Practices’. *Journal of Film Preservation*, no. 101 (October 2019): 8–18.
Murphy, William T. ‘Storage of Acetate Film Materials. A Discussion at the National Archives and Record Administration’. *Journal of Film Preservation*, no. 48 (April 1994): 51–53.
Nowell-Smith, Geoffrey. ‘A European Filmography’. *Journal of Film Preservation*, no. 47 (October 1993): 4–10.
Okajima, Hisashi. ‘A Love Letter to Film’. *Journal of Film Preservation*, no. 89 (November 2013): 9–10.
Olsen, Jan Eberholst. ‘Maintaining Analog Film Projection the Digital Age’. *Journal of Film Preservation*, no. 94 (April 2016): 53–58.
Orwo. *Journal of Film Preservation*, no. 89 (November 2013): 46.
Prijs, Johan. ‘Pilot Experiments with L-Asorbic Acid Developer’. *Journal of Film Preservation*, no. 64 (April 2002): 43–50.
Read, Paul, ed. ‘FIAF Technical Commission Workshop. 'What Is Film?’ 61st FIAF Congress’. *Journal of Film Preservation*, no. 70 (8 June 2005): 56–63.
———. ‘Film Archives on the Threshold of a Digital Era: Technical Issues from the EU FIRST Project’. *Journal of Preservation*, no. 68 (2004): 32–45.
———. ‘Hollywood’s Proposals for Digital Cinema, Digital Projection of Heritage Film Content at Original Frame Rates’. *Journal of Film Preservation*, no. 74–75 (November 2007): 61–70.
———. ‘The Digital Intermediate Post-Production Process in Europe’. *Journal of Film Preservation*, no. 62 (April 2001): 57–69.
‘Regional Meetings: Europe’. *Bulletin FIAF*, no. 41–42 (January 1991): 20–23.
Ricci, Steven. ‘Commissions’ Work: Report on Film Education Workshop’. *Bulletin FIAF*, no. 45 (October 1992): 8–15.
Rockett, Kevin. ‘Dublin – Irish Film & TV Research Online’. *Journal of Film Preservation*, no. 87 (October 2010): 85–86.
Sanogo, Aboubakar. ‘Africa in the World of Moving Image Archiving: Challenges and Opportunities in the 21st Century’. *Journal of Film Preservation*, no. 99 (October 2018): 8–15.
Schou, Henning. ‘Report from the Preservation Commission’. *Bulletin FIAF*, no. 41–42 (January 1991): 14–18.
Tryster, Hillel. ‘Le Giornate del Cinema muto 2002’. *Journal of Film Preservation*, no. 65 (December 2002): 64–68.
Tsuneishi, Fumiko. ‘Digitising 25,000 Films a Year. A Challenge for Filmarchiv Austria’. *Journal of Film Preservation*, no. 99 (October 2018): 133–38.
Verscheure, Jean-Pierre. ‘Synthèse analytique du symposium. Researching the Origins: Archival

Study of Short-lived Film Formats (Tokyo, avril 2007)'. *Journal of Film Preservation*, no. 74–75 (November 2007): 35–56.
Walsh, David. 'Do We Need Film?' *Journal of Film Preservation*, no. 72 (November 2006): 4–8.
———. 'Editorial'. *Journal of Film Preservation*, no. 89 (November 2013): 3.
———. 'Joint Technical Symposium 2007. Audiovisual Heritage and the Digital Universe (28-30 June, Toronto)'. *Journal of Film Preservation*, no. 74–75 (November 2007): 57–60.
———. 'Slow Disasters: How Neglect Continues to Destroy Our Film Heritage'. *Journal of Film Preservation*, no. 99 (October 2018): 23–31.
———. 'Technical Symposium - FIAF Congress 2006 São Paulo: Film Archives in Transition'. *Journal of Film Preservation*, no. 72 (November 2006): 71–76.
———. 'The Advanced Projection Manual by Torkell Saetervadet'. *Journal of Film Preservation*, no. 72 (November 2006): 90–92.
———. 'The Restoration Threshold, or When to Apply Grain Reduction'. *Journal of Film Preservation*, no. 88 (April 2013): 21–29.
Wengström, Jon. 'Report from the Nordic Archive Meeting in Tromso, 7-9 September 2006'. *Journal of Film Preservation*, no. 72 (2006): 81–86.
———. 'Strengthening Archive Identity in an Age of Transition'. *Journal of Film Preservation*, no. 82 (April 2010): 4–5.
———. 'The Coexistence of Analogue and Digital Strategies in the Archival Film Collections of the Swedish Film Institute'. *Journal of Film Preservation*, no. 96 (April 2017): 63–73.

2.3 FIAF Documents: Congress Reports, Programmes, Commissions' Documents

62nd FIAF Congress. Congress Programme. Sao Paolo: Cinemateca brasileira, 2006.
Bagh, Peter von. In *Rediscovering the Role of Film Archives: To Preserve and To Show, Symposium Proceedings, FIAF 1989 Lisbon Congress*, edited by Cinemateca Portugesa, 13–21. Lisbon: Cinemateca Portuguesa / FIAF, 1990.
Baptista, Tiago. 'How I Learned to Stop Worrying and Love the Crisis: The Permanent Crisis of Film Archives'. Presented at the FIAF 2019 Lausanne Symposium, Lausanne, April 2019.
Burrows, Elaine. In *Rediscovering the Role of Film Archives: To Preserve and To Show, Symposium Proceedings, FIAF 1989 Lisbon Congress*, edited by Cinemateca Portugesa, 85–90. Lisbon: Cinemateca Portuguesa / FIAF, 1990.
Catalina Lapuente, Fernando, and Alfonso Del Amo García. 'Cellulose Triacetate Motion Picture Film Bases. A Descriptive Analysis and a Study of the Degradation and Preservation - Related Variables'. Presented at the FIAF 1999 Madrid Congress, Madrid, 1999.
Christensen, Thomas. 'Report of the Technical Commission'. FIAF 2011 Pretoria Congress Report. Brussels: FIAF, 4 April 2011. Appendix 5.3.1.
Cinemateca Portugesa, ed. *Rediscovering the Role of Film Archives: To Preserve and To Show, Symposium Proceedings, FIAF 1989 Lisbon Congress*. Lisbon: Cinemateca Portuguesa / FIAF, 1990.
Costa, Jose Manuel. 'The Role of FIAF: The Major Priorities. RE-FOUNDATION'. FIAF 2006 Sao Paolo Congress Report. Brussels: FIAF, 19 April 2006. Appendix 3.1.
Daudelin, Robert. 'Second Century Forum: The Digital Dragon'. Official Website of FIAF 2004 Hanoi Congress, 2004. https://web.archive.org/web/20040607233506/http://www.fiafcongress.org/SCF.htm.
Erland, Jonathan. 'Frame Rates, Old and New'. Presented at The Reel Thing, FIAF 2016 Bologna Symposium, Bologna, 26 June 2016.
FIAF. 'Fourth Session: ACE Report by Mazzanti'. FIAF 2014 Skopje Congress Report. Brussels: FIAF, 10 May 2014.
FIAF 1982 Oaxtepec Congress Minutes. Brussels: FIAF, 1982.
FIAF 1992 Montevideo Congress Minutes. Brussels: FIAF, 1992.
FIAF 1994 Bologna Congress Minutes. Brussels: FIAF, 1994.
'FIAF 1995. The World's Film Archives Come to Los Angeles'. Press Release. Los Angeles, CA:

UCLA, 1995.
FIAF 1996 Jerusalem Congress Minutes. Brussels: FIAF, 1996.
FIAF 2000 London Congress Minutes. Brussels: FIAF, 2000.
FIAF 2005 Ljubljana Congress Minutes. Brussels: FIAF, 2005.
FIAF 2007 Tokyo. Congress Programme. Tokyo: National Film Center, 2007.
FIAF 2008 Paris Congress Minutes. Brussels: FIAF, 2008.
FIAF 2010 Oslo Congress Report. Brussels: FIAF, 2010.
FIAF 2013 Barcelona Congress Minutes. Brussels: FIAF, 2013.
FIAF Madrid '99. Congress Programme. Madrid: Filmoteca Espanola, 1999.
FIAF Preservation Commission. *Technical Manual of the FIAF Preservation Commission*. Brussels: FIAF, 1993.
FIAF Programming and Access to Collections Commission. 'PACC Report to the FIAF General Assembly'. Appendix 5.2. FIAF 2010 Oslo Congress Report. Brussels: FIAF, 7 May 2010.
———. 'Report to the FIAF Congress 2003 from the Programming and Access to Collections Commission'. FIAF 2003 Stockholm/Helsinki Congress Report. Brussels: FIAF, May 2003.
'FIAF Programming and Access to Collections Commission Workshop'. Congress Programme. FIAF 2005 Ljubljana Congress, 2005.
FIAF Technical Commission. 'Basic Principles of Digital Archiving'. Resources of the Technical Commission. FIAF, 2013.
———. 'Basic Principles of Digital Archiving'. Resources of the Technical Commission. FIAF, 2016. https://www.fiafnet.org/images/tinyUpload/E-Resources/Commission-And-PIP-Resources/TC_resources/Digital%20Preservation%20Principles%20v2%200.pdf.
———. 'Choosing a Film Scanner'. Resources of the Technical Commission. FIAF, 2016. https://www.fiafnet.org/images/tinyUpload/E-Resources/Commission-And-PIP-Resources/TC_resources/Film%20Scanners%20v1%202.pdf.
———. 'Chossing a Film Scanner'. Resources of the Technical Commission. FIAF, 2012. https://www.fiafnet.org/images/tinyUpload/E-Resources/Commission-And-PIP-Resources/TC_resources/Choosing%20a%20Scanner%20v1.1.pdf.
———. 'Digitisation for Film Archives – Assorted Complications'. Digital Technology Guidance Papers. FIAF, 2012. https://www.fiafnet.org/images/tinyUpload/E-Resources/Commission-And-PIP-Resources/TC_resources/Digital%20Complications%20v1.1.pdf.
———. 'FIAF Technical Commission Recommendation: the Deposit and Acquisition of D-Cinema Elements for Long-term Preservation and Access'. Version 1.0. Digital Technology Guidance Papers. FIAF, 2 September 2010. https://www.fiafnet.org/images/tinyUpload/E-Resources/Commission-And-PIP-Resources/TC_resources/D-Cinema%20deposit%20specifications%20v1%200%202010-09-02%20final%201.pdf.
———. 'Film Duplication Resolution Tests'. Resources of the Technical Commission. FIAF, 2016. https://www.fiafnet.org/pages/E-Resources/Duplication-Tests.html.
———. 'The Digital Statement. Part I'. Resources of the Technical Commission. FIAF, 2018. https://www.fiafnet.org/pages/E-Resources/Digital-Statement.html.
———. 'The Digital Statement. Part II: Preservation Scans'. Work in Progress Version, Early 2021. FIAF, 2022.
FIAF Net. International Federation of Film Archives. 'FIAF Timeline'. Accessed 23 December 2021. https://www.fiafnet.org/pages/History/FIAF-Timeline.html.
Fournier, Caroline, and Jeanne Pommeau. 'The Idea of Progress in the Restoration and Dissemination of Film Heritage: Utopias and Perspectives'. Presented at the FIAF 2019 Lausanne Symposium, Lausanne, April 2019.
Friend, Michael. 'FIAF Technical Commission Meeting Report'. FIAF 2000 London Congress Report. Brussels: FIAF, 8 June 2000.
———. 'Specificity of Film and Effects of Digital Restoration'. Presented at the FIAF 1998 Prague Symposium, Prague, 26 April 1998.
Fuji and Sony. 'Technical Debriefing: Two Possibilities of Leading-Edge Technology for Film Archiving'. Presented at the FIAF 2007 Tokyo Symposium, Tokyo, 2007.
Gant, Anne, and Giovanna Fossati. 'Some Considerations When Setting Up a Digitization Workflow'. Digital Technology Guidance Papers. FIAF, 2012.

https://www.fiafnet.org/images/tinyUpload/E-Resources/Commission-And-PIP-Resources/TC_resources/Setting%20up%20a%20digitization%20workflow-%20FIAF%20tech%20paper%20V1.1.pdf.

Klaue, Wolfgang. In *Rediscovering the Role of Film Archives: To Preserve and To Show, Symposium Proceedings, FIAF 1989 Lisbon Congress*, edited by Cinemateca Portugesa. Lisbon: Cinemateca Portuguesa / FIAF, 1990.

Koerber, Martin, and Alexander Horwath. 'The Old Life. Reframing Film Restoration'. Presented at the FIAF 2016 Bologna Symposium, Bologna, June 2016.

Kubelka, Peter. 'Colonisation by Progress, the future of cinema'. In *FIAF 2001 Rabat Congress Report and Minutes*, 32. Brussels: FIAF, 2001.

———. 'What Is Preservation? What Is Restoration? What Is Film?' FIAF 2000 London Congress Minutes and Report. Brussels: FIAF, 2000.

Mazzanti, Nicola. 'Digital vs. Analog, or "A Horse Is a Horse"'. Presented at the FIAF 2016 Bologna Symposium, Bologna, June 2016.

McConnachie, Stephen, and Helen Edmunds. 'How to Digitise 10'000 Films from 10 Archives in 5 Years and Live to Tell the Story...' Presented at the FIAF 2015 Canberra Symposium, Canberra, 2015.

Mohsenin, Maral, Rashad Qasimov, Iris Elezi, and Vladimir Angelov. 'Socio-Political Diversity of Film Archives: Transitions from the Past to the Future'. Roundtable with the Central State's Film Archive of Albania, the Azerbaijan State Film Fund and the Cinematheque of Macedonia presented at the FIAF 2019 Lausanne Symposium, Lausanne, April 2019.

Ng, Yvonne, Jérôme Martinez, Kieran O'Leary, Reto Kromer, and Bert Lemmens. 'Open Source Tools for Open Source Preservation'. Presented at the FIAF 2018 Prague Symposium, Prague, April 2018.

Nowak, Arne. 'Digital Cinema Technologies from the Archive's Perspective'. Digital Technology Guidance Papers. FIAF, 2012. https://www.fiafnet.org/images/tinyUpload/E-Resources/Commission-And-PIP-Resources/TC_resources/Nowak%20-%20Digital%20Cinema%20Technologies%20v2.0%20FIAF-TC_final%20V1.1.pdf.

Okajima, Hisashi. 'Mission Statement by Hisashi Okajima as a Candidate for FIAF's Executive Committee Membership'. FIAF 2003 Stockholm/Helsinki Congress Report. Brussels: FIAF, 2003.

Oliveira, Joao S. de. 'Technical Commission 2001-2003'. FIAF 2003 Stockholm/Helsinki Congress Report. Brussels: FIAF, May 2003. Appendix 2.1.1.

Orbanz, Eva. 'Report of the President on Behalf of the Executive Committee'. In *FIAF 2008 Paris Congress Minutes*. Brussels: FIAF, 2008.

Pappas, Lydia, Laure Gaudenzi, Valentina Rossetto, Nicolas Petiot, and Deborah Steinmetz. 'Session 4: Specialized Archives'. Presented at the FIAF 2019 Lausanne Symposium, Lausanne, April 2019.

'Programme of the Symposium: "Cinema 1900-1906" and of the Symposium: "From Film to Videotape and from Videotape to Film"'. FIAF 1978 Brighton Congress Report. Brussels: FIAF, 1978.

Read, Paul, Pat Loghney, Alfonso Del Amo García, Noël Desmet, and Patricia De Filippi. 'Museology, the Archive as a Record of Film Technology'. Presented at the FIAF 2006 Sao Paolo Symposium, Sao Paolo, 2016.

'Report from the Programming Subcommittee'. FIAF 1990 Havana Congress Report, 1990.

Robert Daudelin. 'Introduction'. In *Rediscovering the Role of Film Archives: To Preserve and To Show, Symposium Proceedings, FIAF 1989 Lisbon Congress*, edited by Cinemateca Portugesa. Lisbon: Cinemateca Portuguesa / FIAF, 1990.

Rosen, Robert. In *Rediscovering the Role of Film Archives: To Preserve and To Show, Symposium Proceedings, FIAF 1989 Lisbon Congress*, edited by Cinemateca Portugesa, 58–62. Lisbon: Cinemateca Portuguesa / FIAF, 1989.

Ruivo, Céline. 'FIAF Technical Commission Report to the General Assembly'. FIAF 2017 Los Angeles Congress Report. Brussels: FIAF, May 2017. Appendix 7.

Ruivo, Céline, and Anne Gant. 'Digital Statement. Part V'. Resources of the Technical Commission. FIAF, April 2019.

https://www.fiafnet.org/images/tinyUpload/2019/04/Preservation_Digital_Statement_Final.pdf.
Saetervadet, Torkell. ‘D-Cinema Equipment Frequently Asked Questions’. Digital Technology Guidance Papers. FIAF, 2012. https://www.fiafnet.org/images/tinyUpload/E-Resources/Commission-And-PIP-Resources/TC_resources/D-Cinema%20FAQs%20release%20FIAF%202012%20V1.1.pdf.
———. *FIAF Digital Projection Guide*. Brussels: FIAF, 2012.
———. *The Advanced Projection Manual*. Oslo: Norwegian Film Institute and FIAF, 2006.
Schou, Henning. ‘Report from the Preservation Commission’. FIAF 1993 Mo I Rana Congress Report. Brussels: FIAF, May 1993.
———. ‘Report from the Technical Commissions’. FIAF 1994 Bologna Congress Report. Brussels: FIAF, April 1994. Appendix 5.3.1.
‘Second Century Forum’. In *FIAF 2010 Oslo Congress Report*, 2. Brussels: FIAF, 2010.
‘Second Century Forum: The Role of FIAF’. In *62nd FIAF Congress*, 28–29. Congress Programme. Sao Paolo: Cinemateca brasileira, 2006.
‘Symposium: Film to Videotape and Videotape to Film - The Present and the Future’. Draft Programme Proposal for FIAF 1978 Brighton Congress. Brighton, 1978.
‘The First Hundred Years... the Next Hundred Years’. Symposium. FIAF 1995 Los Angeles Congress, 1995.
‘The Future of Film Archives’. In *FIAF 2001 Rabat Congress Report and Minutes*, 30–31. Brussels: FIAF, 2001.
‘The Futurology of Film Archiving’. Symposium. FIAF 2000 London Congress, 6 June 2000.
‘UNESCO Document: Possible International Instrument Concerning the Preservation of Moving Images’. FIAF 1978 Brighton Congress Report. Brussels: FIAF, 1978.
Verscheure, Jean-Pierre. ‘The Conservation of the Heritage of the Film Spectacle’. In *FIAF 2007 Tokyo*, 8. Congress Programme. Tokyo: National Film Center, 2007.
Wallmüller, Julia, and Tom Geldhauser. ‘Restoration of Werner Nekes’ Uliisses’. Presented at The Reel Thing, FIAF 2016 Bologna Symposium, Il Cinema Ritrovato, Bologna, 26 June 2016.
Walsh, David. ‘FIAF Technical Commission End of Year Report’. FIAF 2015 Canberra Congress Report. Brussels: FIAF, 23 March 2015. Appendix 7.
———. ‘FIAF Technical Commission End of Year Report to the FIAF General Assembly 2014’. FIAF 2014 Skopje Congress Report. Brussels: FIAF, 14 April 2014. Appendix 4.1.
———. ‘FIAF Technical Commission End of Year Report to the General Assembly’. FIAF 2013 Barcelona Congress Report,. Brussels: FIAF, 4 April 2013. Appendix 4.1.
———. ‘FIAF Technical Commission End-Term Report to the FIAF General Assembly 2012’. FIAF 2012 Beijing Congress Report. Brussels: FIAF, 13 April 2012. Appendix 4.3.
———. ‘Restoration Rules’. Presented at The Reel Thing, FIAF 2016 Bologna Symposium, Il Cinema Ritrovato, Bologna, 26 June 2016.
Wengström, Jon. ‘Digitizing Analog Collections. Selection and Curatorial Policies’. Presented at the FIAF 2015 Canberra Symposium, Canberra, 14 April 2015.
‘What Is Film? FIAF Technical Commission Workshop’. Congress Programme. FIAF 2005 Ljubljana Congress, 2005.

2.4 Joint Technical Symposiums

Allen, Norman, M. Hayes, Michelle Edge, T.S. Jewilt, and Karel Brems. ‘Factors Influencing the Degradation of Polyester Based Cinematographic Film and Audio-Visual Tapes’. In *Archiving the Audiovisual Heritage. Third Joint Technical Symposium*, edited by George Boston, 40–51. Proceedings of the 3rd JTS in Ottawa on May 3-5, 1990. Rushden: Stanley L Hunt (Printers), 1992.
AMIA, ed. *JTS 2004 Programme. Preserving the Audiovisual Heritage – Transition and Access*. Toronto: AMIA, 2004.
———, ed. *JTS 2007 Programme: Audiovisual Heritage and the Digital Universe*. Toronto: AMIA, 2007.

Aubert, Michèle, and Richard Billaud, eds. *Image and Sound Archiving and Access: The Challenges of the 3rd Millennium. Proceedings of the (Fifth) Joint Technical Symposium*. Proceedings of the 5th JTS in Paris on January 20-22, 2000. Paris: CNC, 2000.
Bavi-Vilmont, Léon. 'The Effects of Atmospheric Pollutants SO2 and NO2 on CD-Rom and CD-R'. Poster Presentation presented at the JTS 2000: Image and Sound Archiving and Access. The Challenges of the 3rd Millennium, Paris, 20 January 2000.
Bigourdin, Jean-Louis, and James M. Reilly. 'Vinegar Syndrome: The Effectiveness of Storage Conditions to Control Vinegar Syndrome'. In *Image and Sound Archiving and Access: The Challenges of the 3rd Millennium. Proceedings of the (Fifth) Joint Technical Symposium*, edited by Michèle Aubert and Richard Billaud, 14–34. Paris: CNC, 2000.
Boston, George, ed. *Archiving the Audiovisual Heritage. Third Joint Technical Symposium*. Proceedings of the 3rd JTS in Ottawa on May 3-5, 1990. Rushden: Stanley L Hunt (Printers, 1992.
———. 'Ethical Questions Relating to the Uses of New Technology in Audio-Visual Archives'. In *Technology and Our Audiovisual Heritage. Technology's Role in Preserving the Memory of the World. Fourth Joint Technical Symposium*, edited by George Boston, 17–18. Proceedings of the 4th JTS in London on January 27-29, 1995. Downbarn: Stantonbury Parish Print, 1999.
———. 'Preface'. In *Technology and Our Audiovisual Heritage. Technology's Role in Preserving the Memory of the World. Fourth Joint Technical Symposium*, edited by George Boston, 1–3. Proceedings of the 4th JTS in London on January 27-29, 1995. Downbarn: Stantonbury Parish Print, 1999.
———, ed. *Technology and Our Audiovisual Heritage. Technology's Role in Preserving the Memory of the World. Fourth Joint Technical Symposium*. Proceedings of the 4th JTS in London on January 27-29, 1995. Downbarn: Stantonbury Parish Print, 1999.
Brems, Karel. 'The Archival Quality of Film Bases'. In *Archiving the Audiovisual Heritage. A Joint Technical Symposium*, edited by Eva Orbanz, 31–36. Proceedings of the 2nd JTS in Berlin on May 20-22, 1987. Berlin-West: Stiftung Deutsche Kinemathek, 1988.
Brunetaud, Philippe. 'Restauration de films à parti de formats d'imags autres que le 35mm ou le 16mm. Eléments de réflexion à partir de l'expérience du service des archives du film et du dépôt légal du Centre national de la cinématographie'. In *Image and Sound Archiving and Access: The Challenges of the 3rd Millennium. Proceedings of the (Fifth) Joint Technical Symposium*, edited by Michèle Aubert and Richard Billaud, 187–89. Proceedings of the 5th JTS in Paris on January 20-22, 2000. Paris: CNC, 2000.
Bubestinger-Steindl, Peter. 'Review and Comparison of FFV1 versus Other Lossless Video Codecs for Long-Term Preservation'. In *Sustainable Audiovisual Collections Through Collaboration: Proceedings of the 2016 Joint Technical Symposium*, edited by Rachael Stoeltje, Vicki Shively, George Boston, Lars Gaustad, and Dietrich Schüller, 153–59. Proceedings of JTS 2016 in Singapore on March 7-9, 2016. Bloomington: Indiana University Press, 2017.
Carou, Alain. 'Twenty Years After: Degradation Survey of a Large Collection of Optical Discs'. Presented at the JTS 2004: Preserving the Audiovisual Heritage – Transition and Access, Toronto, June 2004.
Cavena, Dave. 'Archiving Movies in a Digital World'. Presented at the JTS 2007: Audiovisual Heritage and the Digital Universe, Toronto, 28 June 2007.
Collard, Paul, and Craig German. 'The Motion Picture Archive: A Real-World Implementation'. Presented at the JTS 2007: Audiovisual Heritage and the Digital Universe, Toronto, 28 June 2007.
Crisp, Grover, and Michael Friend. 'Welcome to JTS 2004'. In *JTS 2004 Programme*, edited by AMIA. JTS 2004: Preserving the Audiovisual Heritage – Transition and Access, Toronto, 2004.
———. 'Welcome to JTS 2007'. In *JTS 2007 Programme*, edited by AMIA. JTS 2007: Audiovisual Heritage and the Digital Universe. Toronto, 2007.
David, Morgan, and Yuji Sekiguchi. 'The Role of Optical Storage Technologies in Future Digital Archives'. In *Sustainable Audiovisual Collections Through Collaboration: Proceedings of the 2016 Joint Technical Symposium*, edited by Rachael Stoeltje, Vicki Shively, George Boston, Lars Gaustad, and Dietrich Schüller, 170–76. Proceedings of JTS 2016 in Singapore on March

7-9, 2016. Bloomington: Indiana University Press, 2017.
DeVincent, Daniel. ‘Spatial Resolutions: Restoring Motion Pictures at 4K Resolution’. Presented at the JTS 2007: Audiovisual Heritage and the Digital Universe, Toronto, 28 June 2007.
Edge, Michele, and Joan Whitehead. ‘The Decay of Polymers in Information Storage Carriers’. In *Technology and Our Audiovisual Heritage. Technology’s Role in Preserving the Memory of the World. Fourth Joint Technical Symposium*, edited by George Boston, 19–30. Proceedings of the 4th JTS in London on January 27-29, 1995. Downbarn: Stantonbury Parish Print, 1999.
Fairall, Charles. ‘BFI Film Forever: Unlocking Film Heritage’. In *Sustainable Audiovisual Collections Through Collaboration: Proceedings of the 2016 Joint Technical Symposium*, edited by Rachael Stoeltje, Vicki Shively, George Boston, Lars Gaustad, and Dietrich Schüller, 10–15. Proceedings of JTS 2016 in Singapore on March 7-9. 2016. Bloomington: Indiana University Press, 2017.
Fontaine, Jean-Marc. ‘Eléments de caractérisation de la qualité initiale et du vieilissement des disques CD-R’. In *Image and Sound Archiving and Access: The Challenges of the 3rd Millennium. Proceedings of the (Fifth) Joint Technical Symposium*, edited by Michèle Aubert and Richard Billaud, 113–27. Proceedings of the 5th JTS in Paris on January 20-22, 2000. Paris: CNC, 2000.
Fornaro, Peter, and Rudolf Gschwind. ‘Monolith. Migration-Less Long Term Digital Storage for Archives’. Presented at the JTS 2010: Digital Challenges and Digital Opportunities in Audiovisual Archiving, Oslo, 3 May 2010.
Fossati, Giovanna. ‘Images for the Future’. Presented at the JTS 2007: Audiovisual Heritage and the Digital Universe, Toronto, 28 June 2007.
Galt, John. ‘Quality Control in Digital Cinematography’. Presented at the JTS 2007: Audiovisual Heritage and the Digital Universe, Toronto, 28 June 2007.
Glen, William, John Galt, and James Pearman. ‘How Many Pixels in Lawrence of Arabia?’ Presented at the JTS 2004: Preserving the Audiovisual Heritage – Transition and Access, Toronto, June 2004. https://web.archive.org/web/20070817110721/http://www.jts2004.org/english/proceedings/Galt.html.
Gregor, Ulrich. ‘The Ethics of Restoration’. In *Joint Technical Symposium 1987: Archiving the Audiovisual Heritage*, edited by Eva Orbanz, 139. Proceedings of the 2nd JTS in Berlin on May 20-22, 1987. Berlin-West: Stiftung Deutsche Kinemathek, 1988.
Gschwind, Rudolf, Sabine Süsstrunk, and Bernard Besserer. ‘Dust BW: Detection of Dust and Scratches on Photographic Silver Halide (Black/White) Material by Polarized Dark Field Illumination’. Presented at the JTS 2010: Digital Challenges and Digital Opportunities in Audiovisual Archiving, Oslo, 3 May 2010.
Harald Brandes. ‘Digitilization: A Solution for Old, New and Current Restoration Deficits?’ In *Image and Sound Archiving and Access: The Challenges of the 3rd Millennium. Proceedings of the (Fifth) Joint Technical Symposium*, edited by Michèle Aubert and Richard Billaud, 156–63. Proceedings of the 5th JTS in Paris on January 20-22, 2000. Paris: CNC, 2000.
Harrison, Helen P. ‘Preface’. In *Joint Technical Symposium 1987: Archiving the Audiovisual Heritage*, edited by Eva Orbanz, 7–9. Proceedings of the 2nd JTS in Berlin on May 20-22, 1987. Berlin-West: Stiftung Deutsche Kinemathek, 1988.
Heiber, Robert. ‘Abandoning Analog: The Case for Digital Audio Archiving’. Presented at the JTS 2004: Preserving the Audiovisual Heritage – Transition and Access, Toronto, June 2004.
Hoeller, Franz. ‘DeepRestore – AI Techniques for Digital Film Restoration’. Presented at the JTS 2019: Preserve the Legacy, Celebrate the Future, Hilversum, September 2019.
Jonassen, Erlend. ‘Digital Cinema – Bringing Film Classics Back to the Cinema Screen’. Presented at the JTS 2010: Digital Challenges and Digital Opportunities in Audiovisual Archiving, 3 May 2010.
Joyeux, Laurent, Samia Boukir, and Bernard Besserer. ‘Digital Tracking and Removal of Line Scratches’. In *Image and Sound Archiving and Access: The Challenges of the 3rd Millennium. Proceedings of the (Fifth) Joint Technical Symposium*, edited by Michèle Aubert and Richard Billaud, 190–95. Proceedings of the 5th JTS in Paris on January 20-22, 2000. Paris: CNC, 2000.

Kershaw, Don. ‘Electronic Correction of Archive Film’. In *Archiving the Audiovisual Heritage. Third Joint Technical Symposium*, 161–63. Proceedings of the 3rd JTS in Ottawa on May 3-5, 1990. Rushden: Stanley L Hunt (Printers), 1992.
Kromer, Reto. ‘Let’s Emulate the Sound of Colours!’ In *Sustainable Audiovisual Collections Through Collaboration: Proceedings of the 2016 Joint Technical Symposium*, edited by Rachael Stoeltje, Vicki Shively, George Boston, Lars Gaustad, and Dietrich Schüller, 5–9. Proceedings of JTS 2016 in Singapore on March 7-9, 2016. Bloomington: Indiana University Press, 2017.
Krsljanin, Milan. ‘HDVS as a Digital Motion Picture Archival Medium’. In *Technology and Our Audiovisual Heritage. Technology’s Role in Preserving the Memory of the World. Fourth Joint Technical Symposium*, edited by George Boston, 151–54. Proceedings of the 4th JTS in London on January 27-29, 1995. Downbarn: Stantonbury Parish Print, 1999.
Lindner, James, Jim Wheeler, John Spencer, and Richard Hess. ‘Digital Storage Options - A Transitional Perspective How Current Storage Technologies Can Facilitate Longevity and Access’. Presented at the JTS 2007: Audiovisual Heritage and the Digital Universe, Toronto, 28 June 2007.
Mazzanti, Nicola. ‘FIRST’. Presented at the JTS 2004: Preserving the Audiovisual Heritage – Transition and Access, Toronto, June 2004.
Mazzanti, Nicola, and Paul Read. ‘Film Archives: Needs and Requirements in the D-Cinema Age’. Presented at the JTS 2007: Audiovisual Heritage and the Digital Universe, Toronto, 28 June 2007.
Nowak, Arne. ‘Digital Archiving of Audiovisual Material – Pilot Projects in Europe’. Presented at the JTS 2010: Digital Challenges and Digital Opportunities in Audiovisual Archiving, Oslo, 3 May 2010.
Nowak, Arne, Luis Nunes, and Ernesto Santos. ‘The EDCINE Project for Archives: A System for Conservation and Access Based on MXF and JPEG 2000’. Presented at the JTS 2007: Audiovisual Heritage and the Digital Universe, Toronto, 28 June 2007.
Orbanz, Eva, ed. *Archiving the Audiovisual Heritage. A Joint Technical Symposium*. Proceedings of the 2nd JTS in Berlin on May 20-22, 1987. Berlin-West: Stiftung Deutsche Kinemathek, 1988.
Pfluger, David. ‘16mm Reversal Material in the Light of the Transfer to High Definition Video’. Presented at the JTS 2010: Digital Challenges and Digital Opportunities in Audiovisual Archiving, Oslo, 3 May 2010.
Pinel, Vincent. ‘The Responsibility in Daily Work’. In *Joint Technical Symposium 1987: Archiving the Audiovisual Heritage*, edited by Eva Orbanz, 144–46. Proceedings of the 2nd JTS in Berlin on May 20-22, 1987. Berlin-West: Stiftung Deutsche Kinemathek, 1988.
Poynton, Charles. ‘An Archivist’s Introduction to Digital Image Science’. Presented at the JTS 2004: Preserving the Audiovisual Heritage – Transition and Access, Toronto, June 2004.
Raymond Borde. ‘The Moral Responsibility’. In *Joint Technical Symposium 1987: Archiving the Audiovisual Heritage*, edited by Eva Orbanz, 141–44. Proceedings of the 2nd JTS in Berlin on May 20-22, 1987. Berlin-West: Stiftung Deutsche Kinemathek, 1988.
Ristow, Jürgen. ‘Digital Film Restoration: First Experiences and Results’. In *Technology and Our Audiovisual Heritage. Technology’s Role in Preserving the Memory of the World. Fourth Joint Technical Symposium*, edited by George Boston, 131–35. Proceedings of the 4th JTS in London on January 27-29, 1995. Downbarn: Stantonbury Parish Print, 1999.
Scammell, David. ‘Digital Techniques in Film Image Restoration - The Human Touch’. In *Technology and Our Audiovisual Heritage. Technology’s Role in Preserving the Memory of the World. Fourth Joint Technical Symposium*, 144–50. Proceedings of the 4th JTS in London on January 27-29, 1995. Downbarn: Stantonbury Parish Print, 1999.
Schallauer, Peter, and Franz Hoeller. ‘Digital Video Damage in Archives: Detect, Repair, and Prevent—Results from the DAVID Project’. In *Sustainable Audiovisual Collections Through Collaboration: Proceedings of the 2016 Joint Technical Symposium*, edited by Rachael Stoeltje, Vicki Shively, George Boston, Lars Gaustad, and Dietrich Schüller, 123–30. Proceedings of JTS 2016 in Singapore on March 7-9, 2016. Bloomington: Indiana University Press, 2017.
Silverman, Leon. ‘Opening Remarks’. Presented at the JTS 2004: Preserving the Audiovisual Heritage

– Transition and Access, Toronto, June 2004.
Stensland, Jorgen. ‘Norway – on the Brink of a Digital Roll-Out’. Presented at the JTS 2010: Digital Challenges and Digital Opportunities in Audiovisual Archiving, Oslo, 3 May 2010.
Stoeltje, Rachael, Vicki Shively, George Boston, Lars Gaustad, and Dietrich Schüller, eds. *Sustainable Audiovisual Collections Through Collaboration: Proceedings of the 2016 Joint Technical Symposium*. Proceedings of JTS 2016 in Singapore March 7-9, 2016. Bloomington: Indiana University Press, 2017.
Storm, William. ‘The Archivist’s Requirement of a Format’. In *Archiving the Audiovisual Heritage. Third Joint Technical Symposium*, 176–80. Proceedings of the 3rd JTS in Ottawa on May 3-5, 1990. Rushden: Stanley L Hunt (Printers), 1992.
Teruggi, Daniel. ‘PrestoSpace: Preservation Toward Storage and Access Standardised Practices for Audiovisual Contents in Europe’. Presented at the JTS 2004: Preserving the Audiovisual Heritage – Transition and Access, Toronto, June 2004.
Trochu, Xavier, Majed Chambah, and Bernard Besserer. ‘Restitution numérique des couleurs de films’. In *Image and Sound Archiving and Access: The Challenges of the 3rd Millennium. Proceedings of the (Fifth) Joint Technical Symposium*, edited by Michèle Aubert and Richard Billaud, 147–55. Proceedings of the 5th JTS in Paris on January 20-22, 2000. Paris: CNC, 2000.
Trock, Jacob. ‘Permanence of CD-R Media’. In *Image and Sound Archiving and Access: The Challenges of the 3rd Millennium. Proceedings of the (Fifth) Joint Technical Symposium*, edited by Michèle Aubert and Richard Billaud, 104–12. Proceedings of the 5th JTS in Paris on January 20-22, 2000. Paris: CNC, 2000.
Verbruggen, Erwin, Dave Rice, Bert Lemmens, Jérôme Martinez, Ashley Blewer, Emanuel Lorrain, Antonella Fresa, and Claudio Prandoni. ‘PREFORMA and the MediaConch Project: Open-Source Tools for Open Standards’. In *Sustainable Audiovisual Collections Through Collaboration: Proceedings of the 2016 Joint Technical Symposium*, edited by Rachael Stoeltje, Vicki Shively, George Boston, Lars Gaustad, and Dietrich Schüller, 131–36. Proceedings of JTS 2016 in Singapore March 7-9, 2016. Bloomington: Indiana University Press, 2017.
Watkins, Paul. ‘Digital Restoration of Film: The Kodak Cineon Digital Film System’. In *Technology and Our Audiovisual Heritage. Technology’s Role in Preserving the Memory of the World. Fourth Joint Technical Symposium*, 136–43. Proceedings of the 4th JTS in London on January 27-29, 1995. Downbarn: Stantonbury Parish Print, 1999.
Wheeler, James. ‘An Overview of the D1 and D2 Digital Video Tape Formats’. In *Archiving the Audiovisual Heritage. Third Joint Technical Symposium*, 103–5. Proceedings of the 3rd JTS in Ottawa on May 3-5, 1990. Rushden: Stanley L Hunt (Printers), 1992.

3 Presentations, Festivals, Conferences

Abrusci, Concepcion. ‘Biological Degradation of Film Movies: Support and Gelatins. An Initial Study’. Presented at the Archimedia Seminar, Madrid, December 2001.
Alanen, Antti. ‘Il Cinema Ritrovato, Bologna, 1-8 July 2006’. *Antti Alanen: Film Diary* (blog), 2 July 2006. https://anttialanenfilmdiary.blogspot.com/2006/07/il-cinema-ritrovato-bologna-1-8-july.html.
Alice Plutino. ‘Transformation of Film Experience from Analog to Digital’. Presented at the Udine/Gorizia FilmForum, Online, 2021.
Bagh, Peter von, Gian Luca Farinelli, Mariann Lewinsky, and Serge Toubiana. ‘La proiezione dei film del patrimonio tra pellicola e digitale, problemi e possibilità’. Presented at the FIAF Restoration Summer School, Il Cinema Ritrovato, Bologna, 29 June 2012.
Barberis, Gilles, and Lorenzo Rattini. ‘Acoustics for Small Rooms’. Presented at The Reel Thing, Eye International Conference, Amsterdam, 29 May 2017.
Besse, Alain. ‘La Normalisation du numérique’. Presented at the Révolution numérique: et si le cinéma perdait la mémoire?, Cinémathèque française, Paris, October 2011. https://www.canal-u.tv/video/cinematheque_francaise/la_normalisation_du_numerique_intervention_d_alain_bes

se.7755.
Besserer, Bernard. ‘Retour d’expériences : Recherche et valorisation autour de la restauration numérique des images cinématographiques’. Presented at the Congress SPECIF, 2004.
Blot-Wellens, Camille, Christophe Dupin, Martin Koerber, and Peter Bagrov. ‘Physical Characteristics of Early Films as Aids to Identification. New, Expanded Edition of Brown’s 1990 Book’. Presented at the Il Cinema Ritrovato, Bologna, 23 July 2021. https://www.youtube.com/watch?v=lKgKhvTmhE8.
Chong, Man Nang. ‘Safeguarding the Investment in D-Cinema’. Presented at the IEE Conference: Projecting the Digital Future of Cinema Conference, London, 18 November 2003.
Christensen, Thomas. ‘Danish Film Heritage in a Digital Context’. Presented at the Archimages Conference, INP, Paris, November 2008.
———. ‘Passive Preservation & Active Access – Long Term and Short Term Obligations of a Film Archive’. Presented at the FIAF Restoration Summer School, Il Cinema Ritrovato, Bologna, June 2014.
———. ‘Preservation and Digitising for Now and the Future, the Model of the Danish Film Institute’. Presented at the Budapest Classics Film Marathon, Budapest, September 2019.
———. ‘Restoration – an Objective or Creative Process’. Presented at the Digital Film Restoration within Archives, Krems, Austria, 23 September 2011.
Cormier, Laurent, Nicola Mazzanti, Aneglo Cosimano, Lars Karlsson, Tommaso Vergallo, and Christophe Massie. ‘Roundtable. Pour une conservation numérique du cinéma?’ Presented at the Toute la mémoire du monde, Cinémathèque française, Paris, 2013. https://www.canal-u.tv/video/cinematheque_francaise/pour_une_conservation_numerique_du_cinema_table_ronde.14685.
Crisp, Grover. ‘Digital Film Restoration at Sony’. Presented at The Reel Thing, Il Cinema Ritrovato, Bologna, July 1998.
———. ‘Two Projects Exploring the Use of Traditional and Digital Technologies for Restoring Motion Picture Film’. Presented at the Archimedia Seminar, Il Cinema Ritrovato, Bologna, 1 July 2001.
Despas, Bruno. ‘Leçons de 6 années d’expérience numérique d’un laboratoire de restauration’. Presented at the Archimedia Seminar, Il Cinema Ritrovato, Bologna, 1 July 2001.
‘Economies of the Commons 3. Sustainable Futures of Digital Archives.’ Conference presented at the Images for the Future, Amsterdam, October 2012. https://web.archive.org/web/20130706182500/http://ecommons.eu/.
Ede, François. ‘La Conservation des films : le syndrome numérique’. Cinémathèque française, Paris, October 2011. https://www.canal-u.tv/video/cinematheque_francaise/la_conservation_des_films_le_syndrome_numerique_intervention_de_francois_ede_et_ronald_boullet.7763.
Elsaesser, Thomas. ‘On Obsolescence’. Presented at the 9th Orphans Film Symposium, Eye Filmmuseum Netherlands, Amsterdam, 30 March 2014. https://archive.org/details/orphans2014elsaesser.
Flückiger, Barbara. ‘Ästhetik von analogen und digitalen Artefakten’. Presented at the Die digitale Herausforderung - Perspektiven für Archive, Film- und Kinomacher, Berlin, Deutsche Kinemathek, June 2008.
Fossati, Giovanna. ‘The Nederlands FILMMUSEUM Walking Digital Ways to Film Restoration’. Presented at the Le Giornate del cinema muto, Sacile, 2002.
Fossati, Giovanna, and Eef Masson. ‘A Car Ride in the Pyrenees: The FILMMUSEUM’s Approach to Digital Restoration and Its Contribution to the Diamant Project’. Presented at the Archimedia Seminar, Il Cinema Ritrovato, Bologna, 1 July 2001.
Frappat, Marie. ‘Pour une histoire de la restauration des films : des premières reconstructions aux interventions en numérique’. Presented at the Festival Toute la mémoire du monde, Cinémathèque française, Paris, 2015.
Galt, John. ‘Resolution Limitations of Film Scanner: More Pixels Do Not Mean More Resolution’. Presented at The Reel Thing XXII, Hollywood, California, 22 August 2009.
Garandeau, Eric. ‘Introduction’. Presented at the Lancement du plan de restauration et de numérisation des films du patrimoine, CNC, Paris, 2 April 2012.

Helt, François. 'Digital film restoration tools'. Presented at the Archimedia Seminar, Il Cinema Ritrovato, Bologna, 2 July 2001.
Helt, François, and Valérie La Torre. 'Advances in Digital Restoration for Addressing the Vinegar Syndrome Effects', 4 1-4 7. London, 2001.
Il Cinema Ritrovato 1998. Festival Programme. Bologna: Cineteca di Bologna, 1998.
Il Cinema Ritrovato 2001. Festival Programme. Bologna: Cineteca di Bologna, 2001.
Il Cinema Ritrovato 2001. Festival Catalogue. Bologna: Cineteca di Bologna, 2001.
Jurgens, Marc. 'Filmotech'. Presented at the Cinema Expert Group/Film Heritage Subgroup Meeting, Brussels, 15 October 2010.
Koerber, Martin. 'Film Restoration in Current Digital Post-production Workflows: The Way to Go?' Presented at the Révolution numérique: et si le cinéma perdait la mémoire?, Cinémathèque française, Paris, October 2011. https://www.canal-u.tv/video/cinematheque_francaise/en_film_restoration_in_current_digital_postproduction_workflows_the_way_to_go_martin_koerber.7797.
Kokaram, Anil C., Francis Kelly, Hugh Denman, François Pitié, Rozenn Dahyot, Denis Sidorov, Niall Rea, and Justine Grave. 'Restoring Rory O'More'. Poster Presentation, 2002. http://www.mee.tcd.ie/~sigmedia/Research/RoryOMore.
Kromer, Reto. 'Archivage de l'audiovisuel Dans la jungle des formats de fichier'. Presented at the Toute la mémoire du monde, Cinémathèque française, Paris, March 2019.
Kuutti, Mikko. 'A Digital Agenda for Film Archives'. Presented at the ACE Workshop Management Strategies for Film Archives in the Digital Era, Il Cinema Ritrovato, Bologna, 28 June 2012.
———. 'The Pixel'. Presented at the FIAF Restoration Summer School, Il Cinema Ritrovato, Bologna, June 2014.
'La restauration des films'. *Projection privé*. France Culture, 20 July 2013. https://www.franceculture.fr/emissions/projection-privee/la-restauration-des-films.
Lurin, Christian. 'Le futur des laboratoires cinématographiques'. Presented at the Révolution numérique: et si le cinéma perdait la mémoire?, Cinémathèque française, Paris, October 2011. https://www.canal-u.tv/video/cinematheque_francaise/le_futur_des_laboratoires_cinematographiques_intervention_de_christian_lurin.7760.
Lutz, Kevin. 'Keynote'. Presented at the Digital Preservation Winter School, The Netherlands Institute for Sound & Vision, Hilversum, January 2019. https://vimeo.com/311233890.
Mannoni, Laurent. 'De l'argentique au numérique'. Cinémathèque française, Paris, October 2011. https://www.canal-u.tv/video/cinematheque_francaise/de_l_argentique_au_numerique_intervention_de_laurent_mannoni.7771.
Matheron, Georges, and Jean Serra. 'The Birth of Mathematical Morphology'. Presented at the ISMM 2000, Xerox Center, Palo Alto, California, June 2000.
Mazzanti, Nicola. 'Archives Going Digital: The Issues on the Table'. Presented at the Archimedia Seminar, Il Cinema Ritrovato, Bologna, 1 July 2001.
———. 'DAEFH... What Now?' Presented at the Workshop Management Strategies for Film Archives in the Digital Era, Il Cinema Ritrovato, Bologna, 28 June 2012.
———. 'It Is All in the Workflow, Folks!' Presented at the FIAF Restoration Summer School, Il Cinema Ritrovato, Bologna, June 2014.
MediaAreda. 'No Time to Wait: Standardizing FFV1 and Matroska for Preservation'. Report from the No Time to Wait Conference. Berlin: Deutsche Kinemathek, Zuse Institute Berlin, MediaArea, 2016. https://mediaarea.net/blog/2016/07/26/No-Time-To-Wait-Preservation-FFV1-Matroska-Symposium.
Meyer, Mark-Paul. 'As Seen from the Netherlands'. Presented at the Archimages Conference, INP, Paris, November 2008.
———. 'Ethics in Film Restoration'. Presented at the Archimedia Seminar, London, September 1997.
Mohsenin, Maral. 'Description of Material Defects: From Analog to Digital Film'. Presented at the Resisting Matter: Describing Archival Objects, Lausanne, 3 April 2019.
Mohsenin, Maral, Giovanna Fossati, Juana Suarez, Aboubakar Sanogo, and Karen Chan. 'Global Audiovisual Archiving: North-South Exchange in Knowledge and Practices'. Presented at the

Eye International Conference 2021, Amsterdam, June 2021.
Morley, Steven A. ‘Making Digital Cinema Actually Happen – What It Takes and Who’s Going to Do It’. Presented at the 140th SMPTE Technical Conference and Exhibit, Pasadena, CA, 28 October 1998.
Newham, Mick, Trevor Carter, Greg Moss, and Rod Butler. ‘Digital Disaster Recovery for Audiovisual Collections’. Presented at the UNESCO Memory of the World in the Digital Age Conference, Vancouver, 26 September 2012. http://www.unesco.org/new/fileadmin/MULTIMEDIA/HQ/CI/CI/pdf/mow/VC_Newnham_28_B_1150.pdf.
Nowak, Arne. ‘Fraunhofer Digital Cinema’. Presented at the AMIA Conference, Rochester, 26 September 2007.
Ogden, Clive. ‘A Future for Film’. Presented at the Révolution numérique: et si le cinéma perdait la mémoire?, Cinémathèque française, Paris, October 2011. https://www.canal-u.tv/video/cinematheque_francaise/en_a_future_for_film_lecture_by_clive_ogden.7762.
Pappadà, Guido. ‘Film in a Digital Environment: Basics of Theory and Practice’. Presented at the Archimedia Seminar, Il Cinema Ritrovato, Bologna, 1 July 2001.
Pasterczyk, Bev. ‘Image Is Everything - Protect It! - Kodak Update’. Presented at The Reel Thing XXIX, Hollywood, California, 23 August 2012.
Payne, Alexander, José Manuel Costa, Renato Berta, Gabe Klinger, Pietro Marcello, Jonathan Nossiter, Christian Richter, et al. ‘Il Futuro della pellicola/The Future of Film’. Promoted by FIAF and Cineteca di Bologna presented at the Lezione di Cinema, incontri sur restauro, Il Cinema Ritrovato, Bologna, 1 July 2015. https://www.youtube.com/watch?v=J427vQTxvbc&list=PLx3uAGILdftAgDkjgyYnA-WJGCQqW8sg2&index=12.
Pichard, Hervé, Bruno Despas, and Léon Rousseau. ‘Film Restoration Case Study: Une Partie de Campagne and La Chienne’. Presented at the FIAF Restoration Summer School, Il Cinema Ritrovato, Bologna, June 2014.
Price, Ned, Shawn Belston, and Grover Crisp. ‘Comparing Digital Restoration and Original on Film’. Presented at the Lezioni di Cinema, Il Cinema Ritrovato, Bologna, June 2014.
Purday, Jon. ‘Integrating Europe’s Digitsied Memory’. Presented at the Cinema Expert Group/Film Heritage Subgroup Meeting, Brussels, 9 June 2008.
Rauger, Jean-François, Serge Bozon, Gian Luca Farinelli, Jean-Marie Dreujou, and Angelo Cosimano. ‘Roundtable. Que projetterons-nous demain en salle: quel futur pour la projection pellicule, quelle questions la projection numérique soulève-t-elle?’ Roundtable presented at the Toute la mémoire du monde, Cinémathèque française, Paris, 2015. https://www.canal-u.tv/video/cinematheque_francaise/table_ronde_que_projetterons_nous_demain_en_salle_quel_futur_pour_la_projection_pellicule_quelles_questions_la_projection_numerique_souleve_t_elle.17147.
Read, Paul. ‘Digital Restoration Routes for Archive Films’. Presented at the Archimedia Seminar, London, September 1997.
———. ‘Film Production and the Digital: What Is Changing in the Archival Perspective’. Presented at the Archimedia Seminar, Il Cinema Ritrovato, Bologna, 1 July 2001.
‘Restoration in the Era of New Technologies: Prospects and Risks’. Presented at the Archimedia Seminar, London, September 1997.
Richter, Christian. ‘The Importance of Film’. Il Cinema Ritrovato, Bologna, 29 June 2016.
Rizzi, Alessandro. ‘Alternative Methods for Digital Colour Restoration’. Presented at the Fourth International Conference Colour in Film, London, 2019.
Roux, Martin. ‘Image numérique et image argentique, quelles différences perceptives ?’ Presented at the Toute la mémoire du monde, Cinémathèque française, Paris, 2016. https://vimeo.com/160244246.
Tames, David. ‘Film Restoration at Cineric’. Presented at The Reel Thing, Il Cinema Ritrovato, Bologna, July 1998.
The Nitrate Picture Show. Festival Programme. Rochester: George Eastman House, 2015.
Trumpy, Giorgio, Josephine Diecke, David Pfluger, and Barbara Flückiger. ‘Reconsidering Rigid Procedures of Color Film Digitization: Toning, Lenticular Processes, Chromogenic Stock, and

Mroz-Farbenfilm'. Presented at the Orphan Film Symposium: Radicals, Vienna, June 2019.
'Vers un cinéma hybride? Dialogue avec Jean-Pierre Beauviala'. Presented at the Révolution numérique: et si le cinéma perdait la mémoire?, Cinémathèque française, Paris, October 2011. https://www.canal-u.tv/video/cinematheque_francaise/vers_un_cinema_hybride_dialogue_avec_jean_pierre_beauviala.7767.
Von Sychowski, Patrick. 'Digital Cinema – an Overview'. Presented at the IEE Conference: Projecting the Digital Future of Cinema Conference, London, 18 November 2003.
Wengström, Jon. 'Co-existence of Analogue and Digital Strategies in the Swedish Film Archive'. Presented at the Film:ReStored_01. The Film Heritage Festival, Deutsche Kinemathek, Berlin, 24 September 2016.
Wilson, Peter. 'Compression Mastering for Digital Cinema'. Presented at the IEE Conference: Projecting the Digital Future of Cinema, London, 18 November 2003.
Wiskochil, Steve. 'Digital Restoration at EDS'. Presented at The Reel Thing, Il Cinema Ritrovato, Bologna, July 1998.

4 Press and Magazines

Alan Brakoniecki. Press Release of the Restoration of Snow White and the Seven Dwarfs. Burbank, California: Eastman Kodak Company, 24 June 1993.
'Announcement on Motion Picture Film Business of Fujifilm'. Press Release. Fujifilm, 13 September 2012. https://www.fujifilm.com/news/n120913.html.
Auger, Bob. 'A Stream Cannot Rise above Its Source'. *Image Technology* 80, no. 9 (October 1998): 9–11.
Azoury, Philippe. 'Une image trop propre abolit la distance du temps'. *Libération,* 13 October 2004. http://next.liberation.fr/cinema/0101505149-une-image-trop-propre-abolit-la-distance-du-temps,.
Champagne, Aurélie. 'Cinéma : LTC ferme, que vont devenir toutes ces bobines ?' *L'OBS*, 15 December 2011. https://www.nouvelobs.com/rue89/rue89-cinema/20111215.RUE6487/cinema-ltc-ferme-que-vont-devenir-toutes-ces-bobines.html.
Champeau, Guillaume. 'Les fims numériques doivent être fournis sur pellicule au CNC'. Numerama, 15 July 2013. https://www.numerama.com/magazine/26514-les-films-numeriques-doivent-etre-fournis-sur-pellicule-au-cnc.html.
Champetier, Caroline. 'Solidarité'. *La Lettre AFC,* 5 January 2012. https://www.afcinema.com/Solidarite-7416.html.
Chételat, Valerie. 'Das Ende einer Ära'. Der Bund, 29 September 2011. https://www.derbund.ch/bern/stadt/das-ende-einer-aera/story/15840387.
Dager, Nick. 'Sony to Stop Manufacturing Digital Cinema Projectors'. *Digital Cinema Report* (blog), 26 April 2020. https://www.digitalcinemareport.com/news/sony-stop-manufacturing-digital-cinema-projectors.
Der Tagesspiegel. 'Das Gedächtnis der Bilder', 6 August 2018. https://www.tagesspiegel.de/kultur/digitalisierung-des-filmerbes-das-gedaechtnis-der-bilder/22882062.html.
'Disney Classic "Snow White" Undergoes Complete Digital Restoration at Kodak Facility'. Press Release, 24 June 1993. http://www.thefreelibrary.com/DISNEY+CLASSIC+%27SNOW+WHITE%27+UNDERGOES+.
Webtime Medias. 'Dust ressuscite les films', 24 November 1999. https://www.webtimemedias.com/article/dust-ressuscite-les-films.
Egan, Jack. 'Director László Nemes Goes Inside Auschwitz in Son of Saul'. Below the Line, 7 December 2015. https://www.btlnews.com/awards/director-laszlo-nemes-goes-inside-auschwitz-in-son-of-saul/.
Field, Roy, and Tony Iles. 'Getting the Pictures Together for the Movies'. *Image Technology* 84, no. 6, 7, 9 (2002).

———. ‘Getting the Pictures Together for the Movies’. *Image Technology* 85, no. 1 (February 2003): 33–37.
———. ‘The Colour Difference Process Arrives’. *Image Technology* 85, no. 2 (April 2003): 34–35.
———. ‘Travelling Matte Enters the Digital Age!’ *Image Technology* 85, no. 3 (May 2003): 34–36.
Fisher, Bob. ‘Off to Work We Go: The Digital Restoration of Snow White’. *American Cinematographer* 74, no. 9 (September 1993): 48–54.
———. ‘Tomorrow’s Technology – the ASC and DCI Join Forces to Set Standards for Digital Projection’. *American Cinematographer* 85, no. 1 (January 2004): 121–22.
Fox, Barry. ‘Domino effect conquers the big screen’. *New Scientist Magazine*, no. 1957 (24 December 1994). https://www.newscientist.com/article/mg14419573-500-domino-effect-conquers-the-big-screen/.
Frazer, Bryant. ‘Shot on 35: Why Film Matters for Son of Saul’. Studio daily, 25 February 2016. https://www.studiodaily.com/2016/02/shot-on-35-why-film-matters-for-son-of-saul/.
Fritz, Ben. ‘Movie Film, at Death’s Door, Gets a Reprive’. *The Wall Street Journal*, 29 July 2014. https://www.wsj.com/articles/kodak-movie-film-at-deaths-door-gets-a-reprieve-1406674752?tesla=y&mg=reno64-wsj&cb=logged0.10335595766082406.
Giardina, Carolyn. ‘Kodak Inks Deals With Studios to Extend Film’s Life’. The Hollywood Reporter, 4 February 2015. https://www.hollywoodreporter.com/movies/movie-news/kodak-inks-deals-studios-extend-770300/.
Herbst, Helmut. ‘Na dann priorisiert mal schön’, 2017. https://kinematheken.info/na-dann-priorisiert-mal-schoen/.
———. ‘Wer hat Angst vorm Vinegar-Syndrome?’ Kameramann.de, 11 November 2013. https://www.kameramann.de/branche/wer-hat-angst-vorm-vinegar-syndrome/.
Herlemont, Quentin. ‘Une page de l’histoire du cinema se tourne’. AFCinema, 8 March 2012. https://www.afcinema.com/Une-page-de-l-histoire-du-cinema-se-tourne.html.
Film and Digital Times. ‘History of ARRI in a Century of Cinema’, September 2017, sec. Special Issue. http://www.filmanddigitaltimes.com/wp-content/uploads/2017/09/FDTimes-ARRI-Centennial-84-3.05-200m.pdf.
Holben, Jay. ‘Roger Deakins, ASC, BSC Adopts Digital Capture on the Sci-Fi Thriller In Time’. *American Cinematographer* 92, no. 11 (November 2011): 32–38.
Iles, Tony. ‘What Has Digital Done for Special Effects?’ *Image Technology* 87, no. 4 (July 2005): 8–9.
Imhoof, Markus. ‘Von der römischen Kapelle zurück ins Kino’. *Memoriav Bulletin*, no. 11 (May 2004): 6–7.
James, Nick. ‘Digital Deluge’. *Sight & Sound* 11, no. 10 (October 2001): 20–24.
L’Abominable. ‘Film in the Digital Age?’ Translated by Cinéma du Réel. L’Abominable, March 2013. http://www.l-abominable.org/en/history/a-traduire-en-en_us-largentique-a-lheure-du-numerique/.
Lang, Brent. ‘Magnificent Obsession: David Fincher on His Three-Decade Quest to Bring “Mank” to Life’. Variety, 2020. https://variety.com/2020/film/news/david-fincher-mank-netflix-citizen-kane-1234834134/.
‘Le laboratoire LTC, pan du patrimoine cinematographique français, en liquidation juridique’. *L’Humanité*, 16 December 2011. https://www.humanite.fr/le-laboratoire-ltc-pan-du-patrimoine-cinematographique-francais-en-liquidation-judiciaire.
Long, David, Mike Ryan, and Roger Morton. ‘A New Kodak Color Negative Film for the Digital Future’. *Image Technology* 88, no. 3 (May 2006): 16–23.
Manohla Dargis. ‘An Iranian Director’s Film Class, but without Film’. *The New York Times*, 25 February 2005. https://www.nytimes.com/2005/02/25/movies/an-iranian-directors-film-class-but-without-film.html.
Margutti, Victor L.A. ‘Some Practical Travelling Matte Process’. *American Cinematographer*, November 1960, 670–71, 684–89.
McClintock, Pamela. ‘How Christopher Nolan’s Crusade to Save Film Is Working’. The Hollywood Reporter, October 2014. https://www.hollywoodreporter.com/news/how-christopher-nolans-crusade-save-737191.
Merolli, Stefano. ‘Active-Pixel-Sensor vs. CDD. Who Is the Clear Winner?’ Accessed 6 January

2021. https://meroli.web.cern.ch/lecture_cmos_vs_ccd_pixel_sensor.html.
Pollack, Andrew. ‘Digital Film Restoration Raises Questions About Fixing Flaws’. *New York Times*, 1998.
FlandersToday. ‘Self-Preservation’, 30 March 2011. https://web.archive.org/web/20210101045234/http://www.flanderstoday.eu/arts/self-preservation.
Slater, Jim. ‘BBC R&D Open Day’. *Image Technology* 85, no. 5 (October 2003): 28–33.
———. ‘Digital Cinema: A Major Theme at IBC 2002’. *Image Technology* 9, no. 84 (November 2002): 22–24.
———. ‘Digital Projection Comes to the Hippodrome’. *Image Technology* 79, no. 8 (September 1997): 26–28.
———. ‘DLP Back Projection from TI’. *Image Technology* 83, no. 3 (April 2001): 13–16.
———. ‘IBC 2004’. *Image Technology* 86, no. 5 (October 2004): 8–11.
———. ‘IBC D-Cinema Day’. *Image Technology* 85, no. 1 (February 2003): 26–32.
———. ‘Looking at Digital Cinema from All Aspects’. *Image Technology* 89, no. 1 (February 2007): 20–24.
———. ‘Something Special from Fuji’. *Image Technology* 87, no. 3 (May 2005): 30–32.
———. ‘Standards - Making Sure That WYSIWYG’. *Image Technology* 86, no. 6 (November 2004): 4.
Stanbrook, Alan. ‘As It Was in the Beginning’. *Sight & Sound* 59, no. 1 (1989): 32.
Swart, Sharon, and Carolyn Giardina. ‘Film Fighters All in One Frame’. The Hollywood Reporter, 17 December 2014. http://www.savefilm.org/news/film-fighters-all-in-one-frame-j-j-abrams-judd-apatow-bennett-miller-christopher-nolan-and-edgar-wright/.
Swinton, Peter. ‘A Crazy View of Film?’ *Image Technology* 85, no. 3 (May 2003): 18–19.
———. ‘S16 Mm for HD, up-Convert from SD or Re-Scan?’ *Image Technology* 86, no. 2 (April 2004): 20–24.
———. ‘The Film Look. Can It Really Be Defined?’ *Image Technology* 87, no. 1 (January 2005): 17–22.
———. ‘The Film Look. Can It Really Be Defined? Part II’. *Image Technology* 87, no. 2 (April 2005): 9–12.
‘The Future of Filmmaking: The Future as Seen by Cinematographers’. *American Cinematographer* 81, no. 9 (September 2000): 2–9.
Vandervelde, Thomas. ‘Beyond Silicon: The Search for New Semiconductors’. The Conversation, 10 March 2016. https://theconversation.com/beyond-silicon-the-search-for-new-semiconductors-55795.
Zinsli, Hans Jürg. ‘Ein schwarzer Tag für den Schweizer Film’. *Berner Zeitung*, 30 September 2011. https://www.bernerzeitung.ch/region/bern/ein-schwarzer-tag-fuer-den-schweizer-film/story/30945890.

5 Publications

5.1 On Archives

Academy of Motion Picture Arts and Sciences. *Digital Dilemma*. Los Angeles: A.M.P.A.S, 2007.
Albera, François. ‘Restaurez, restaurez, il en restera toujours quelque chose’. *1895*, no. 40 (2003): 89–101.
Antoniazzi, Luca. ‘Film Heritage and Neoliberalism’. *Museum Management and Curatorship* 34, no. 1 (2 January 2019): 79–95.
———. ‘The Sustainability of Film Heritage: Cultural Policy, Digitalisation and Value’. PhD Thesis, University of Leeds, 2017. http://etheses.whiterose.ac.uk/16918/.
Besser, Howard. *Digital Longevity*. Edited by Maxine Sitts. Andover, MA: Northeast Document Conservation Center, 2000. http://besser.tsoa.nyu.edu/howard/Papers/sfs-longevity.html.
———. ‘Digital Preservation of Moving Image Material?’ *The Moving Image* 1, no. 2 (2001): 39–55.

Borde, Raymond. ‘Film Restoration: Ethical Problems’. *Archives* 1 (1986): 90–98.
———. *Les Cinémathèques*. Lausanne: L’Âge d’Homme, 1983.
Borde, Raymond, and Freddy Buache. *La crise des cinémathèques... et du monde*. Lausanne: L’Age d’Homme, 1997.
Bowser, Eileen. ‘Alcuni principi del restauro del film’. *Griffithiana* 13, no. 38–39 (October 1990): 172–73.
———. ‘Some Principles of Film Restoration’. *Griffithiana* 13, no. 38–39 (October 1990): 170–73.
Bowser, Eileen, and John Kuiper, eds. *A Handbook for Film Archives*. London and New York: Garland Publishing, 1991.
Brown, Harold. *Physical Characteristics of Early Films as Aids to Identification*. Brussels: FIAF, 1990.
Buache, Freddy. ‘Préface’. In *Les Cinémathèques*, by Raymond Borde. Lausanne: L’Âge d’Homme, 1983.
Busche, Andreas. ‘Just Another Form of Ideology? Ethical and Methodological Principles in Film Restoration’. *The Moving Image* 6, no. 2 (2006): 1–29.
Campanini, Sonia. ‘Film Sound in Preservation and Presentation’. PhD Thesis, University of Udine, University of Amsterdam, 2014.
Catanese, Rossella. *Lacune binarie. Il restauro dei film e le tecnologie digitali*. Rome: Bulzoni, 2013.
———. ‘The Digital Restoration of Film’. *BiD: Textos Universitaris de Biblioteconomia i Documentació*, no. 33 (December 2014). http://bid.ub.edu/en/33/catanese3.htm.
Cavallotti, Diego. ‘From Grain to Pixel? Notes on the Technical Dialectics in the Small Gauge Film Archive’. *NECSUS. European Journal of Media Studies*, July 2018. https://necsus-ejms.org/from-grain-to-pixel-notes-on-the-technical-dialectics-in-the-small-gauge-film-archive/.
Cavallotti, Diego, Denis Lotti, and Andrea Mariani. ‘Dalla Vaga Suggestione al Reperto Censito. Note per Una Storia Del Cinema e Dei Media Attraverso Gli Archivi’. In *Scrivere La Storia, Costruire l’archivio. Note per Una Storiografia Del Cinema et Dei Media*, 11–38. Milan: Meltemi, 2021.
Cave, Dylan. ‘Born Digital – Raised an Orphan?’ *The Moving Image* 8, no. 1 (2008): 2–13.
Centre national du cinéma et de l’image animée (CNC). *1969 - 2009. Les Archives françaises du film. Histoire, collections, restauration*. Paris: CNC, 2009.
Cherchi Usai, Paolo. ‘Are All (Analog) Films Orphans?’ *The Moving Image* 9, no. 1 (2009): 1–18.
———. *Burning Passions: Introduction to the Study of Silent Cinema*. 1st ed. London: British Film Institute, 1994.
———. ‘Early Films in the Age of Content; or, “Cinema of Attractions” Pursued by Digital Means’. In *A Companion to Early Cinema*, edited by André Gaudreault, Nicolas Dulac, and Santiago Hidalgo, 525–49. Chichester: John Wiley & Sons, Ltd, 2012.
———. ‘Film as an Art Object’. In *Preserve Then Show*, edited by Dan Niseen, Lisbeth Richter Larsen, Thomas C. Christensen, and Jesper Stub Johnsen, 22–38. Copenhagen: Danish Film Institute, 2002.
———. *Silent Cinema: A Guide to Study, Research and Curatorship*. Bloomsbury Publishing, 2019.
———. *Silent Cinema: An Introduction*. 1st ed. London: British Film Institute, 2000.
———. ‘The Conservation of Moving Images’. *Studies in Conservation* 55, no. 4 (2010): 250–57.
———. *The Death of Cinema. History, Cultural Memory and the Digital Dark Age*. London: British Film Institute, 2001.
———. ‘The Demise of Digital (Print #1)’. *Film Quarterly* 59, no. 3 (2006): 3.
Cherchi Usai, Paolo, Spencer Christiano, Catherine A. Surowiec, and Timothy J. Wagner, eds. *The Art of Film Projection: A Beginner’s Guide*. Rochester: George Eastman Museum, 2019.
Cherchi Usai, Paolo, David Francis, Alexander Horwath, and Michael Loebenstein. *Film Curatorship: Archives, Museums and the Digital Marketplace*. Vienna: Austrian Film Museum/Synema, 2008.
Christensen, Thomas. ‘Restoring a Danish Silent Film – Nedbrudte Nerver’. In *Preserve Then Show*, edited by Dan Niseen, Lisbeth Richter Larsen, Thomas C. Christensen, and Jesper Stub Johnsen, 138–45. Copenhagen: Danish Film Institute, 2002.
Comencini, Luisa, and Mattheo Pavesi, eds. *Restauro, Conservazione et Distruzione dei Film*.

Fondazione Cineteca Italiana. Milan: Il Castoro S.r.l, 2001.
Comte, Christian, and Nicolas Ricordel. ‘Sacha, un Scanner pour s’affranchir du temps’. *Lettre no. 9 des AFF du CNC*, January 2009. http://www.cnc-aff.fr/Internet/LettreInfo/Lettre09/lettre_09.html.
Cot, Jean-Louis. ‘Bucking Broadway : Historique d’une restauration’. *Positif*, no. 504 (February 2003): 90.
Darlington, Jeffrey, Andy Finney, and Adrian Pearce. ‘Domesday Redux: The Rescue of the BBC Domesday Project Videodiscs’. *Microfilm and Imaging Review* 32, no. 4 (January 2003).
Daudelin, Robert. ‘Le syndrome du numérique. Et si le cinéma perdait la mémoire’. *24 images*, no. 155 (2011): 38–39.
Dean, Tacita, and Christopher Nolan. ‘Foreword’. In *The Art of Film Projection: A Beginner’s Guide*, by Paolo Cherchi Usai, Spencer Christiano, Catherine A. Surowiec, and Timothy J. Wagner. Rochester: George Eastman Museum, 2019.
Del Amo García, Alfonso. *Clasificar para preservar*. Mexico: Cineteca Nacional, 2006.
Della Rovere, Lorenzo, Claudio Santancini, Mirco Santi, Gianandrea Sasso, and Simone Venturini. ‘Behind an Experimental Film Heritage: Preservation and Restoration Protocols and Issues’. *Journal of Film Preservation*, no. 89 (November 2013): 115–23.
Despas, Bruno, and François Helt, eds. *La restauration numérique des films cinématographiques*. Paris: CST, CNC, 1997.
Dupin, Christophe. ‘Je t’aime ... Moi Non plus: Ernst Lindgren and Henri Langlois, Pioneers of the Film Archive Movement’. In *The British Film Institute, the Government, and Film Culture, 1933-2000*, edited by Geoffrey Nowell-Smith and Christophe Dupin, 46–68. Manchester & New York: Manchester University Press, 2012.
Edmondson, Ray. *Audiovisual Archiving: Philosophy and Principles*. 3rd ed. Bangkok, Thailand: UNESCO, 2016. https://unesdoc.unesco.org/ark:/48223/pf0000243973.
———. ‘Is Film Archiving a Profession?’ *Film History* 7, no. 3 (1995): 245–55.
Enticknap, Leo. ‘Film Industry’s Conversion from Nitrate to Safety’. In *This Film Is Dangerous. A Celebration of Nitrate Film*, edited by Catherine Surowiec and Roger Smither, 202–12. Brussels: FIAF, 2002.
———. *Film Restoration. The Culture and Science of Audiovisual Heritage*. New York: Palgrave Macmillan, 2013.
———. ‘Have Digital Technologies Reopened the Lindgren/Langlois Debate?’ *Spectator* 27, no. 1 (2007): 10–20.
———. ‘Nitrate’s Still Waiting’. *The Velvet Light Trap* 64, no. 1 (January 2009): 86–87.
Farinelli, Gian Luca, and Nicola Mazzanti. *Il Cinema Ritrovato, Teoria e Metodologia del Restauro cinematografico*. Bologna: Grafis Edizioni, 1994.
Flueckiger, Barbara. ‘Material Properties of Historical Film in the Digital Age’. *NECSUS. European Journal of Media Studies* 1, no. 2 (November 2012): 135–53.
Fontaine, Gilles, and Patrizia Simone. *The Exploitation of Film Heritage Works in the Digital Era*. Strasbourg: European Audiovisual Observatory, 2016. http://ec.europa.eu/newsroom/dae/document.cfm?action=display&doc_id=16404.
Fossati, Giovanna. ‘Film Heritage Beyond the Digital Turn’. Inaugural Lecture, University of Amsterdam. Amsterdam: University of Amsterdam, 28 October 2016.
———. ‘For a Global Approach to Audiovisual Heritage: A Plea for North/South Exchange in Research and Practice’. *NECSUS. European Journal of Media Studies*, no. Autumn 2021_#Futures (13 December 2021). https://necsus-ejms.org/for-a-global-approach-to-audiovisual-heritage-a-plea-for-north-south-exchange-in-research-and-practice/.
———. *From Grain to Pixel: The Archival Life of Film in Transition*. 1st ed. Amsterdam: Amsterdam University Press, 2009.
———. *From Grain to Pixel: The Archival Life of Film in Transition*. 3rd ed. Amsterdam: Amsterdam University Press, 2018.
———. ‘Multiple Originals: The (Digital) Restoration and Exhibition of Early Films’. In *A Companion to Early Cinema*, edited by André Gaudreault, Nicolas Dulac, and Santiago Hidalgo, 550–67. Malden: Wiley-Blackwell, 2012.
———. ‘Obsolescence and Film Restoration: The Case of Colored Silent Films’. *Techné*, no. 37

(2013): 103–6.
———. ‘The Restoration of Beyond the Rocks’. In *Work/s in Progress. Digital Film Restoration within Archives*, edited by Kerstin Perth, Oliver Hanley, and Thomas Ballhausen, 111–20. Vienna: Synema, 2013.
Fossati, Giovanna, and Annie van den Oever, eds. *Exposing the Film Apparatus: The Film Archives as a Research Laboratory*. Amsterdam: Amsterdam University Press, 2016.
———, eds. ‘Introduction: Exposing the Film Apparatus’. In *Exposing the Film Apparatus: The Film Archives as a Research Laboratory*. Amsterdam: Amsterdam University Press, 2016.
Fossati, Giovanna, and Nanna Verhoeff. ‘Beyond Distribution: Some Thoughts on the Future of Archival Films’. In *Networks of Entertainment. Early Film Distribution 1895-1915*, edited by Frank Kessler and Nanna Verhoeff, 331–39. Eastleigh: John Libbey Publishing, 2007.
Frappat, Marie. ‘“L’école bolonaise” de restauration des films’. In *L’avenir de la mémoire: Patrimoine, restauration et réemploi cinématographiques*, edited by André Habib and Michel Marie, 39–45. Villeneuve-d’Ascq: Presses Universitaires du Septentrion, 2013.
———. ‘L’invention de la restauration des films’. PhD Thesis, Université Sorbonne Nouvelle Paris III, 2015.
Frick, Caroline. *Saving Cinema: The Politics of Preservation*. New York: Oxford University Press, 2011.
Galt, John. ‘The Truth about 2K, 4K and the Future of Pixels’. CreativeCOW.net, 2009.
Gamma Group. *The Use of New Technologies Applied to Film Restoration: Technical and Ethical Problems*. Caleidoscopo. Bologna: Gamma, 1996.
———. *Tutti I Colori Del Mondo/All the Colors in the World*. Bologna: Diabasis, 2000.
———. *Vinegar Syndrome. A Handbook*. Bologna: Gamma, 1998.
Gitt, Robert. ‘Bringing Vitaphone Back to Life’. *Film History* 5, no. 3 (1993): 262–74.
Gitt, Robert, and Richard Dayton. ‘Restoring Becky Sharp’. *American Cinematographer* 65, no. 10 (November 1984): 99–106.
Gracy, Karen F. *Film Preservation: Competing Definitions of Value, Use, and Practice*. Chicago: The Society of American Archivists, 2007.
Hendershot, Heather. ‘In Focus: The Death of 16mm?’ *Cinema Journal* 45, no. 3 (2006): 109–12.
Hielscher, Eva. ‘Amateur Film, Benjamin’s Aura and the Archive or: The Archive as Amateur Film’s Age of Technological Reproducibility’. In *The Archive/L’Archivio. Filmforum 2011. Atti Del 18° Convegno Internazionale Di Studi Sul Cinema.*, edited by Alessandro Bordina, Sonia Campanini, and Andrea Mariani, 149–61. Udine: Forum Edizioni, 2012.
Horak, Jan Christopher. ‘Archiving, Preserving, Screening 16mm’. *Cinema Journal* 45, no. 3 (2006): 112–18.
Houston, Penelope. *The Keepers of the Frame. The Film Archives*. London: British Film Institute, 1994.
Jeavons, Clyde. ‘Film Preservation – Why Bother? Part Three’. *Image Technology* 82, no. 4 (May 2000): 16–19.
Keidl, Philipp Dominik, and Christian Gosvig Olesen, eds. ‘Institutionalizing Moving Image Archival Training: Analyses, Histories, Theories’. *Synoptique* 6, no. 1 (2018).
Koerber, Martin. ‘Notes on the Proliferation of Metropolis’. In *Preserve Then Show*, edited by Dan Niseen, Lisbeth Richter Larsen, Thomas C. Christensen, and Jesper Stub Johnsen. Copenhagen: Danish Film Institute, 2002.
Lameris, Bregt. *Film Museum Practice and Film Historiography. The Case of the Nederlands Filmmuseum (1946-2000*. Amsterdam: Amsterdam University Press, 2017.
Lenk, Sabine. ‘Archives and Their Film Collection in a Digital World; Or, What Futures for the Analog Print?’ *The Moving Image* 14, no. 2 (2014): 100–110.
———. ‘Pour une théorie de la restauration de films’. Mediologie, 2008. https://sites.google.com/view/mediologie/m%C3%A9moire-et-m%C3%A9dias/sabine-lenk.
Lipman, Ross. ‘The Gray Zone. A Restorationist’s Travel Guide’. *The Moving Image* 9, no. 2 (2009): 1–29.
Louis, Stéphanie E. *La cinémathèque-musée. Une innovation cinéphile au cœur de la patrimonialisation du cinéma en France (1944-1968)*. Paris: AFRHC, 2020.
Matuszewski, Bolesław. ‘A New Source of History [1898]’. Translated by Laura U. Marks and Diane

Koszarski. *Film History* 7, no. 3 (Autumn 1995): 322–24.
Mazzanti, Nicola. 'Digital Cinema Technologies from the Archive's Perspective. Part 2'. *AMIA Tech Review*, no. 3 (April 2011): 1–15.
———. 'Footnotes'. In *Restauro, Conservazione et Distruzione dei Film*, edited by Luisa Comencini and Mattheo Pavesi. Fondazione Cineteca Italiana. Milan: Il Castoro S.r.l, 2001.
———. 'Introduction'. In *The Use of New Technologies Applied to Film Restoration*, edited by Gamma Group. Bologna: Gamma, 1996.
Meyer, Mark-Paul. 'Work in Progress: Ethics of Film Restoration and New Technologies'. In *The Use of New Technologies Applied to Film Restoration*, edited by Gamma Group. Caleidoscopo. Bologna: Gamma, 1996.
Monizza, Simona. 'Stretching the Borders. Preserving the Installations of Marijke van Warmerdam'. In *Work/s in Progress. Digital Film Restoration within Archives*, edited by Kerstin Perth, Oliver Hanley, and Thomas Ballhausen, 68–79. Vienna: Synema, 2013.
Negri, Sabrina. 'Simulating the Past. Digital Preservation of Moving Images and the "End of Cinema."' *Cinéma & Cie: International Film Studies Journal* 16, no. 26–27 (2016): 45–53.
Niseen, Dan, Lisbeth Richter Larsen, Thomas C. Christensen, and Jesper Stub Johnsen, eds. *Preserve Then Show*. Copenhagen: Danish Film Institute, 2002.
Nowak, Arne. 'Digital Cinema Technologies from the Archive's Perspective'. *AMIA Tech Review*, no. 2 (October 2010): 1–12.
Olesen, Christian Gosvig. 'Film History in the Making: Film Historiography, Digitised Archives and Digital Research Dispositifs'. PhD Thesis, University of Amsterdam, 2017.
Païni, Dominique. *Le temps exposé, le cinéma de la salle au musée*. Paris: Cahiers du cinéma/essais, 2002.
Parth, Kerstin, Oliver Hanley, and Thomas Ballhausen, eds. *Work/s in Progress. Digital Film Restoration within Archives*. Vienna: Synema, 2013.
Pescetelli, Marco. 'The Art of Not Forgetting: Towards a Practical Hermeneutics of Film Restoration'. PhD Thesis, University College London, 2010.
Pinel, Vincent. 'La Restauration des films'. *La Cinémathèque Française* 4 (1985): 8–14.
———. 'Pour une déontologie de la restauration des films'. *Positif* 421 (1993): 90–93.
Pommeau, Jeanne, and Jiří Anger. 'The Digitization of Jan Kříženecký's Films'. *Iluminace* 31, no. 1 (2019): 104–7.
Read, Paul. 'A Short History of Cinema Film Post-Production'. In *Zur Geschichte Des Filmkopierwerks*, edited by Joachim Polzer, 41–132. Potsdam: Polzer, 2006.
———. 'Archiving Digital Media'. In *The EDCF Guide to Digital Cinema Production*, edited by Lasse Svanberg, 143–56. Burlington/Oxford: Focal Press, 2004.
———. 'Digital Image Restoration – Black Art or White Magic?' In *Preserve Then Show*, edited by Dan Niseen, Lisbeth Richter Larsen, Thomas C. Christensen, and Jesper Stub Johnsen, 158–67. Copenhagen: Danish Film Institute, 2002.
———. 'New Technologies for Archive Film Restoration and Access: Film Image'. In *The Use of New Technologies Applied to Film Restoration*, edited by Gamma Group, 37–50. Bologna: Gamma, 1996.
———. '"Unnatural Colours": An Introduction to Colouring Techniques in Silent Era Movies'. *Film History* 21, no. 1 (June 2009): 9–46.
Read, Paul, and Mark-Paul Meyer, eds. *Restoration of Motion Picture Film*. Oxford: Butterworth-Heinemann, 2000.
Ricordel, Nicolas. 'l'Ere numérique, la morphine des films?' *KinéTraces Editions*, no. 2 (2017): 145–55.
Rodrigue, Carl. 'Restauration des films'. *Séquences : la revue de cinéma*, no. 232 (2004): 24–29.
Roy, Éric Le. *Cinémathèques et archives du film*. Paris: Armand Colin, 2013.
Ruivo, Céline. 'Le Technicolor trichrome : Histoire d'un procédé et enjeux de sa restauration'. PhD Thesis, Université Sorbonne Nouvelle–Paris 3, 2016.
Slide, Anthony. *Nitrate Won't Wait: A History of Film Preservation in the United States*. Jefferson North Carolina/London: Mac Farland & Company, 2000.
Smither, Roger, and Catherine A. Surowiec, eds. *This Film is Dangerous: A Celebration of Nitrate Film*. Brussels: FIAF, 2002.

Suárez, Juana. ‘New Buildings, New Pathways: Toward Dynamic Archives in Latin America and the Caribbean’. *The Moving Image* 21, no. 1 (2021): 26–54.
Surowiec, Catherine A. *The Lumiere Project: The European Film Archives at the Crossroads*. Lisbon: Guide - Artes Graphica, 1996.
Trope, Alison. ‘Le Cinéma Pour Le Cinéma – Making a Museum of the Moving Image’. *The Moving Image* 1, no. 1 (2001): 29–67.
Tsuneishi, Fumiko. ‘Pragmatic Solutions for Problematic Sources’. In *Work/s in Progress. Digital Film Restoration within Archives,* edited by Kerstin Perth, Oliver Hanley, and Thomas Ballhausen, 56–67. Vienna: Synema, 2013.
Turci, Arianna. ‘The Use of Digital Restoration within European Film Archives: A Case Study’. *The Moving Image* 6, no. 1 (2006): 111–24.
Tybjerg, Casper. ‘The Raw Material of Film History’. In *Preserve Then Show*, edited by Dan Niseen, Lisbeth Richter Larsen, Thomas C. Christensen, and Jesper Stub Johnsen, 14–21.
Copenhagen: Danish Film Institute, 2002.
Venturini, Simone. ‘From Edge to Edge: The Restoration of *La Battaglia Dall’Astico al Piave* (1918) and the Search for a Digital Historical-Critical Infrastructure’. Edited by Christian Gosvig Olesen, Rossella Catanese, and Adelheid Heftberger. *Cinergie – Il Cinema e Le Altre Arti*, no. 20 (20 December 2021): 45–68.
———, ed. *Il Restauro Cinematografico: principi, teorie, metodi*. Pasian di Prato: Campanotto Editore, 2006.
———. ‘Introduzione’. In *Il Restauro Cinematografico: principi, teorie, metodi,* edited by Simone Venturini. Pasian di Prato: Campanotto Editore, 2006.
———. ‘La Restauration de films : une Histoire (post-)moderne’. *Techné*, no. 37 (2013): 97–101.
———. ‘Tecnologie, tecniche, testi. Problematiche teoriche e metodologiche di restauro del film sonoro italiano dei primi anni Trenta’. In *Svolte tecnologiche nel cinema italiano*, edited by Sandro Bernardi, 49–66. Rome: Carocci editore, 2006.
Venturini, Simone, and Mirco Santi. ‘The History and Technological Characteristics of Cinematographic Production and Reception Device”’. In *Preserving and Exhibiting Media Art. Challenges and Perspectives*, edited by Julia Noordegraaf, Cosetta Saba, Barbara Le Maître, and Vinzenz Hediger. Amsterdam: University of Amsterdam Press, 2013.
Verscheure, Jean-Pierre. ‘The Challenge of Sound Restoration from 1927 to Digital’. *Film History* 7, no. 3 (Autumn 1995): 264–76.
Vizner, Pamela, and Juana Suarez. ‘Education Through International Collaboration: The Audiovisual Preservation Exchange (APEX) Program’. *Synoptique* 6, no. 1 (2017): 102.
Wallmüller, Julia. ‘Criteria for the Use of Digital Technology in Moving Image Restoration’. *The Moving Image* 7, no. 1 (2007): 78–91.
Walsh, David. ‘How to Preserve Your Films Forever’. *The Moving Image* 8, no. 1 (2008): 38–41.
———. ‘There Is No Such Thing as Digital Restoration’. In *Work/s in Progress. Digital Film Restoration within Archives*, edited by Kerstin Perth, Oliver Hanley, and Thomas Ballhausen, 30–42. Vienna: Synema, 2013.
Wengström, Jon. ‘Access to film heritage in the digital era – Challenges and opportunities’. *Högskolan I Borås, Nordisk Kulturpolitisk Tidskrift* 16, no. 1 (2013): 125–36.

5.2 On Image Science

Adelson, Edward H., and Peter J. Burt. ‘Image Data Compression with the Laplacian Pyramid’. In *Proceedings of the Pattern Recognition and Information Processing Conference*, 218–23. Dallas, Texas, 1981.
Adelson, E.H., C.H. Anderson, J.R. Bergen, P.J. Burt, and J.M. Ogden. ‘Pyramid Methods in Image Processing’. *RCA Engineer* 29, no. 6 (November 1984): 33–41.
Ahmed, Nasir U., T. Natarajan, and K.R. Rao. ‘Discrete Cosine Transform’. *IEEE Transactions on Computers* C–23, no. 1 (January 1974): 90–93.
Andriani, S., G. Calvagno, M. Durigon, R. Rinaldo, M. Knww, P. Walland, and M. Kopetz. ‘Comparison of Lossy to Lossless Compression Techniques for Digital Cinema’, 512–16.

Singapore, 2004.
Ansley, David A. ‘Coherent Optical Scanning Analog Processor’. *Applied Optics* 12, no. 12 (December 1973): 2890–93.
Antonini, Marc, Eduardo de Silva, Melpomeni Dimpoulou, Touradj Ebrahimi, Siegfried Foessel, Fernando Pereira, Antonio Pinheiro, and Mohamad Raad. ‘DNA-Based Media Storage: State-of-the-Art, Challenges, Use Cases and Requirements Version 3.0’. Public Report. JPEG DNA Exploration, January 2021.
Aubert, Gilles, and Pierre Kornprobst. *Mathematical Problems in Image Processing*. 2nd ed. New York: Springer, 2006.
Awcock, G.J., and R. Thomas. *Applied Image Processing*. London: MacMillan, 1995.
Baker, Thorn. *Wireless Pictures and Television: A Practical Description of the Telegraphy of Pictures, Photographs, and Visual Images*. London: Constable and Co., Ltd, 1926.
Baroncini, Vittorio, Henry Mahler, and Matthieu Sintas. ‘The Image Resolution of 35mm Cinema Film in Theatrical Presentation’. *SMPTE Motion Imaging*, February 2004, 60–66.
Bernardes, A., and T. Roque. ‘History of Matrices’. In *Mathematics, Education and History. ICME-13 Monographs*, edited by K. Clark, T. Kjeldsen, S. Schorcht, and C. Tzanakis. Cham: Springer, 2018.
Besserer, Bernard, and Cedric Thiré. ‘Detection and Tracking Scheme for Line Scratch Removal in an Image Sequence’. Edited by T. Pajdla and J. Matas. *ECCV 2004*. Berlin Heidelberg: Springer-Verlag, 2004.
Biemond, J., P.M.B. Roosmalen, and R.L. Lagendijk. ‘Restoration of Old Film Sequences, AURORA Project’. In *CERN School of Computing*, edited by Carlo E. Vandoni, 1–9. Egmond aan Zee, The Netherlands, 1996.
Blotner (RCA), Joseph L. ‘This Electronic Memory Device Never Forgets’. *Radio Age. Research, Manufacturing, Communications, Broadcasting, Television* 12, no. 4 (October 1953): 12–14.
Boyle, W.S., and G.E. Smith. ‘Charge Coupled Semiconductor Devices’. *Bell Labs Technical Journal* 49, no. 4 (April 1970): 587–93.
Bracamonte, Javier, Michael Ansorge, and Fausto Pellandini. ‘Adaptive Block-Size Transform Coding for Image Compression’. In *1997 IEEE International Conference on Acoustics, Speech, and Signal Processing*, 2721–24. Munich, 1997.
Bradley, H.C. ‘Corrective Reproduction of Faded Color Motion Picture Prints’. *SMPTE Journal* 90, no. 7 (1981): 591–96.
Brechenmacher, Frédéric. ‘Les matrices : formes de représentation et pratiques opératoires (1850-1930’. In *CultureMATH – Site expert ENS Ulm / DESCO*, 1–6, 2006. https://hal.archives-ouvertes.fr/hal-00637378/document.
Brian W. Keelan. *Handbook of Image Quality. Characterization and Prediction*. New York and Basel: Marcel Dekker, 2002.
Buisson, Olivier, Bernard Besserer, Samia Boukir, and Laurent Joyeux. ‘Deterioration Detection in a Sequence of Large Images’. In *IWISP’96, 3rd International Workshop on Image and Signal Processing*, 593–96. Manchester, UK, 1996.
Buisson, Olivier, Laurent Joyeux, Bernard Besserer, François Helt, and Samia Boukir. ‘Restauration des documents cinématographiques par des méthodes numériques’, 175–84. Paris, 1997.
Burt, Peter J., and Edward H. Adelson. ‘The Laplacian Pyramid as a Compact Image Code’. *IEEE Transactions on Communications* 31, no. 4 (April 1983): 532–40.
Canny, John. ‘A Computational Approach to Edge Detection’. *IEEE Transactions on Pattern Analysis and Machine Intelligence* 8, no. 6 (November 1986): 679–98.
Carl, K. J., J. W. Erwin, S. J. Powell, F. R. Reinking, R. C. Sehlin, S. W. Spakowsky, W. A. Szafranski, and R. W. Wien. ‘Eastman Color Print Film 5384’. *SMPTE Journal* 91, no. 12 (December 1982): 1161–70.
Chambah, Majed, and Bernard Besserer. ‘Digital Color Restoration of Faded Motion Pictures’. In *Proceedings of the 1st International Conference on Color in Graphics and Image Processing - CGIP’2000*. Saint-Etienne, France, 2000.
Chen, Peisong, and John W. Woods. ‘Video Coding for Digital Cinema’. In *Proceedings of the 2002 International Conference on Image Processing*, 749–52. Rochester: IEEE, 2002.
Cinesite Digital Film Center. ‘Grayscale Transformations of Cineon Digital Film Data for Display,

Conversion, and Film Recording'. Version 1.1, 12 April 1993.
Crabtree, J.I., and C.H. Schwingel. 'The Duplication of Motion Picture Negative'. *Journal of the Society of Motion Picture Engineers* 19, no. 1 (July 1932): 891–908.
Craig, Dwin R. 'Image Sharpness Meter'. *Photographic Science and Engineering* 5 (December 1961): 337–42.
Crowley, James L., and Arthur C. Sanderson. 'Multiple Resolution Representation and Probabilistic Matching of 2-D Gray-Scale Shape'. Technical Report. The Robotics Institute, Carnegie Mellon University, December 1984.
Dainty, J.C., and R. Shaw. *Image Science: Principles, Analysis and Evaluation of Photographic-Type Imaging Processes*. London: Academic Press, 1974.
Daly, Scott. 'The Visible Differences Predictor: An Algorithm for the Assessment of Image Fidelity'. In *Proceedings of Spie 1666. Human Vision, Visual Processing, and Digital Display III*, edited by Bernice E. Rogowitz, 1666:2–15. SPIE, 1992.
Daubechies, Ingrid. 'Orthonormal bases of compactly supported wavelets'. *Communications on Pure and Applied Mathematics* 41, no. 7 (1988): 909–96.
———. *Ten Lectures on Wavelets*. Philadelphia and Pennsylvania: Society for Industrial and Applied Mathematics, 1992.
Debnath, Lokenath. 'Brief Historical Introduction to Wavelet Transforms'. *International Journal of Mathematical Education in Science and Technology* 29, no. 5 (1998): 677–88.
Decencière Ferrandière, Etienne. 'Restauration automatique de films anciens'. Ecole Nationale Supérieure des Mines de Paris, 1997.
Deceniève, Etienne. 'Restoration Quality Assessment', 1 1-1 6. London, 2001.
DIN. *Empfehlungen zur Digitalisierung von kinematografischem Film. DIN SPEC 15587:2019-04*. Berlin: Beuth Verlag, 2019.
Dougherty, Edward R. *Electronic Imaging Technology*. Bellingham: SPIE Optical Engineering Press, 1999.
DuMont, Allen B. 'The Relation of Television to Motion Pictures'. *Journal of the Society of Motion Picture Engineers* 47, no. 3 (September 1946): 238–47.
Eastman Kodak Company. 'Restoring Faded Transparencies by Duplication (Tricolor Printing Method)'. *Current Information Summary CIS*, no. 23 (August 1979).
———. 'Restoring Faded Transparencies by Duplication (White Light Printing Methods)'. *Current Information Summary (CIS)*, no. 22 (July 1979).
ECMA. '12,65 mm Wide Magnetic Tape Cassette for Information Interchange - Helical Scan Recording - DTF-2'. Standard ECMA-315, December 2000.
Eichman, George, and B.Z. Dong. 'Coherent Optical Production of the Hough Transform'. *Applied Optics* 22, no. 6 (March 1983): 830–34.
Engebretson, M., and J. Eargle. 'Cinema Sound Reproduction Systems: Technology Advances and System Design Considerations'. *SMPTE Journal* 91, no. 11 (November 1982): 1046–57.
Fellgett, P.B., and E.H. Linfoot. 'On the Assessment of Optical Images'. *Series A. Mathematical and Physical Sciences* 247, no. 931 (17 February 1955): 369–407.
Fellgett, Peter. 'Concerning Photographic Grain, Signal-to-Noise Ratio and Information'. *Journal of the Optical Society of America* 43, no. 4 (April 1953): 271–82.
Fielding, Gabriel, Ryan Hsu, Paul Jones, and Christopher L. DuMont. 'Aliasing and Reconstruction Distortion in Digital Intermediates'. *SMPTE Motion Imaging Journal* 115, no. 4 (April 2006): 128–36.
Frieser, H. 'Uber das Auflösungsvermögen von photographischen Schichten'. *Kino-Technik*, no. 17 (1935): 167–72.
Fujio, Takashi, Junichi Ishida, Taro Komoto, and Taiji Nishizawa. 'High-Definition Television System — Signal Standard and Transmission'. *SMPTE Journal* 80, no. 8 (August 1980): 570–84.
Geman, Stuart, Donald E. McClure, and Donald Geman. 'A Nonlinear Filter for Film Restoration and Other Problems in Image Processing'. In *CVGIP: Graphical Models and Image Processing*, 54:281–89, 1992.
Ghanbari, Mohammad. *Standard Codecs. Image Compression to Advanced Video Coding*. 3rd ed. IET

Telecommunications Series 54. London: The Institution of Engineering and Technology, 2011.
Goldmark, Peter C., and John M. Hollywood. 'A New Technique for Improving the Sharpness of Television Pictures'. *Proceedings of the IRE* 57, no. 4 (October 1951): 382–96.
Goodman, Joseph W. 'Analog Optical Signal and Image Processing'. In *Handbook of Optics. Volume I: Geometrical and Physical Optics. Polarized Light, Components and Instruments*, edited by Michael Bass, Casimer DeCusatis, Jay Enoch, Vasudevan Lakshminarayanan, Guifang Li, Carolyn Macdonald, Virendra Mahajan, and Eric Van Stryland, 3rd ed., 30.1-30.24. New York: McGraw-Hill, 2009.
Graff, Werner, Axel Wittmann, Lukas Rosenthaler, Anton Gunzinger, and Rudolf Gschwind. 'New Scanning Approach for Motion Picture Digitizing'. In *Proceedings of SPIE 3409. Electronic Imaging: Processing, Printing, and Publishing in Color*, 3409:194–201. Zurich: SPIE, 1998.
Gray, Frank, J.W. Horton, and R.C. Mathes. 'The Production and Utilization of Television Signals'. *Transactions of the American Institute of Electrical Engineers* 6, no. 4 (June 1927): 918–39.
Gregg, E.C. 'Analog techniques for processing image data'. In *Quantitative Organ Visualization in Nuclear Medicine*, edited by P.J. Kenny and E.M. Smith, 417–29. Miami: University of Miami Press, 1971.
Gregory, Carl Louis. 'Resurrection of Early Motion Pictures'. *Journal of the Society of Motion Picture Engineers* 42, no. 3 (March 1944): 159–69.
Gschwind, Rudolf. 'Restoration of Faded Color Photographs by Digital Image Processing'. In *Proceedings of SPIE 1135. Image Processing III*, 1135:27–30. Paris: SPIE, 1989.
Gschwind, Rudolf, and Franziska Frey. 'Electronic Imaging, a Tool for the Reconstruction of Faded Color Photographs and Color Movies'. *Journal of Imaging Science and Technology* 38, no. 6 (1994).
Gschwind, Rudolf, Franziska Frey, and Lukas Rosenthaler. 'Electronic Imaging: A Tool for the Reconstruction of Faded Color Photographs and Color Movies'. In *Proceedings of Spie 2421. Image and Video Processing III*, 2421:57–63. San Jose, USA: SPIE, 1995.
Haar, Alfred. 'Zur Theorie der orthogonalen Funktionensysteme'. *Mathematische Annalen* 69 (1910): 331–71.
Hall, W.D., and N.G. Massey. 'Optical Spatial Filtering'. In *Quantitative Organ Visualization in Nuclear Medicine*, edited by P.J. Kenny and E.M. Smith, 619–49. Miami: University of Miami Press, 1971.
Hamilton, John F. 'The Photographic Grain'. *Applied Optics* 11, no. 1 (January 1972): 13–21.
Harcourt, Tony. 'Exposure Levels and Perception of Grain'. *Image Technology* 81, no. 10 (January 1999): 19–20.
Harris, James L. 'Image Evaluation and Restoration'. *Journal of the Optical Society of America* 56, no. 5 (May 1966): 569–74.
Haskell, Barry G., Atul Puri, and Arun N. Netravali. *Digital Video: An Introduction to MPEG-2*. New York: Springer, 1996.
Heinsohn, Hugh R. 'Revelations on the Coming of Digital Cinema'. *SMPTE Journal* 109, no. 10 (October 2000): 800–804.
Helt, François, and Valérie La Torre. 'Advances in Digital Restoration for Addressing the Vinegar Syndrome Effects', 4 1-4 7. London, 2001.
Higgins, G.C., and L.A. Jones. 'The Nature and Evaluation of the Sharpness of Photographic Images'. *Journal of the SMPTE* 58, no. 4 (April 1952): 277–90.
Higgins, George C., and Robert N. Wolfe. 'The Relation of Definition to Sharpness and Resolving Power in a Photographic System'. *Journal of the Optical Society of America* 45, no. 2 (February 1955): 121–29.
Hilliard, John K. 'A Brief History of Early Motion Picture Sound Recording and Reproducing Practices'. *Journal of the Audio Engineering Society* 33, no. 4 (April 1985): 271–78.
———. 'SMPTE Historical Note: Basic Sound Recording and Reproducing Practices between 1927 and 1940'. *SMPTE Journal* 92, no. 2 (February 1983): 207–10.
Hornbeck, Larry J. 'Deformable-Mirror Spatial Light Modulators'. In *Proceedings of SPIE 1150. Spatial Light Modulators and Applications III*, 1150:86–102. San Diego: SPIE, 1990.
———. 'Digital Light Processing: A New MEMS-Based Display Technology', 1996.

http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.118.2556&rep=rep1&type=pdf.
———. ‘Digital Light Processing and MEMS: An Overview’. In *Digest IEEE/Leos 1996 Summer Topical Meeting. Advanced Applications of Lasers in Materials and Processing*. Keystone, USA, 1996. https://www.ti.com/pdfs/dlpdmd/107_DLP_MEMS_Overview.pdf.
———. ‘Spatial Light Modulator and Method’, December 1987. https://patentimages.storage.googleapis.com/db/61/02/0574b4c3eff0ea/US4710732.pdf.
Hose, J., M. Winchell, K. Walker, and J. Ratzel. ‘Data Transport and Processing in a Digital Cinema Theater’. *SMPTE Motion Imaging Journal* 111, no. 12 (December 2002): 600–608.
Hurter, Ferdinand, and Vero C. Driffield. ‘Photo Chemical Investigation and a New Method of Determination of the Sensitiveness of Photographic Plates’. Edited by W.B. Fergusen. *The Journal of the Society of Chemical Industry* 9, no. 5 (1920): 76–122.
‘Interoperable Master Format — Core Constraints’. SMPTE Standard, 2016.
Irvine, Ann C., and Kadayam Thyagajaran. Hybrid Lossy and Lossless Compression Method and Apparatus. US Patent 2003/0012431 A1, issued 16 January 2003.
Ives, C.E., and E. Huse. ‘On Making Duplicate Negatives’. *Transactions of the Society of Motion Picture Engineers* 13, no. 34 (1928): 382–89.
Jaquette, G. A. ‘LTO: A Better Format for Mid-Range Tape’. *IBM Journal of Research and Development* 47, no. 4 (July 2003): 429–44.
Jensen, Axel G. ‘Film Scanner for Use in Television Transmission Tests’. In *Proceedings of the I.R.E,* 29:243–49, 1941.
Jones, Loyd A. ‘Psychophysics and Photography’. *Journal of the Optical Society of America* 34, no. 2 (February 1944): 66–88.
Jones, Robert Clark. ‘New Method of Describing and Measuring the Granularity of Photographic Materials’. *Journal of the Optical Society of America* 45, no. 10 (1 October 1955): 799–808.
Joyeux, Laurent, Samia Boukir, and Bernard Besserer. ‘Film Line Scratch Removal Using Kalman Filtering and Bayesian Restoration’. In *WACV’2000, IEEE Workshop on the Application of Computer Vision*. Palm Springs, California, 2000.
Joyeux, Laurent, Samia Boukir, Bernard Besserer, and Olivier Buisson. ‘Reconstruction of Degraded Image Sequences. Application to Film Restoration’. *Image and Vision Computing* 19, no. 8 (May 2001): 503–16.
Joyeux, Laurent, Olivier Buisson, Bernard Besserer, and Samia Boukir. ‘Detection and Removal of Line Scratches in Motion Picture Films’. In *CVPR’99, IEEE International Conference on Computer Vision and Pattern Recognition*, 548–53. Colorado, USA, 1999.
Kalman, Rudolf E. ‘A New Approach to Linear Filtering and Prediction Problems’. *Journal of Basic Engineering* 82, no. 1 (March 1960): 35–45.
Kelly, D. H. ‘Image-Processing Experiments’. *Journal of the Optical Society of America* 51, no. 10 (October 1961): 1095–1101.
Kennel, Glen. ‘Digital Film Scanning and Recording: The Technology and Practice’. *Journal of the SMPTE* 103, no. 3 (March 1994): 174–81.
Kodak. *Kodak Basic Photographic Sensitometry Workbook*. H.-740, 2006. https://www.kodak.com/content/products-brochures/Film/Basic-Photographic-Sensitometry-Workbook.pdf.
Koenderink, Jan J. ‘The Structure of Images’. *Biological Cybernetics,* no. 50 (1984): 360–70.
Kofron, J.T., and R.E. Booms. ‘KODAK T-Grain Emulsions in Color Films’. *Journal of Society of Photographic Science and Technology Japan* 49, no. 6 (1986): 499–504.
Kokaram, Anil C. ‘Advances in the Detection and Reconstruction of Blotches in Archived Film and Video’, 7 1-7 6. London, 2001.
———. ‘Motion Picture Restoration’. PhD Thesis, University of Cambridge, 1993.
———. *Motion Picture Restoration. Digital Algorithms for Artefact Suppression in Degraded Motion Picture Film and Video*. London: Springer-Verlag, 1998.
Kokaram, Anil C., Bill Collis, and Simon Robinson. ‘Automated Rig Removal with Bayesian Motion Interpolation’. *IEE Proceedings - Vision Image and Signal Processing* 152, no. 4 (September 2005): 407–14.
Kokaram, Anil C., Robin D. Morris, William J. Fitzgerald, and Peter J.W. Eayner. ‘Interpolation of Missing Data in Image Sequences’. *IEEE Transactions On Image Processing* 4, no. 11

(November 1995): 1509–19.
Koppe, Egbert, and Jörg Houpert. ‘DIN SPEC 15587 – the New Standard for the Digitization of Cinematographic Film’. Updated and translated from an article in FKT (German Magazine for television, film and electronic media in the professional field), 1 February 2019. https://www.cube-tec.com/en/news/announcements/fkt-din-spec-15587.
Korn, Arthur. ‘The Transmission of Photographs and Drawings by Wireless Telegraphy, The Wireless World’. *The Wireless World* 1, no. 6 (September 1913): 353–57.
Kovasznay, L. S. G., and H. M. Joseph. ‘Image Processing’. *Proceedings of the IRE* 43, no. 5 (May 1955): 560–74.
Linfoot, E.H. ‘Transmission Factors and Optical Design’. *Journal of the Optical Society of America* 46, no. 9 (September 1956): 740–52.
Lohninger, Hans. *Fundamentals of Statistics*. E-Book. Accessed 16 April 2021. http://www.statistics4u.com/fundstat_eng/ee_inter_extrapolation.html.
Lunt, Barry M., Douglas Hansen, and Matthew Linford. ‘Optical Disc Life Expectancy: A Field Report’. In *Nonlinear Optics*. Kauai, Hawaii: Optical Society of America, 2011.
Mallat, S. G. ‘A Theory for Multiresolution Signal Decomposition: The Wavelet Representation’. *IEEE Transactions on Pattern Analysis and Machine Intelligence* 11, no. 7 (July 1989): 674–93.
Manhall, S., and N.R. Harvey. ‘Film and Video Archive Restoration Using Mathematical Morphology’, 9 1-9 5. London, 2001.
Marcellin, Michael W., and Ali Bilgin. ‘JPEG 2000 for Digital Cinema’. In *VidTrans and SMPTE Advanced Motion Imaging 2005*. Atlanta, Georgia, 2005.
Matchell, Ray. ‘Digital Techniques in Film Scanning’. *IEE Proceedings* 129/Part A, no. 7 (September 1982): 445–53.
McLean, I., and S. Witt. ‘Telecine Noise Reduction’, 2 1-2 6. London, 2001.
Mees, C.E. Kenneth. ‘On the Resolving Power of Photographic Plates’. *Proceedings of the Royal Society of London* 83, no. 559 (3 November 1909): 10–18.
———. ‘The Structure of Photographic Image’. *Journal of the Franklin Institute* 191, no. 5 (May 1921): 631–50.
Meldola, Raphael. ‘The Photographic Image’. *Nature* 42, no. 1080 (10 July 1890): 246–50.
Mertz, Pierre. ‘Television – The Scanning Process’. *Proceedings of the I.R.E* 29, no. 10 (October 1941): 529–37.
Meyer, Yves. ‘Orthonormal Wavelets’. In *Wavelets*, edited by Jean-Michel Combes, Alexander Grossmann, and Philippe Tchamitchian, 21–37. Inverse Problems and Theoretical Imaging. Berlin, Heidelberg: Springer, 1989.
———. *Wavelets and Operators: Volume 1*. Cambridge: Cambridge University Press, 1992.
Mirakami, Hikari. ‘Fujicolor F-400’. *Image Technology* 83, no. 4 (May 2001): 21–24.
Mokhoff, Nicholas. ‘Towards a Perfect Resolution’. *IEEE Spectrum* 18, no. 8 (July 1981): 56–60.
Morton, Roger R. A., Christopher L. DuMont, and Michelle A. Maurer. ‘Relationships between Pixel Count, Aliasing, and Limiting Resolution in Digital Motion Picture Systems’. *SMPTE Motion Imaging Journal* 112, no. 7–8 (July 2003): 217–24.
Morton, Roger R. A., Michelle A. Maurer, and Christopher L. DuMont. ‘An Introduction to Aliasing and Sharpening in Digital Motion Picture Systems’. *SMPTE Motion Imaging Journal* 112, no. 5–6 (May 2003): 161–71.
Muller, Heimo, Walter Plaschzug, and Klaus Glatz. ‘3D Interpolation for the Digital Restoration of 35mm Film’. In *Proceedings of SPIE 3309. Visual Communications and Image Processing ’98*, 3309:287–96. San Jose, USA: SPIE, 1998.
Nohara, Norimasa, Takehjro Tomjtanj, and Elichi Tanaka. ‘Analog Image Processing in Two Dimensions by Omnidirectional Scanning’. *Journal of Nuclear Medicine* 15, no. 10 (1974): 844–47.
Nordman, Charles. ‘Revue scientifique : les cent ans de la photographie, Revue des Deux Mondes (1829-1971’. *Septième période* 28, no. 4 (15 August 1925): 932–42.
Nutting, Perley G. ‘XXXII. On the Absorption of Light in Heterogeneous Media’. *The London, Edinburgh, and Dublin Philosophical Magazine and Journal of Science* 26, no. 153 (1913): 423–26.

Ooue, Shingo. ‘VI The Photographic Image’. *Progress in Optics* 7 (1969): 299–358.
Perry, John, and W.E. Ayrton. ‘Seeing by Electricity’. *Nature* 21, no. 589 (22 April 1880).
Petrou, Maria, and Panagiota Bosdogianni. *Image Processing. The Fundamentals*. Chichester: John Wiley and Sons, 1999.
Photographic Sound Technology. London: British Kinematograph, Sound and Television Society, 1980.
Plutino, Alice, and Alessandro Rizzi. ‘Algorithms for Film Digital Restoration: Unsupervised Approaches for Film Frames Enhancement’. In *Moving Pictures, Living Machines: Automation, Animation and the Imitation of Life in Cinema and Media. Conference Proceedings Series*, edited by Greta Plaitano, Simone Venturini, and Paolo Villa, 265–72. Udine/Gorizia: Mimesis Edizioni, 2020.
Pratt, William K. *Digital Image Processing*. New York: Third Edition, 2001.
Putora, Ivan, and Pablo Weinschenk-Tabernero. ‘The Sharpness Indicator’. *SMPTE Journal* 78, no. 11 (November 1969).
———. ‘The Sharpness Indicator’. *SMPTE Journal* 107, no. 2 (February 1998): 106–12.
Rares, A., M.J.T. Reinder, and J. Biemond. ‘Statistical Analysis of Pathological Motion Areas’, 8 1-8 28. London, 2001.
‘Report of the Committee on Preservation of Film’. *Journal of the Society of Motion Picture Engineers* 35, no. 6 (December 1940): 584–606.
Roosmalen, P.M.B. ‘Restoration of Archived Film and Video’. PhD Thesis, Delft Technical University, 1999.
Rosen, Daniel Scott. Digital Optical Tape Storage System. US Patent 9,640,214 B2, issued 2 May 2017. https://patentimages.storage.googleapis.com/9b/c5/bd/60abdbb68c103d/US9640214.pdf.
Rosenthaler, Lukas, and Rudolf Gschwind. ‘Restoration of Movie Films by Digital Image Processing’, 6 1-6 5. London, 2001.
Rosenthaler, Lukas, Armin Wittmann, Arno Günzl, and Rudolf Gschwind. ‘Restoration of Old Movie Films by Digital Image Processing’. In *Proceedings of IMAGE’COM 96*. Bordeaux/Arcachon, France, 1996.
Ross, Frank E. ‘Photographic Sharpness and Resolving Power’. *The Astrophysical Journal* 52, no. 4 (November 1920): 201–31.
Rothacker, Watterson R., and Joseph Aller. ‘Problems of the Film Finishing Laboratory’. *Transactions of the Society of Motion Picture Engineers* 7, no. 16 (May 1923): 120–25.
Ruiu, Dragos. ‘An Overview of MPEG-2’, 1997. https://literature.cdn.keysight.com/litweb/pdf/5966-1031E.pdf.
Ruppel, Wolfgang, Stephan Breide, Michael Dutka, and Christoph Moldrzyk. ‘A DVB-Compliant Electronic Cinema Solution’. In *140th SMPTE Technical Conference*. Los Angeles, CA, 1998.
Russell, John K. ‘A Visual Image Processor’. *IEEE Transactions on Computers* C–17, no. 7 (July 1968): 635–39.
Schade, Otto H. ‘A New System of Measuring and Specifying Image Definition’. *National Bureau of Standards Circular*, no. 526 (1954): 231–58.
———. ‘Image Gradation, Graininess and Sharpness in Television and Motion Picture Systems. Part I: Image Structure and Transfer Characteristics’. *Journal of the Society of Motion Picture and Television Engineers* 56, no. 2 (February 1951): 137–77.
———. ‘Image Quality. A Comparison of Photographic and Television Systems’. *Journal of the SMPTE* 96, no. 6 (June 1987): 567–648.
Schallauer, Peter. ‘Digital Image Sequence Restoration’. Technical University of Graz and Joanneum Research, 1996.
Schallauer, Peter, and Roland Mörzinger. ‘Film Grain Synthesis and Its Application to Re-Graining’. In *Proceedings of SPIE 6059. Image Quality and System Performance III*, Vol. 6059. San Jose, USA: SPIE, 2006.
———. ‘Rapid and Reliable Detection of Film Grain Noise’. In *Proceedings of ICIP International Conference on Image Processing*. Atlanta, USA, 2006.
Schallauer, Peter, Axel Pinz, and Werner Haas. ‘Automatic Restoration Algorithms for 35mm Film’.

Videre: Journal of Computer Vision Research 1, no. 3 (Summer 1999): 60–85.
Schallauer, Peter, Georg Thallinger, and Matthew J. Addis. ‘Diamant – Digital Film Manipulation Platform’, 3 1-3 3. London, 2001.
Senlecq, Constantin-Marie. ‘The Telectroscopre’. *Scientific American* 9, no. 275 (9 April 1881). https://www.gutenberg.org/files/8195/8195-h/8195-h.htm.
Shannon, Claude Elwood. ‘A Mathematical Theory of Communication’. *The Bell System Technical Journal* 27, no. 3 (July 1948): 379–423.
———. ‘A Mathematical Theory of Communication’. *The Bell System Technical Journal* 27, no. 4 (October 1948): 623–56.
Shannon, Claude Elwood, and Warren Weaver. *The Mathematical Theory of Communication*. Urbana: University of Illinois Press, 1998.
Sheppard, S.E., A.P.H. Trivelli, and R.P. Loveland. ‘Studies in Photographic Sensitivity: VI. The Formation of the Latent Image’. *Journal of the Franklin Institute* 200, no. 1 (July 1925): 51–86.
Silberstein, L. ‘XIX. The Quantum Theory of Photographic Exposure’. *The London, Edinburgh, and Dublin Philosophical Magazine and Journal of Science* 44, no. 259 (1922): 257–73.
Smith, Willoughby. ‘Effect of Light on Selenium During the Passage of An Electric Current’. *Nature* 7, no. 303 (20 February 1873).
Snider, David, Glenn Kennel, Ken Curry, and Michael McCrackan. ‘Digital Moving-Picture Exchange: File Format and Calibration’. *SMPTE Journal* 102, no. 8 (August 1993): 712–14.
Sommerville, Stuart M. ‘Archangel – Automated Real-Time Archive Restoration’, 5 1-5 30. London, 2001.
Stroke, George W., Maurice Halioua, Friedrich Thon, and Dieter H. Willasch. ‘Image Improvement and Three-Dimensional Reconstruction Using Holographic Image Processing’. *Proceedings of the IEEE* 65, no. 1 (January 1977): 39–62.
Stryker, N.R. ‘Scanning Losses in Reproduction’. *Journal of the Society of Motion Picture Engineers* 15, no. 5 (November 1930): 610–23.
Swindell, William. ‘A Noncoherent Optical Analog Image Processor’. *Applied Optics* 9, no. 11 (n.d.): 2459–69.
———. ‘Progress in Analog Image Processing’. Technical Report. Tucson, Arizona: Optical Sciences Center, University of Arizona, 1969.
Szeliski, Richard. *Computer Vision. Algorithms and Applications*. London: Springer-Verlag, 2011.
Taubman, David, and M. Marcellin. *JPEG2000 Image Compression Fundamentals, Standards and Practice*. New York: Springer Science+Business Media, 2002.
Taubman, David S. ‘Embedded Block Coding with Optimized Truncation’, 17 August 2004.
Taubman, David S., and Michael Marcellin. ‘JPEG 2000: Standard for Interactive Imaging’. *Proceedings of the IEEE* 90, no. 8 (August 2002): 1336–57.
‘The Grain in Photographic Film’. *Nature* 70, no. 1823 (6 October 1904): 571.
Theisen, Earl. ‘The History of Nitrocellulose as Film Base’. *Journal of the Society of Motion Picture Engineers* 20, no. 3 (March 1933): 259–62.
Thomas S. Huang. ‘The Use of Digital Computer in Optical Image Processing’. *IEEE Journal of Quantum Electronics* 3, no. 6 (June 1967): 245–245.
Thyagarajan, Kadayam. *Digital Image Processing with Application to Digital Cinema*. Oxford: Focal Press/Elsevier, 2006.
Tudor, P. N. ‘MPEG-2 Video Compression’. *Elctronics & Communication Engineering Journal*, December 1995. https://web.archive.org/web/20110831043337/http://www.bbc.co.uk/rd/pubs/papers/paper_14/paper_14.shtml.
Uray, Peter, Heimo Mueller-Seelich, Walter Plaschzug, and Werner Haas. ‘Visualizing artifacts, meta-information, and quality parameters of image sequences’. In *Proceedings of SPIE 3298. Visual Data Exploration and Analysis V*, 3298:145–52. San Jose, USA: SPIE, 1998.
Van Dam, K. H. ‘Capturing Socio-Technical Systems with Agent-Based Modelling’. PhD Thesis, Technical University Delft, 2009. https://repository.tudelft.nl/islandora/object/uuid%3A1b36bc02-c7fe-4773-9ab2-3daa3b891754.

Van Dam, Koen H., Igor Nikolic, and Zofia Lukszo. *Agent-Based Modelling of Socio-Technical Systems*. Dordrecht, Heidelberg, New York, London: Springer Science & Business Media, 2012.
Vlachos, Theo. 'A Non-Linear Model of Flicker for Archived Film Sequences', 10 1-10 7. London, 2001.
Voges, C., and J. Fröhlich. 'Applications of Data Storage on Cinematographic Film for Long-Term Preservation of Digital Productions'. *SMPTE Motion Imaging Journal* 121, no. 1 (February 2012): 39–42.
Wallace, Robert James. 'The Daylight Sensitometry of Photographic Plates, and a Suggestion Standard Dispersion-Piece'. *Astrophysical Journal* 25 (March 1907): 116–50.
White, Deane R., Charles J. Gass, Emery Meschter, and Wilton R. Holm. 'Polyester Photographic Film Base'. *Journal of the SMPTE* 64, no. 12 (December 1955): 674–78.
Wiegand, Thomas, Gary J. Sullivan, Gisle Bjøntegaard, and Ajay Luthra. 'Overview of the H.264/AVC Video Coding Standard'. *IEEE Transactions on Circuits and Systems For Video Technology* 13, no. 7 (July 2003): 560–76.
Wiener, Norbert. 'Cybernetics'. *Scientific American* 179, no. 5 (November 1948): 14–19.
William F. Schreiber. 'Image Processing for Quality Improvement'. *Proceedings of the IEEE* 66, no. 12 (December 1978): 1640–51.
Wittmann, Armin. 'One Long Image. A New Approach to the Creation and Archiving of Digital Motion Picture Data'. PhD Thesis, ETH, 1999.
Woolfe, Geoffrey John, Bruce Harold Pillman, and Michael James Barry. Restoration of Faded Images. US Patent 5,796,874, issued 18 August 1998.
Zeng, Jianfen, and Liang Fan. 'Video Coding Techniques for Digital Cinema', 415–18. Taipei, 2004.

5.3 On Cinema

Abramson, Albert. *Electronic Motion Pictures: A History of Television Camera*. Berkeley and Los Angeles: University of California Press, 1955.
Albera, François, and Maria Tortajada, eds. *Ciné-dispositfs. spectacles, cinéma, télévision, littérature*. Histoire et théorie du cinéma. Lausanne: L'Âge d'Homme, 2011.
———. 'The Dispositive Does Not Exist!' In *Cine-Dispositives: Essays in Epistemology Across Media*, edited by François Albera and Maria Tortajada, 21–44. Amsterdam: Amsterdam University Press, 2015.
———. 'Introduction to an Epistemology of Viewing and Listening Dispositives'. In *Cinema Beyond Film: Media Epistemology in the Modern Era*, edited by François Albera and Maria Tortajada. Amsterdam: Amsterdam University Press, 2010.
———. 'The 1900 Episteme'. In *Cinema Beyond Film: Media Epistemology in the Modern Era*, edited by François Albera and Maria Tortajada, 25–44. Amsterdam: Amsterdam University Press, 2010.
Altman, Rick. 'Toward a Theory of the History of Representational Technologies'. *Iris* 2, no. 2 (1984): 111–25.
Aumont, Jacques. *L'image*. Paris: Armand Colin, 2011.
———. 'Que reste-t-il du cinéma?' *Rivista di estetica*, no. 46 (2011): 17–31.
Battiston, John H. *Movies for TV*. New York: The MacMillan Company, 1950.
Beau, Frank, Philippe Dubois, and Gérard Le Blanc. *Cinéma et dernières technologies*. Paris: De Boeck Supérieur, 1998.
Bellour, Raymond. *La querelle des dispositifs, Cinéma – installations, expositions*. Paris: P.O.L. éditeur, 2012.
Belton, John. 'Digital Cinema: A False Revolution'. *October* 100 (2002): 98–114.
———. 'Painting by Numbers: The Digital Intermediate'. *Film Quarterly* 61, no. 3 (2008): 58–65.
———. 'Psychology of the Photographic, Cinematic, Televisual, and Digital Image'. *New Review of Film and Television Studies* 12, no. 3 (2014): 234–46.
Benjamin, Walter. 'The Work of Art in the Age of Mechanical Reproduction'. In *Illuminations*, edited by Hannah Arendt and Harry Zohn. New York: Schocken Books, 1969.

https://web.mit.edu/allanmc/www/benjamin.pdf.
Bennett, Bruce, and Marc Furstenau. ‘Formats’. In *Cinema and Technology: Cultures, Theories, Practices*, edited by Bruce Bennett, Marc Furstenau, and Adrian Mackenzie, 19–21. London: Palgrave Macmillan, 2008.
Bennett, Bruce, Marc Furstenau, and Adrian Mackenzie, eds. *Cinema and Technology: Cultures, Theories, Practices*. London: Palgrave Macmillan, 2008.
———, eds. ‘Introduction’. In *Cinema and Technology: Cultures, Theories, Practices*, 1–18. London: Palgrave Macmillan, 2008.
Bennett, James, and Tom Brown, eds. *Film and Television After DVD*. London and New York: Routledge, 2008.
Bomsel, Olivier, and Gilles Le Blanc. *Dernier tango argentique : le cinéma face à la numérisation*. Paris: Presse des Mines, 2002.
Bordwell, David. *Pandora’s Digital Box: Films, Files, and the Future of Movies*. Madison, WI: Irvington Way Institute Press, 2012.
Casetti, Francesco. ‘Sutured Reality: Film, from Photographic to Digital’. *October* 138 (2011): 95–106.
Casetti, Francesco, and Antonio Somaini. ‘Resolution: Digital Materialities, Thresholds of Visibility’. *NECSUS*, July 2012. https://necsus-ejms.org/resolution-digital-materialities-thresholds-of-visibility/.
Charles Swartz. *Understanding Digital Cinema*. Burlington and Oxford: Focal Press, Elsevier, 2005.
Chateau, Dominique. ‘Pensées lacunaires et nouvelles technologies’. In *Cinéma et dernières technologies*, edited by Frank Beau, Philippe Dubois, and Gérard Le Blanc, 67–84. Paris: De Boeck Supérieur, 1998.
Christie, Ian. ‘Digital Frontiers: 2K to 4K and Beyond’. In *Exposing the Film Apparatus: The Film Archive as a Research Laboratory*, edited by Giovanna Fossati and Annie van den Oever. Amsterdam: Amsterdam University Press, 2016.
Couchot, Edmond. *Images: de l’optique au numérique*. Paris: Hermès, 1988.
Crary, Jonathan. *Techniques of the Observer: On Vision and Modernity in the Nine-Teenth Century*. Cambridge, MA: MIT Press, 1992.
Creton, Laurent, and Kira Kitsopanidou, eds. *Les salles de cinema. Enjeux, défis et perspectives*. Paris: Armand Colin, 2013.
Crisp, Virginia, and Gabriel Menotti Gonring, eds. *Besides the Screen: Moving Images through Distribution, Promotion and Curation*. Basingstoke: Palgrave Macmillan, 2015.
Crofts, Charlotte. ‘Cinema Distribution in the Age of Digital Projection’. *Post Script: Essays in Film and the Humanities* 30, no. 2 (July 2011): 82–98.
———. ‘Digital Decay’. *The Moving Image* 8, no. 2 (2008): 13–35.
Cubitt, Sean. *The Cinema Effect*. Cambridge, MA and London: The MIT Press, 2004.
———. *The Practice of Light: A Genealogy of Visual Technologies from Prints to Pixels*. Cambridge, MA: MIT Press, 2014.
Culkin, Nigel, and Keith Randle. ‘Digital Cinema. Opportunities and Challenges’. *Convergence* 9, no. 4 (2003): 79–98.
Cullinan, Nicholas, ed. *FILM Tacita Dean: A Book about Film and the Importance of Analogue in the Digital Age*. London: Tate, 2011.
Eidsvik, Charles. ‘Film Technology in the Age of Video’. *Film Quarterly* 42, no. 2 (1988): 18–23.
Elsaesser, Thomas. ‘Early Film History and Multi-Media. An Archeology of Possible Futures?’ In *New Media, Old Media. A History and Theory Reader*, edited by Wendy Hui Kyong Chun and Thomas Keenan. London: Routledge, 2006.
———. *Film History as Media Archaeology. Tracking Digital Cinema*. Amsterdam: Amsterdam University Press, 2016.
———. ‘Media Archaeology as Symptom’. *New Review of Film and Television Studies* 14, no. 2 (2016): 181–215.
———. ‘Truth or Dare: Reality Checks on Indexicality, or the Future of Illusionism’. In *Cinema Studies into Visual Theory?*, edited by Anu Koivunnen and Astrid Soderbergh Widding, 31–50. Turku: D-Vision, 1998.
Elsaesser, Thomas, and Kay Hoffmann, eds. *Cinema Futures: Cain, Abel or Cable? The Screen Arts

in the Digital Age. Amsterdam: Amsterdam University Press, 1998.
Enticknap, Leo. ‘Electronic Enlightenment or the Digital Dark Age? Anticipating Film in an Age Without Film’. *Quarterly Review of Film and Video* 26, no. 5 (October 2009): 415–24.
———. *Moving Image Technology: From Zoetrope to Digital*. London and New York: Wallflower, 2005.
Fickers, Andreas, and Annie van den Oever. ‘Experimental Media Archaeology: A Plea for New Directions’. In *Techné/Technology: Researching Cinema and Media Technologies – Their Development, Use, and Impact,* edited by Annie van den Oever, 272–78. Amsterdam: Amsterdam University Press, 2014.
Field, Roy, and Tony Iles. ‘Getting the Pictures Together for the Movies’. *Image Technology* 84, no. 6, 7, 9 (2002).
———. ‘Getting the Pictures Together for the Movies’. *Image Technology* 85, no. 1 (February 2003): 33–37.
———. ‘The Colour Difference Process Arrives’. *Image Technology* 85, no. 2 (April 2003): 34–35.
———. ‘Travelling Matte Enters the Digital Age!’ *Image Technology* 85, no. 3 (May 2003): 34–36.
Fielding, Raymond. *The Technique of Special Effects Cinematography*. 4th ed. Focal Press, 1985.
Flückiger, Barbara. ‘Das digitale Kino: Eine Momentaufnahme’. *Montage/av* 12, no. 1 (2003): 28–51.
Fossati, Giovanna, and Annie van den Oever, eds. *Exposing the Film Apparatus: The Film Archives as a Research Laboratory*. Amsterdam: Amsterdam University Press, 2016.
Ganz, Adam, and Lina Khatib. ‘Digital Cinema: The Transformation of Film Practice and Aesthetics’. *New Cinemas: Journal of Contemporary Film* 4, no. 1 (May 2006): 21–36.
Gaudreault, André, and Martin Lefebvre. ‘Présentation’. In *Techniques et technologies du cinéma. Modalités, usages et pratiques des dispositifs cinématographiques à travers l’histoire*, edited by André Gaudreault and Martin Lefebvre, 9–17. Rennes: Presses universitaires de Rennes, 2015.
———, eds. *Techniques et technologies du cinéma. Modalités, usages et pratiques des dispositifs cinématographiques à travers l’histoire*. Rennes: Presses universitaires de Rennes, 2015.
Gaudreault, André, and Philippe Marion. *La fin du cinéma*. Paris: Armand Colin, 2013.
———. ‘The Cinema as a Model for Genealogy of Media’. Translated by Timothy Barnard. *Convergence* 8, no. 4 (2002): 12–18.
———. *The End of Cinema. A Medium in Crisis in the Digital Age*. Translated by Timothy Barnard. New York: Columbia University Press, 2015.
Gomery, Douglas. *Shared Pleasures: A History of Movie Presentation in the United States*. London: BFI Publishing, 1992.
Goudineau, Daniel. ‘Adieu à la pellicule ? Les enjeux de la projection numérique’. Paris: CNC, August 2006.
Gunning, Tom. ‘Moving Away from the Index: Cinema and the Impression of Reality’. *Differences* 18, no. 1 (2007): 29–52.
———. ‘What’s the Point of an Index? Or, Faking Photographs’. *The 16th Nordic Conference on Media and Communication Research* 1, no. 2 (2004): 39–49.
———. ‘What’s the Point of an Index? Or, Faking Photographs’. In *Still Moving: Between Cinema and Photography*, edited by Karen Beckman and Jean Ma. Durham: Duke University Press, 2008.
Habib, André. ‘Rayures, poussière, grain. “L’effet-pellicule” au temps du numérique, ou la survivance simulée de l’involontaire (un essai de reconnaissance)’. In *La haute et la basse définition des images. Photographie, cinéma, art contemporain, culture visuelle*, edited by Franceso Casetti and Antonio Somaini, 125–42. Images, médiums. Sesto S. Giovanni: Mimesis, 2021.
Hadjioannou, Markos. *From Light to Byte: Towards an Ethics of Digital Cinema*. Minneapolis and London: University of Minnesota Press, 2012.
Hagener, Malte, Vinzenz Hediger, and Alena Strohmaier, eds. *The State of Post-Cinema: Tracing the Movie Image in the Age of Digital Dissemination*. London: Palgrave MacMillan, 2016.
Hediger, Vinzenz. ‘Can We Have the Cave and Leave It Too? On the Meaning of Cinema as Technology’. In *Technology and Film Scholarship. Experience, Study, Theory,* edited by Santiago Hidalgo, 213–38. Amsterdam: Amsterdam University Press, 2017.
———. ‘Politique Des Archives: European Cinema and the Invention of Tradition in the Digital Age’.

Rouge 12 (2008). http://www.rouge.com.au/12/hediger.html.
Hediger, Vinzenz, and Stephen Keane. 'The Original Is Always Lost'. In *Film, Convergence and New Media*, edited by Marijke De Valck and Malte Hagener, 135–49. Amsterdam: Amsterdam University Press, 2005.
Hidalgo, Santiago. 'Introduction'. In *Technology and Film Scholarship. Experience, Study, Theory*, edited by Santiago Hidalgo, 13–30. Amsterdam: Amsterdam University Press, 2017.
———, ed. *Technology and Film Scholarship. Experience, Study, Theory*. Amsterdam: Amsterdam University Press, 2017.
Iordanova, Dina, and Stuart Cunningham, eds. *Digital Disruption: Cinema Moves On-Line*. St Andrews: St Andrews Film Studies, 2012.
Jancovic, Marek. 'Lossless Compression and the Future of Memory'. *Interactions: Studies in Communication & Culture* 8, no. 1 (2017): 45–61.
Jancovic, Marek, Axel Volmar, and Alexandra Schneider, eds. *Format Matters*. Lüneburg: Meson press, 2020.
Jones, Jimi. 'So Many Standards, So Little Time: A History and Analysis of Four Digital Video Standards'. PhD Thesis, University of Illinois at Urbana-Champaign, 2019.
Kessler, Frank. 'Notes on Dispositif', 2007. http://frankkessler.nl/wp-content/uploads/2010/05/Dispositif-Notes.pdf.
———. 'What You Get Is What You See: Digital Images and the Claim on the Real'. In *Digital Material. Tracing New Media in Everyday Life and Technology*, edited by Marianne Boomen, Sybille Lammes, Ann-Sophie Lehmann, Joost Raessens, and Mirko Tobias Sch.fer, 187–97. Amsterdam: Amsterdam University Press, 2009.
Kessler, Frank, and Sabine Lenk. 'Digital Cinema or What Happens to the Dispositif?' In *Exposing the Film Apparatus. The Film Archive as a Research Laboratory*, edited by Giovanna Fossati and Annie van den Oever, 301–10. Amsterdam: Amsterdam University Press, 2016.
Kitsopanidou, Kira, and Giusy Pisano. 'L'émergence du hors-film sur grand écran ou la « nouvelle » polyvalence des salles de cinéma'. In *Les Salles de cinéma. Enjeux, défis et perspectives*, edited by Laurent Creton and Kira Kitsopanidou, 147–78. Paris: Armand Colin, 2013.
Knowles, Kim. *Experimental Film and Photochemical Practices*. Experimental Film and Artists' Moving Image. London: Palgrave Macmillan, 2020.
Le Blanc, Gilles. 'Innovations numériques, distribution et différenciation : le cas de la projection numérique dans le cinéma'. *Entreprises et Histoire*, no. 43 (June 2006): 82–92.
Le Forestier, Laurent, Gilles Mouëllic, and Benoît Turquety, eds. *Techniques et machines de cinéma, objets, gestes, discours*. Ecrans 13. Paris: Classiques Garnier, 2020.
Loertscher, M.L., D. Weibel, S. Spiegel, B. Flueckiger, P. Mennel, F.W. Mast, and C. Iseli. 'As Film Goes Byte: The Change from Analog to Digital Film Perception'. *Psychology of Aesthetics, Creativity, and the Arts* 10, no. 4 (2016): 458–71.
Loiperdinger, Martin, ed. *Celluloid Goes Digital. Historical-Critical Editions of Films on DVD and the Internet. Proceedings of the First International Trier Conference on Film and New Media*. Trier: WVT Wissenschaftlicher Verlag, 2002.
Lundemo, Trond. 'Archives and Technological Selection'. *Cinémas* 2, no. 3 (2014): 17–39.
———. 'Conversion, Convergence, Conflation: Archival Networks in the Digital Turn'. In *The Archive/L'Archivio. Filmforum 2011. Atti Del 18° Convegno Internazionale Di Studi Sul Cinema.*, edited by Alessandro Bordina, Sonia Campanini, and Andrea Mariani, 177–82. Udine: Forum Edizioni, 2012.
———. 'The Impact of Technological Innovations on the Historiography and Theory of Cinema, La Cinémathèque Québécoise, Montreal (1-6 November 2011)'. NECSUS, 2012. https://necsus-ejms.org/the-impact-of-technological-innovations-on-the-historiography-and-theory-of-cinema-la-cinematheque-quebecoise-montreal-1-6-november-2011/.
Mabillot, David. 'The Pandora's Box of Dcinema', March 2011. https://www.youscribe.com/BookReader/Index/546578/?documentId=517698.
Manovich, Lev. *The Paradoxes of Digital Photography*. Photography after Photography Exhibition Catalogue. Germany, 1995. http://www.manovich.net/TEXT/digital_photo.html.
———. *What Is Digital Cinema?*, 1995. http://manovich.net/content/04-projects/009-what-is-digital-cinema/07_article_1995.pdf.

Masson, Eef. *Watch and Learn: Rhetoric Devices in Classroom Films after 1940*. Amsterdam: Amsterdam University Press, 2012.
Menotti, Gabriel, and Virginia Crisp, eds. *Practices of Projection*. Oxford: Oxford University Press, 2020.
Mitchell, William J. *The Reconfigured Eye*. Cambridge, MA: MIT Press, 1992.
Neale, Steve. *Cinema and Technology: Image, Sound, Colour*. London: Macmillan, 1985.
Nikoltchev, Susanne, ed. *IRIS plus 2010-2: Digital Cinema*. Strasbourg: European Audiovisual Observatory, 2010.
Plaitano, Greta, Simone Venturini, and Paolo Villa, eds. *Moving Pictures, Living Machines: Automation, Animation and the Imitation of Life in Cinema and Media. Conference Proceedings Series*. Udine/Gorizia: Mimesis Edizioni, 2020.
Polzer, Joachim. *Zur Geschichte des Filmkopierwerks*. Weltwunder der Kinematographie. Beiträge zu einer Kulturgeschichte der Filmtechnik. Potsdam: Polzer, 2006.
Prince, Stephen. 'The Emergence of Filmic Artifacts: Cinema and Cinematography in the Digital Era'. *Film Quarterly* 57, no. 3 (2004): 24–33.
Rhodes, Lis. 'Play it Again?' In *FILM Tacita Dean: A book about film and the importance of analogue in the digital age*, edited by Nicholas Cullinan. London: Tate, 2011.
Rickitt, Richard. *Special Effects. The History and the Technique*. Billboard Books, 2000.
Rodowick, David N. *The Virtual Life of Film*. Cambridge, MA: Harvard University Press, 2007.
Rombes, Nicholas. *Cinema in the Digital Age*. London and New York: Wallflower Press, 2009.
Ryninks, Kees, and Bjorn Koll. 'European DocuZone (EDZ)'. In *The EDCF Guide to Digital Cinema Production*, edited by Lasse Svanberg, 115–20. Burlington/Oxford: Focal Press, 2004.
Salt, Barry. *Film Style and Technology: History and Analysis*. London: Starwood, 1983.
Silverman, Leon. 'The New Post Production Workflow: Today and Tomorrow'. In *Understanding Digital Cinema*, edited by Charles Swartz, 15–56. Burlington/Oxford: Focal Press/Elsevier, 2005.
Smits, Roderik, and E. W. Nikdel. 'Beyond Netflix and Amazon: MUBI and the Curation of on-Demand Film'. *Studies in European Cinema* 16, no. 1 (2 January 2019): 22–37.
Spehr, Paul C. 'Unaltered to Date : Developing 35mm Film'. In *Moving Images : From Edison to the Webcam (Stockholm Studies in Cinema)*, edited by John Fullerton and Astrid Söderbergh Widding, 3–28. Sydney, John Libbey, 2000.
Spottiswoode, Raymond. *Film and Its Techniques*. Berkeley: University of California Press, 1951.
Streible, Dan. 'Moving Image History and the F-Word; or, "Digital Film" Is an Oxymoron'. *Film History* 25, no. 1–2 (2013): 227–35.
Svanberg, Lasse, ed. *The EDCF Guide to Digital Cinema Production*. Burlington/Oxford: Focal Press, 2004.
Symes, Peter. 'Compression for Digital Cinema'. In *Understanding Digital Cinema*, edited by Charles Swartz, 121–48. Burlington/Oxford: Focal Press/Elsevier, 2005.
Tortajada, Maria. 'Archéologie du cinéma'. *Cinémas* 14, no. 2–3 (2004): 19–51.
Trier, Lars von and Thomas Vinterberg. 'Dogma 95. Vows of Chastity'. In *Technology and Culture. The Film Reader*, edited by Andrew Utterson, 87–88. Oxford: Psychology Press, 2005.
Turquety, Benoît. 'Formes de machines, formes de movement'. In *Ciné-dispositifs*, edited by François Albera and Maria Tortajada. Lausanne: L'Âge d'Homme, 2011.
———. 'Forms of Machines, Forms of Movement'. In *Cine-Dispositives: Essays in Epistemology Across Media*, edited by François Albera and Maria Tortajada, translated by Franck Le Gac, 275–98. Film Culture in Transition. Amsterdam: Amsterdam University Press, 2015.
———. *Inventer le cinéma. Épistémologie: problèmes, machines*. Lausanne: L'Âge d'Homme, 2014.
———. *Inventing Cinema. Machines, Gestures and Media History*. Translated by Timothy Barnard. Amsterdam: Amsterdam University Press, 2019.
———. 'On Viewfinders, Video Assist Systems, and Tape Splicers: Questioning the History of Techniques and Technology in Cinema'. In *Technology and Film Scholarship. Experience, Study, Theory*, edited by Santiago Hidalgo, 239–59. Amsterdam: Amsterdam University Press, 2017.
———. 'Pour une archéologie des techniques cinématographiques. L'exemple du Kinemacolor'. In *The Archive/L'Archivio. Filmforum 2011. Atti del 18° Convegno internazionale di studi sul*

cinema., edited by Alessandro Borina, Sonia Campanini, and Andrea Mariani, 163–69. Udine: Forum Edizioni, 2012.
———. *The Displacements of Film: Medium, Format, Configuration*. Lüneburg: Meson Press, 2019.
———. 'Towards an Archaeology of Cinema/Technology Relation: From Mechanization to "Digital Cinema"'. In *Techné/Technology. Researching Cinema and Media Technologies – Their Development, Use, and Impact*, edited by Annie van den Oever, 63–64. Amsterdam: Amsterdam University Press, 2014.
Turquety, Benoît, and Sélim Krichane. *Des avant-dernières machines. Cinéma, techniques, histoire*. Lausanne: L'Âge d'Homme, 2020.
van den Oever, Annie. 'From Technology to Medium. The Apparatuses in the Archive as a Source for a New Film and Media History'. In *The Archive/L'Archivio. Filmforum 2011. Atti Del 18° Convegno Internazionale Di Studi Sul Cinema.*, edited by Alessandro Bordina, Sonia Campanini, and Andrea Mariani, 131–40. Udine: Forum Edizioni, 2012.
———, ed. *Techné/Technology. Researching Cinema and Media Technologies – Their Development, Use, and Impact*. Amsterdam: Amsterdam University Press, 2014.
Vélez-Serna, Maria. *Ephemeral Cinema Spaces. Stories of Reinvention, Resistance and Community*. Film Culture in Transition Series. Amsterdam: Amsterdam University Press, 2020.
Véray, Laurent. *Les Images d'archives face à l'Histoire. De la conservation à la création*. Paris: SCEREN-CNDP-CRDP, 2011.
Weis, Elisabeth, and John Belton, eds. *Film Sound: Theory and Practice*. New York: Columbia University Press, 1985.
Willis, Holly. *New Digital Cinema : Reinventing the Moving Image*. London and New York: Wallflower Press, 2005.
Winston, Brian. *Technologies of Seeing: Photography, Cinematography and Television*. London: British Film Institute, 1996.
Wittwer, Nicolas. 'Normalisation et institutionnalisation : le cas de la transition numérique dans les secteurs de la diffusion (2004-2012)'. In *Des avant-dernières machines. Cinéma, techniques, histoire*, edited by Benoît Turquety and Sélim Krichane, 277–93. Lausanne: L'Âge d'Homme, 2020.
———. 'Revolution numérique? Analyse de l'instauration et de la réception des recommandations et normes techniques du cinéma numérique dans les secteurs de la distribution et de l'exploitation (2004-2012)'. Master Thesis, University of Lausanne, 2012.

5.4 Other

Armitage, John. 'From Discourse Networks to Cultural Mathematics. An Interview with Friedrich A. Kittler'. *Theory, Culture & Society* 23, no. 7–8 (2006): 17–38.
Bachelard, Gaston. *La Formation de l'esprit Scientifique*. 5th ed. Paris: Librairie philosophique J. VRIN, 1967.
———. *La Formation de l'esprit Scientifique*. Digital Edition by Jean-Marie Tremblay, 2012. http://classiques.uqac.ca/classiques/bachelard_gaston/formation_esprit_scientifique/formation_esprit.pdf.
Bird, Alexander. 'The Epistemology of Science—a Bird's-Eye View'. *Synthese* 175 (2010): 5–16.
Bolter, Jay, and Richard Grusin. *Remediation: Understanding New Media*. Cambridge, MA: MIT Press, 1999.
Boullier, Dominique. *Sociologie du numérique*. Paris: Armand Colin, 2019.
Brand, Stewart. 'Written on the Wind'. *Civilization*, November 1998. https://longnow.org/essays/written-wind/.
Brandi, Cesare. *Teoria del restauro*. Rome: Edizioni di Storia e Letteratura, 1963.
Casemajor, Nathalie. 'Digital Materialisms: Frameworks for Digital Media Studies'. *Westminster Papers in Culture and Communication* 10, no. 1 (15 September 2015): 4–17.
Creeber, Glen, and Martin Royston. *Digital Culture: Understanding Digital Media*. Berkshire: McGraw-Hill Open University Press, 2009.
Diebold, John. 'Automation'. *Textile Research Journal* 25, no. 7 (July 1955).

Durkheim, Emile. ‘Technology (1901)’. In *Marcel Mauss. Techniques, Technology and Civilisation*, edited and translated by Nathan Schlanger, 1st ed., 31–32. New York and Oxford: Durkheim Press and Berghahn Books, 2006.
Ernst, Wolfgang. ‘Radical Media Archaeology (Its Epistemology, Aesthetics and Case Studies)’. Edited by Pau Alsina, Ana Rodríguez, and Vanina Y. Hofman. *Artnodes. “Media Archaeology”*, no. 21 (23 July 2018): 35–43.
Foucault, Michel. *Archaeology of Knowledge & the Discourse on Language*. Translated by A. M. Sheridan Smith. New York: Pantheon Books, 1972.
Fuery, Kelli. *New Media: Culture and Image*. New York: Palgrave Macmillan, 2009.
Gane, Nicholas, and David Beer. *New Media: The Key Concepts*. Oxford and New York: Berg Publishers, 2008.
Geels, Frank W. ‘From Sectoral Systems of Innovation to Socio-Technical Systems: Insights about Dynamics and Change from Sociology and Institutional Theory’. *Research Policy* 33, no. 6 (1 September 2004): 897–920.
Gere, Richard. *Digital Culture*. Expanded 2nd. London: Reaktion Books, 2002.
Hof, Barbara E. ‘The Cybernetic “General Model Theory”: Unifying Science or Epistemic Change?’ *Perspectives on Science* 26, no. 1 (1 February 2018): 76–96.
Holl, Ute. *Cinema, Trance and Cybernetics*. Amsterdam: Amsterdam University Press, 2017.
Hubert, Henri. ‘Technology. Introduction’. In *Marcel Mauss. Techniques, Technology and Civilisation*, edited and translated by Nathan Schlanger, 1st ed., 33–34. New York and Oxford: Durkheim Press and Berghahn Books, 2006.
Huhtamo, Erkki, and Jussi Parikka, eds. *Media Archaeology. Approaches, Applications, and Implications*. Berkeley: University of California Press, 2011.
Information, Task Force on Archiving of Digital, Donald J. Waters, Commission on Preservation and Access, John Garrett, and Research Libraries Group. ‘Preserving Digital Information: Report of the Task Force on Archiving of Digital Information’. Commission on Preservation and Access, 1996.
Iraci, Joe. ‘Longevity of Optical Disc Media: Accelerated Ageing Predictions and Natural Ageing Data’. *Restaurator. International Journal for the Preservation of Library and Archival Material* 38, no. 3 (1 September 2017): 273–98.
Jenkins, Henry. *Convergence Culture: Where Old and New Media Collide*. New York: New York University Press, 2006.
Kittler, Friedrich. *Discourse Networks 1800-1900*. Translated by Michel Metteer and Chris Cullens. Stanford: Stanford University Press, 1990.
———. *Gramophone, Film, Typewriter*. Stanford: Stanford University Press, 1999.
Kuhn, Thomas S. *The Structure of Scientific Revolutions*. 2nd Enlarged. Chicago and London: The University of Chicago Press, 1970.
Lang, André. Histoire de la télévision, 2018. https://www.histv.net/?lang=fr.
Latour, Bruno. ‘On Actor-Network Theory: A Few Clarifications’. *Soziale Welt* 47, no. 4 (1996): 369–81.
Lister, Martin. *The Photographic Image in Digital Culture*. 1st ed. Hove, East Sussex: Psychology Press, 1995.
———. *The Photographic Image in Digital Culture*. 2nd ed. London: Routledge, 2013.
Lister, Martin, Jon Dovey, Seth Giddings, Iain Grant, and Kieran Kelly. *New Media: A Critical Introduction*. London: Routledge, 2008.
Lunenfeld, Peter. *The Digital Dialectic: Essays on New Media*. Cambridge, MA: MIT Press, 1999.
Manovich, Lev. *The Language of New Media*. Cambridge, MA and London: MIT Press, 2001.
———. *The Paradoxes of Digital Photography*. Photography after Photography Exhibition Catalogue. Germany, 1995. http://www.manovich.net/TEXT/digital_photo.html.
Marx, Leo. ‘Technology: The Emergence of a Hazardous Concept’. *Technology and Culture* 51, no. 3 (July 2010): 561–77.
Maxwell, J.C. ‘On Governors’. *Proceedings of the Royal Society*, no. 100 (1868): 270–83.
Miller, Vincent. *Understanding Digital Culture*. London: SAGE Publications, 2012.
Mumford, Lewis. *Technics and Civilization*. 7th ed. London: Routledge and Kegan Paul, 1955.
Negroponte, Nicholas. *Being Digital*. New York: Vintage Books, 1995.

Nye, David E. *Technology Matters: Questions to Live With*. Cambridge, MA/London: The MIT Press, 2006.
Panofsky, Erwin. 'Original and Facsimile Reproduction [1930]'. Translated by Timothy Grundy. *RES: Anthropology and Aesthetics*, no. 57–58 (2010): 330–38.
Parikka, Jussi. *What Is Media Archaeology?* Cambridge: Polity Press, 2012.
Parry, Richard. 'Episteme and Techne'. Stanford Encyclopedia of Philosophy, 27 March 2020. https://plato.stanford.edu/entries/episteme-techne/?utm_campaign=elearningindustry.com&utm_source=%2Ftransfection-trans-infection-teaching-molecular-biology-common-elearning&utm_medium=link.
Pinch, Trevor J., and Wiebe E. Bijker. 'The Social Construction of Facts and Artefacts: Or How the Sociology of Science and the Sociology of Technology Might Benefit Each Other'. *Social Studies of Science* 14, no. 3 (1984): 399–441.
Riegl, Alois. *Der moderne Denkmalkultus: sein Wesen und seine Entstehung*. Braumüller, 1903. https://diglib.tugraz.at/der-moderne-denkmalkultus-1903.
Safarzyńska, Karolina, Koen Frenken, and Jeroen C. J. M. Van den Bergh. 'Evolutionary Theorizing and Modeling of Sustainability Transitions'. *Research Policy*, Special Section on Sustainability Transitions, 41, no. 6 (1 July 2012): 1011–24.
Schlanger, Nathan. *Marcel Mauss. Techniques, Technology and Civilisation*. New York and Oxford: Durkheim Press, Berghahn Books, 2006.
Stachowiak, Herbert. *Allgemeine Modelltheorie*. Vienna: Springer, 1973.
Sterne, Jonathan. *MP3: The Meaning of a Format*. Durham: Duke University Press, 2012.
Taylor, Charles. *Modern Social Imaginaries*. Public Planet Books. Durham and London: Duke University Press, 2004.
Thorburn, David, and Henry Jenkins, eds. *Rethinking Media Change: The Aesthetics of Transition*. Cambridge, MA: MIT Press, 2003.
Wellberry, David E. 'Foreword'. In *Discourse Networks 1800-1900*, by Friedrich Kittler, translated by Michel Metteer and Chris Cullens. Stanford: Stanford University Press, 1990.
Wiener, Norbert. *Cybernetics or Control and Communication in the Animal and the Machine*. 1st ed. Cambridge, MA: MIT Press, 1948.
Williams, Robin, and David Edge. 'The Social Shaping of Technology'. *Research Policy* 25, no. 6 (1 September 1996): 865–99.
Wilson, George. 'What Is Technology?' Inaugural Lecture, University of Edinburgh, 1855.
Zielinski, Siegfried. 'Media Archaeology'. *CTheory* Special Issue: Global Algorithm (11 July 1996). https://journals.uvic.ca/index.php/ctheory/article/view/14321/5097.

Appendix 1: Archival Conferences

A non-exhaustive list of archival conferences

Conference title	Place	Year	Related project, institution
Preserve Then Show	Copenhagen	2001	
IEE Seminar on Digital Restoration of Film and Video Archives	London	2001	
IEE Projecting the Digtal Future of Cinema	London	2003	
What's a film image? What resolution? What bit depth?	London	2004	FIRST
Archimages (2). Cinéma et audiovisuel : quelles mémoires numériques pour l'Europe ?	Paris	2008	
Journées d'études: du film au numérique. Vie et mort de la pellicule	Paris	2008	
Die digitale Herausforderung	Berlin	2008	
Economies of the Commons 1	Amsterdam	2008	Images for the Future
Archimages. Recherche / Archives. Numériser les images, et après ?	Paris	2009	
Economies of the Commons 2	Amsterdam	2010	Images for the Future
Révolution numérique. Et si le cinéma perdait la mémoire?	Paris	2011	
Digital Restoration within Film Archives	Krems, Austria	2011	
Taking Care Of Orphan Works. EFG Open Conference on Rights Clearance in European Film Archives	Amsterdam	2011	EFG
EFG. Film archives and their users in the 'Second Century'. Risks and benefits of the transition to digital	Bologna	2011	EFG
EFG Workshop on Data Quality and Semantic Interoperability Issues in European Film Archives	Franfurt	2011	EFG
Digital Agenda for European Film Heritage Final Workshop	Brussels	2011	DAEFH
Management Strategies for Film Archives in the Digital Era	Bologna	2012	ACE
Economies of the Commons 3	Amsterdam	2012	Images for the Future
Our images. Our future. Securing cinema's past and future in the digital era Presentations	Brussels	2013	Cinema Expert Group
FOCAL Conference: What is Restoration?	London	2013	
Collecting, Conserving and Exhibiting in a Digital World	Bologna	2013	ACE
Orphan Film Symposium: The Future of Obsolescence	Amsterdam	2014	
Tagung. Film im digitalen Zeitaler	Zürich	2014	DIASTOR
Acquisition and Collection Policy in the Digital Era	Bologna	2014	ACE
Kinétraces. La Mort des films	Paris	2015	
Archival Film Today	Prague	2015	
Showing a Film is not Enough. Cinema Programming in the Digital Era	Bologna	2015	ACE
The Reel Thing/FIAF Symposium	Bologna	2016	
Fi:re	Warsaw	2017	
Orphans Paris: tests, essais, expérimentations	Paris	2017	
The Reel Thing/Eye International Conference	Amsterdam	2018	
Orphans Vienna: Radicals	Vienna	2019	

Appendix 2: European Projects

A non-exhaustive list of European-funded archival (transnational) projects regarding the safeguarding of audiovisual heritage

Name	Complete name	Start date	End date	EU fund	Coordinator	Film Archives involved	Other notable partners	Remarks
LUMIERE		Year 1991	Year 1996	Media I Programme	ACE			Not related to digital technologies. Collaboration between archives. Large-scale restoration project.
	Search for Lost Films	Year 1997	Year 1999	RAPHAEL	ACE			Not related to digital technologies. Raphael was a EU prgramme in favour of cultural heritage in Europe.
ARCHIMEDIA	Archimedia European Network Training for the Promotion of Cinema Heritage	Year 1997	Year 2004	Media Plus Programme	ACE			Training. Including many seminars on digital technologies.
LIMELIGHT	A new generation of fast and high resolution digital system to scan process and print cinema quality images	15.07.1994	15.01.1997	Eureka Network	Joanneum Research	Laboratoire Neyrac Film, CNC	L3i (Université de la Rochelle), Danel Technologies, Debrie-CTM, Bertin, IBZ Frankfurt and SUN.	No direct EU funding. Funding was provided on national levels. In France ANVAR (l'Agence française de l'Innovation) and CNC. In Austria Forschungsförderungsfonds (f.d. gewerbliche Wirtschaft). Budgets undisclosed.
FRAME		01.07.1997	Year 1998	FP4-ESPRIT	Joanneum Research	Laboratoire Neyrac Film	HS-Art. European Centre for Parallel Computing (Vienna). Quadrics Supercomputers World (Roma)	HS-Art's first software introduced in 1999.
AURORA	AUtomated Restoration of ORiginal film and video Archives	01.09.1995	31.08.1998	FP4-ACTS	INA	None	Technology companies, universities, TV archives.	Development of a fast and effective video restoration system in real time. Specific to TV archives. Overall budget € 3 704 000 EU contribution € 1 815 000
DFilm	Digital film support network	01.10.1998	30.09.2000	FP4-ESPRIT	DIGITAL FILM CENTER EUROPE BV Netherlands	None	Frauenhofer IIS and HSArt	Not an archive project, but a digital cinema project, which was also at the origin of the Dutch project, DIGITAL FILM CENTER (in collaboration with NFM).
FOAL	Film Archives On-Line	Around 2000		Leonardo	Bologna	Gamma Group		Part of Gamma Group's activities. Idea since 1992 under the FORCE project.
DIAMANT	Digital Film Manipulation System	01.01.2000	31.03.2002	FP5-IST	Joanneum Research	Nederlands Filmmuseum, Laboratoires Neyrac		DIAMANT will develop a solution for high-speed manipulation of uncompressed film and video and HDTV using commercial off-the-shelf computation and state of the art interconnect hardware. Overal budget: € 2 291 757, EU Contribution: € 1 339 168
BRAVA	Broadcast Restoration of Archives through Video Analysis	01.02.2000	31.05.2002	FP5-IST	INA	None	Technology companies, universities (DELFT, Trinity College Ireland with Anil Kokaram), TV archives.	The goal is to significantly enhance the efficiency of film and video-originated archive restorations and prepare them for dissemination. Reduce costs. Overall budget € 4 781 177 EU contribution € 2 500 000.
ECHO	European Chronicles on-Line	01.02.2000	30.04.2003	FP5-IST	Consiglio Nazionale delle Ricerche	None	Universities, research centers and Tech companies, as well as TV archives (Sound&Vision, INA) and Istituto Luce, Memoriav	Putting online the European documentary films documenting life in Europe via a digital library service.
PRESTO	Preservation Technology for European Broadcast Archives	29.08.2000	28.10.2002	FP5-IST	BBC	None	Joanneum Research, INA, BBC, RAI, etc.	First attempt to evaluate, understand and define digital solutions for transfer from analog to digital. Overall budget € 4 826 170, EU contribution € 2 413 083
COLLATE	Collaboratory for Annotation, Indexing and Retrieval of Digitised Historical Archive Material	01.09.2000	30.11.2003	FP5-IST	Frauenhofer	Prague, DFF, Filmarchiv Austria		Digital humanities approach. Results consider also the "dangers" of WWW, like piracy.
AMICITIA	Asset Management Integration of Cultural heritage In The Interchange between Archives	01.10.2000	28.02.2003	FP5-IST	TECHMATH (DE)	None	TV archives: BBC, Sound&Vision, ORF, etc. Also Joanneum Research.	Aimed at developing digital preservation and archiving system enabling access to archives.
PRIMAVERA	Personalised Retrieval and Indexing of Media Assets in Virtual Environments for Realtime Access	01.11.2000	31.10.2002	FP5-IST	TECHMATH (DE)	None	One TV archive (ORF), Fraunhofer (Munich), etc.	Building of Content management system for broadcast. Quite axed on metadata and content distribution.
FIRST	Film Restoration and Conservation Strategies	01.06.2002	30.05.2004	The FIRST Project was an "Accompanying Measure" in the context of the IST Programme.	ACE, Cinémathèque royale belge	Cinémathèque royale de Belgique	Also TV archives INA, RTBF and ORF, as well as Tech companies involved (and in some workgroups they are coordinators).	Nicola Mazzanti in charge. Final report: EUROPEAN FILM HERITAGE ON THE THRESHOLD OF THE DIGITAL ERA. Overall budget € 732 998, EU contribution € 732 998

PrestoSpace		01.02.2004	30.06.2007	FP6-2002-IST-1	INA	Nederlands Filmmuseum	Joanneum, Snell & Wilcox, Trinity College Dublin, CubeTec, HSArt, Centrimage, etc.	Broadcast Archives Project. The project's objective is to provide technical solutions and integrated systems for a complete digital preservation of all kinds of audiovisual collections. In 4 workgroups: preservation, restoration, storage, access. Overall budget € 15 752 750, EU contribution € 9 000 000
WorldScreen	Layered Scheme Compression for Digital Cinema and Cross Media Conversion	01.09.2004	30.04.2007	FP6-IST	IIS Frauenhofer	None	Kodak partner, ARRI and WarnerBros advisors.	Not an archive project, but on digital cinema. Objective: Investigation of the use of scalable video coding in digital cinema workflows. Overall budget € 5 986 579, EU contribution € 3 050 000
TAPE	Training for Audiovisual Preservation in Europe	01.09.2004		Culture 2000	European Commission on Preservation and Access	None		Larger than film & video archives.
IP-RACINE	Integrated Project - Research Area CINE	01.10.2004	31.03.2008	FP6-IST	University of Pompeu Fabra	None	Joanneum Research	Huge (annexe) project on digital cinema, not related to archives.
MIDAS	Moving Image Database for Access and Re-use of European Film Collections	01.01.2006	Year 2009	Media Plus Programme	ACE	BFI, Belgium, EYE, DFF, SDK, Bologna, Prague, Budapest, Norway, Lichtspiel, Lithuania, Milan, DEFA, Slovenia, Greece		Development of an online portal dedicated to European filmography (these archives' holdings)
EDCINE	Enhanced digital cinema	01.07.2006	30.06.2009	FP6-IST	Université catholique de Louvain	Cinémathèque royale de Belgique	Archival section: Frauenhofer, MOG Solutions (Portugal).	EDCINE focuses on the optimisation; enhancement and interoperability issues of Digital Cinema based future standards. Overall budget € 17 425 168, EU contribution € 9 384 000
EFG	European Film Gateway	01.09.2008	30.08.2011	EU Community programme eContentplus as part of the i2010 policy	Deutsches Filminstitut und Filmmuseum Frankfurt (DFF)	Portugal, Denmark, Bologna, Filmarchiv Austria, EYE, Lichtspiel, Oslo, Prague, Budapest, Vilnius, Helsinki, Cinémathèque française, Warsaw	Europeana, Tech companies.	Initiated by ACE and Europeana. Development of an online portal to widen access to European films online. Metadata and cataloguing an important part of the project. Followed by EFG14 (2012-2014) for the centunary of WWI (where other archives also contributed content)
PrestoPRIME		01.01.2009	30.06.2012	FP7-ICT-2007-3	INA	None	Joanneum Research	Broadcast Archives project. Assuring the existence of digital data on a long-term perspective. ICT: Information Communication Technologies.
DAVID	Digital AV Media Damage Prevention and Repair	01.12.2012	31.052015	FP7-ICT	Joanneum Research	None		Detection, monitoring and restoration of damages. TV archives: ORF, INA
Presto4U	European Technology for Digital Audiovisual Media Preservation	01.01.2013	31.12.2014	FP7-ICT	Sound & Vision	Danish Film Institute	Joanneum involved. BBC, INA, ORF, RAI + universities (Southampton who was also involved in Diamant).	Broadcast Archives project. The aim of the project is to identify useful results of research into digital audiovisual preservation and to raise awareness and improve the adoption of these both by technology and service providers as well as media owners.
FORWARD	Framework for a EU-wide Audiovisual Orphan Works Registry	01.07.2013	31.01.2017		Cinémathèque royale de Belgique	DFF, CNC, Eye, ACE, Prague, Warsaw, Helsinki, Danish Film Institute, Bologna		Orphan works, copyright.
I-Media-Cities	Innovative e-environment for Research on Cities and the Media	01.04.2016	31.03.2019	H2020-EU.3.6.3. - Reflective societies - cultural heritage and European identity	Cinémathèque royale de Belgique	Museo Nazionale del cinema Torino, Filmmuseum Austria, Swedish Film Institute, Danish Film Institute, DFF		Initiative of 9 European Film Libraries, 5 research institutions, 2 technological providers and a specialist of digital business models to share access to and valorise audiovisual (AV) content from their collections for research purposes in a wide range of social sciences (sociology, anthropology, urban planning, etc). Cities in European society and identity. Mostly focused on DH and research. Frauenhofer is also a partner.
Cinarts		01.11.2018	30.10.2020	Creative Europe	Bologna	Hungary, Belgium, Portugal		Study on the relationship of cinema and other arts to define cinema's place. Education.

Appendix 3: OFC Documents

Documents related to contractual deposit of films financed by Federal Office for Culture (OFC) at the Cinémathèque suisse, Switzerland.

Document no. 1: the text on the Cinémathèque website regarding the OFC deposits, 2011
Document no. 2: the list of "standards" for the OFC deposits, 2011
Document no. 3: the list of "standards" for the OFC deposits, 2013
Document no. 4: the text on the Cinémathèque website regarding the OFC deposits, 2016
Document no. 4: the information on the OFC deposits, 2017
Document no. 5: the "Technical Specifications" for the OFC deposits

All of the documents have been publicly available on the website of Cinémathèque suisse.

Dépôt de films ayant reçu une aide financière de l'OFC

Conformément à l'article 6 de l'Ordonnance du DFI sur l'encouragement du cinéma (OECin), tous les films ayant reçu un soutien de l'OFC doivent être déposés à la Cinémathèque suisse.

Si le film a été tourné sur pellicule, la copie déposée doit être neuve. Jusqu'à présent, une copie sur pellicule demeure en effet le meilleur support de conservation possible.

D'autres supports sont acceptés lorsque le film a été tourné en format numérique, voir liste des formats acceptés.

La copie ne doit pas comporter de sous-titres. S'ils existent, nous les acceptons et les conservons sous forme de fichiers.

Liens

en français

http://www.admin.ch/ch/f/rs/4/443.113.fr.pdf

http://www.bak.admin.ch/themen/kulturfoerderung/00486/00492/index.html?lang=fr

en allemand

http://www.admin.ch/ch/d/sr/4/443.113.de.pdf

http://www.bak.admin.ch/themen/kulturfoerderung/00486/00492/index.html?lang=de

Imprimer la confirmation de dépôt

confirmationdépôtOFC2011 (.doc)

Liste des formats acceptés

standards dépôts OFC 2011 (.pdf)

Standards pour le dépôt de copies d'archives à la Cinémathèque suisse

Vidéo et numérique

Bandes (K7) :
HDCAM (SR)
BETA DIGITAL
BETA SP
IMX
HDV
DV/DVCAM
LTO

Disques optiques :
PRO DISCS (XDCAM ALL PROFILES/IMX/DVCAM)

Vidéo :
UNCOMPRESSED
MJPEG
MJPEG 2000
DIRAC
MPEG 1
MPEG 2 (Part 2)
MPEG 4 (Part 2/ASP)
MPEG 4 (Part 10/AVC)
DV (25/50/100)
THEORA

Image :
JPEG
JPEG2000
TIFF
TGA
PNG

Audio :
PCM
MPEG 1 Layer III (MP3)
MPEG 1 Layer II
MPEG 1 Layer I
VORBIS
AAC
HE AAC
FLAC

Containers :
.DPX
.MXF
.AVI
.MPEG-TS

.MP4
.MKV
.OGG
.WAV
.AIFF

Digital Cinema :

DI (Digital Intermediate)*
DCDM (Digital Cinema Distribution Master)**
DCP (Digital Cinema Package)**

IMPORTANT !

La Cinémathèque suisse, tout comme bon nombre d'autres archives, a fait le choix de privilégier les formats « ouverts » , et, dans la mesure du possible, normalisés, ceci dans un souci de pérennité et d'inter-opérabilité.

C'est pourquoi, les containers et/ou formats propriétaires fermés (type QuickTime ou Windows Media) ne sont pas acceptés.***

Les oeuvres produites en haute-définition (HD) doivent au minimum faire l'objet d'une copie de définition équivalente.

Etant donné l'évolution rapide des technologies, les informations contenues dans ce document sont susceptibles d'être modifiées à tout moment.

* selon normes ANSI/SMPTE
** selon normes DCI, **non crypté**
***Transcodage nécessaire, frais en sus

Standards pour le dépôt
de copies d'archives à la Cinémathèque suisse

Vidéo et numérique

Bandes (K7) :
- HDCAM (SR)
- BETA DIGITAL
- BETA SP
- IMX
- HDV
- DV/DVCAM
- LTO

Disques optiques :
- PRO DISCS (XDCAM ALL PROFILES/IMX/DVCAM)

Vidéo :
- UNCOMPRESSED
- MJPEG
- MJPEG 2000
- DIRAC
- MPEG 1
- MPEG 2 (Part 2)
- MPEG 4 (Part 2/ASP)
- MPEG 4 (Part 10/AVC)
- DV (25/50/100)
- THEORA

Image :
- JPEG
- JPEG2000
- TIFF
- TGA
- PNG

Audio :
- PCM
- MPEG 1 Layer III (MP3)
- MPEG 1 Layer II
- MPEG 1 Layer I
- VORBIS
- AAC
- HE AAC
- FLAC

cinémathèque suisse

Containers :
- .DPX
- .MXF
- .AVI
- .MPEG-TS
- .MP4
- .MKV
- .OGG
- .WAV
- .AIFF

Digital Cinema :
- DI (Digital Intermediate)*
- DCDM (Digital Cinema Distribution Master)**
- DCP (Digital Cinema Package)**

IMPORTANT !

La Cinémathèque suisse, tout comme bon nombre d'autres archives, a fait le choix de privilégier les formats « ouverts », et, dans la mesure du possible, normalisés, ceci dans un souci de pérennité et d'inter-opérabilité.

C'est pourquoi, les containers et/ou formats propriétaires fermés (type QuickTime ou Windows Media) ne sont pas acceptés.***

Les oeuvres produites en haute-définition (HD) doivent faire l'objet d'une copie de définition équivalente.

Etant donné l'évolution rapide des technologies, les informations contenues dans ce document sont susceptibles d'être modifiées à tout moment.

* selon normes ANSI/SMPTE
** selon normes DCI, non crypté
***Transcodage nécessaire, frais en sus (cf. actes dépôts numériques)

Dépôt de films soutenus par l'OFC et/ou cinéforom

Conformément à l'article 6 de l'Ordonnance du DFI sur l'encouragement du cinéma (OECin), et conformément à l'article 24 du règlement général des soutiens à la production de cinéforom, quiconque a obtenu une aide sélective à la réalisation d'un film suisse ou d'une coproduction est tenu de déposer une copie auprès de la Cinémathèque suisse.

Il s'agit de conserver une version de l'œuvre dans la meilleure qualité possible et qui puisse servir de référence.

Une œuvre distribuée sur pellicule doit également être déposée dans ce format (copie neuve). En effet, la pellicule 35mm demeure à ce jour le meilleur support de conservation. En ce cas, la copie ne doit pas être sous-titrée. S'ils existent, les sous-titres doivent être livrés sous forme de fichiers électroniques.

Une œuvre tournée et distribuée en numérique doit être déposée dans un format correspondant au format d'origine (suite de DPX, suite de TIFF, XDCam, ProRes…) et/ou au format de diffusion (DCP, XDCam…)

Les fichiers ne doivent pas être cryptés et les supports livrés tels que clés USB, disques durs, bandes LTO (LTFS ou TAR) doivent être accessibles sans permissions.

Pour de plus amples renseignements, la Cinémathèque suisse est à votre disposition au 058 800 0200 et à l'adresse info(at)cinematheque.ch

Nous vous remercions de compléter la confirmation de dépôt et de l'adresser à la Cinémathèque suisse en même temps que la copie :

Cinémathèque suisse
Département Archives Film
chemin de La Vaux 1
case postale
1303 Penthaz.

Une fois le dépôt validé, la maison de production en est informée par e-mail et la confirmation de dépôt est envoyée directement à l'OFC et/ou à cinéforom.

La Cinémathèque suisse collecte également le matériel d'exploitation lié aux films qu'elle conserve. Ces objets sont pris en charge par le secteur iconographie et appareils cinématographiques au sein du Département non-film. Afin de préserver ces documents du cinéma suisse, nous vous serions reconnaissants de bien vouloir joindre à votre envoi 6 exemplaires de chaque modèle d'affiche, 3 jeux de chaque modèle de photos d'exploitation ainsi que 3 exemplaires de chaque modèle du flyer ou de la carte postale.

Documents

- Confirmation de dépôt (pdf)

Dépôts OFC/cineforom

La Cinémathèque suisse conserve :

- le master image (montage final), dans le meilleur format possible (ex. DCDM, DPX, HD ProRes), sans sous-titres

- les fichiers de sous-titres séparés

- mixage son final (5.1 et/ou 2.0)

- les livraisons doivent être accompagnées d'une liste exhaustive de leur contenu

- si 2 versions (24 et 25 i/s : la Cinémathèque suisse ne conserve que le framerate d'origine, autant pour l'image que pour le son)

- provisoirement, la CS conserve les fichiers cleanfeed

- si plusieurs versions linguistiques, la CS conserve plutôt un DCP par version qu'un DCP multiversion

La Cinémathèque suisse ne conserve pas :

- les fichiers son non mixés

- les rushes et fichiers de travail

- les fichiers remaniés pour des usages particuliers (ex. version télévision pour un film sorti en salle, fichiers remaniés en vue d'édition DVD, etc.)

La Cinémathèque suisse valide les dépôts OFC/cinéforom qui respectent ces critères.

La Cinémathèque suisse ne valide pas les dépôt OFC/cinéforom qui ne correspondent pas à ces critères et réclame une nouvelle livraison conforme.

La Cinémathèque suisse se réserve le droit de supprimer tous les fichiers ne correspondant pas à ces critères, en avertissant le déposant au préalable.

cinémathèque suisse

Spécifications techniques pour le dépôt obligatoire d'éléments de film numériques

Conformément à l'article 63 de l'Ordonnance du Département fédéral de l'intérieur (DFI) sur l'encouragement du cinéma (OECin) du 21 avril 2016, le bénéficiaire d'une aide financière fédérale à la réalisation est tenu de faire parvenir à la fondation Cinémathèque suisse les fichiers de base ayant servi à la production de la version finale du film (masterfile).

Les œuvres soutenues par d'autres fonds régionaux (cinéforom, Berner Filmförderung, Zürcher Filmstiftung, etc.) peuvent également être soumises à cette obligation.

Afin d'assurer sa mission de conservation, la Cinémathèque suisse (CS) a établi des spécifications techniques relatives au dépôt de fichiers numériques.

Il s'agit de conserver une version de l'œuvre dans la meilleure qualité possible et dans un format compatible avec l'archivage. Ainsi, la Cinémathèque suisse demande un master non compressé et une copie de distribution non cryptée. S'il n'existe pas de master non compressé, le producteur peut, après discussion avec la CS, déposer un master compressé.

Master non compressé

Image

L'image doit être non compressée, non cryptée et dans la résolution, le format (aspect ratio) et la cadence (frame rate) d'origine.

Les images doivent être livrées en séquence :

Format de fichier :	DPX ou TIFF
Profondeur de couleur (bit depth) :	10 bits / 12 bits / 16 bits
Espace colorimétrique :	RGB Rec 709 (full range) RGB DCI P3 sRGB XYZ 1931 CIE

Les fichiers doivent être structurés dans des dossiers et libellés de la façon suivante : titre_n°defichier.extension. La numérotation des fichiers doit comporter au moins 7 positions. Si le film est divisé en plusieurs bobines, chaque bobine doit faire l'objet d'un sous-dossier et numérotée en conséquence.

Exemple : Goettliche-Ordnung_0000001.dpx

Son

Format de son : WAV (PCM)

Profondeur de bit : 16 bits/sample ou 24 bits/sample

Fréquence d'échantillonnage : 48 kHz ou 96 kHz

La Cinémathèque suisse conserve les sons mixés finaux. Les fichiers doivent être libellés avec le titre, le nombre d'images par seconde (frame rate) et le type de mixage (stereo, 5.1). Les différents mixages doivent être livrés dans des dossiers séparés.

Exemple : 🗁 BRIGHT-LIGHT_AUDIO_FR_DCP_51_25fps
🗋 BL_FR_DCP_51_25FPS_DEF_C
🗋 BL_FR_DCP_51_25FPS_DEF_L
…

Le son et l'image doivent être exactement de la même durée et synchronisés. Le premier photogramme de la séquence doit correspondre au premier photogramme de l'action. Bips sonores et autres décomptes en sont exclus.

Sous-titres

Les sous-titres doivent être livrés en fichiers séparés et correspondre à la cadence d'image et à la durée de l'image. Si le master est divisé en bobines, les sous-titres doivent l'être également. Les sous-titres non séparables gravés sur l'image (burnt-in) ne sont pas acceptés.

Formats de sous-titres recommandés : XML / SRT / STL

Master compressé

Image et son

Si la post-production du film a été réalisée de telle façon que les éléments correspondant aux spécifications susmentionnées ne sont pas disponibles, un fichier ProRes (4444 ou 422HQ) non sous-titré peut être accepté comme master, mais uniquement après consultation de la Cinémathèque suisse.
S'il s'agit d'un film destiné à la télévision, il est possible de livrer un fichier dans un format de diffusion TV (par exemple : XDCam HD422 1080i/50).
Cependant, les mêmes exigences relatives au format d'image (aspect ratio), à la cadence (frame rate) et aux sous-titres sont en vigueur.

Compléments

Si elle l'estime pertinent, la CS accepte également d'autres éléments en plus, tels que :
- Cleans
- Sons mixés dans d'autres cadences d'image et d'autres configurations de canaux
- Sous-titres optionnels (dans d'autres formats ou dans d'autres langues par exemple)
- Trailers

Copies de distribution non cryptées

Outre les masters, afin de pouvoir contrôler l'élément de diffusion, la Cinémathèque suisse demande une ou plusieurs copies de distribution non cryptées.

Les copies de distribution numériques doivent être livrées sous forme de DCP non crypté et sous forme de fichier ProRes (4444 ou 422HQ). Pour les films non distribués en salles, un fichier ProRes (422HQ) est suffisant.

S'il existe plusieurs versions linguistiques, la CS conserve soit un DCP par version soit un DCP multiversion, selon l'existant. Par contre, les DCP de type supplemental sont refusés.

Pour les fichiers ProRes, il est demandé un fichier par version linguistique ou un fichier non sous-titré avec des fichiers de sous-titres séparés (voir le point « Sous-titres » ci-dessus).

Somme de contrôle (checksum)

Les fichiers doivent être accompagnés de checksum (fichiers MD5) qui permettent de vérifier l'intégrité des données.

Chaque niveau de dossier contenant une séquence d'images, un DCP ou d'autres fichiers doit contenir un fichier texte nommé cs-md5.md5. Celui-ci doit contenir le md5 puis le nom du fichier sans son chemin d'accès, selon l'exemple ci-dessous :

1dc73d751cdf3425a42d42c377ae9c31 DENE-WOS-GUT-GEIT_000002.dpx

637bf8999cd15aa558a873a4e05ac076 DENE-WOS-GUT-GEIT_000003.dpx

59feaae7b5c26043ec0f6cd95a240624 DENE-WOS-GUT-GEIT_000004.dpx

Accessibilité

Plurilinguisme

Selon l'article 65 de l'Ordonnance du Département fédéral de l'intérieur (DFI) sur l'encouragement du cinéma (OECin), les films bénéficiant d'une aide à la réalisation doivent être synchronisés ou sous-titrés dans au moins une autre langue nationale.

Audiodescription

De plus, les films remplissant les critères ci-dessous doivent être disponibles en audiodescription dans au moins une langue nationale :

- Les longs métrages documentaires ayant obtenu une subvention fédérale de plus de 125'000 francs

- Les longs métrages de fiction ayant obtenu une subvention fédérale de plus de 300'000 francs.

Livraison et contrôle

Le matériel doit être livré sur un disque dur, une clé USB ou une bande LTO-6. Le support n'est pas rendu au déposant.

Pour les disques durs et les clés USB, les formatages acceptés sont NTFS, EXT2, EXT3, EXT4 et exFAT. Les bandes LTO doivent être conformes au système LTFS ou au programme d'archivage TAR.

Les livraisons doivent être accompagnées d'une liste détaillée de leur contenu.

La Cinémathèque suisse se réserve le droit de supprimer tous les fichiers ne correspondant pas à ces spécifications, en avertissant le déposant au préalable.

La CS a l'obligation de vérifier les éléments déposés et de statuer sur leur validation dans les 30 jours suivant la réception du matériel.

Merci d'adresser l'envoi à :
Cinémathèque suisse
Centre de recherche et d'archivage
Département Film
Chemin de la Vaux 1
1303 Penthaz

Maral Mohsenin

Personal Data

Place and Date of Birth: Tehran, Iran | 07 September 1988
Address: Chemin de Beau-Rivage 12, 1006 Lausanne
Phone: +41 78 908 9131
email: maral.mohsenin@gmail.com
maral.mohsenin@unil.ch
Nationality: Iranian, Swiss permanent resident

Education

Mar. 2016 - Sept. 2022
Defense date: October 7, 2022

Joint PhD. in Film Studies

University of Amsterdam, Amsterdam, The Netherlands
University of Lausanne, Lausanne, Switzerland

Thesis title: **"The Archives Must Go On: An Archeology of Digital Images Technologies within European National Film Archives"**
Advisors: Prof. Giovanna Fossati (University of Amsterdam)
Prof. Benoît Turquety (University of Lausanne),

Sept. 2013 - Jan. 2016

Master of Arts with specialisation in Film Studies
University of Lausanne, Lausanne, Switzerland
Optional modules: Filmmaking, Film Economy

Thesis: **"Du documentaire télévisé au film s pectaculaire: La carrière de Pierre Koralnik à la Télévision suisse romande"**
In collaboration with the archives of RTS (Radio-Télévision suisse)
Advisors: Prof. Maria Tortajada (Department of Cinema)
Prof. François Vallotton (Department of History)

Sept. 2011 - Aug. 2013

Master of Arts in Computer and Mathematics in Human Sciences
University of Lausanne, Lausanne, Switzerland
Optional modules (30 credits): Film Studies

Thesis: **"Restauration du patrimoine filmique à l'ère du numérique"**
Advisors: Prof. Benoît Turquety (Department of Cinema)
Prof. François Bavaud (Department of Mathematics in Human Sciences)

Sept. 2011 - June 2014

Complementary Bachelor Courses at the Department of Cinema
University of Lausanne, Lausanne, Switzerland

Sept. 2006 - July 2011

Bachelor of Science in Electrical Engineering
Department of Electrical and Computer Engineering
University of Tehran, Tehran, Iran
Major: Control Engineering
Ranked 320^{th} among 300,000 people in the Nation-wide University Entrance Exam

Work Experience

Jan. - July 2022	Film Lecturer, at the **Department of Cinema, University of Lausanne**, Lausanne, Switzerland (10%) Course title: ”L’image cinématographique: entre sepctacle et technologie”, BA-Théories.
From October 2017	Film Restorer and Conserver at the **Cinémathèque suisse**, Lausanne, Switzerland (80%) In charge of several restoration projects of Swiss films, notably: *Charles mort ou vif* (Alain Tanner, 1969), *La Paloma* (Daniel Schmid, 1974)
From July 2015	Programmer at the **Geneva International Film Festival (ex-Tous Ecrans)**, Geneva, Switzerland (currently 20% annulaised) June 2018 - Now: In charge of TV Series January 2016 - June 2018: Retrospective and TV Series Programmer, Programming Assistant July - November 2015: Retrospective Programmer
Jan. - Sept. 2017	Assistant at the Film Restoration and Conservation Sector at the **Cinémathèque suisse**, Lausanne, Switzerland
Jan. - Dec. 2016	Intern at the Film Restoration and Conservation Sector at **Cinémathèque suisse**, Lausanne, Switzerland
Jan. - Apr. 2016	Accreditation Manager at the Festival **Visions du réel**, Nyon, Switzerland
Jan. - Dec. 2015	Intern at the Communication Department at the **Cinémathèque suisse**, Lausanne, Switzerland
April 2015	Intern in the Doc Market at the Festival **Visions du réel**, Nyon, Switzerland
Aug. 2013 - Dec. 2015	Assistant in service, support and helpdesk at the **Centre informatique (Ci), University of Lausanne**, Lausanne, Switzerland
Feb. - Aug. 2013	Intern in Film Archives of **Lichtspiel**, Bern, Switzerland

Publications

Maral Mohsenin, ”Silent Film Speeds throughout Film History: Standards and Practices”, *Journal of Film Preservation*, No. 101, October 2019, pp. 8-18.

Maral Mohsenin, ”La restauration de Romeo und Julia auf dem Dorfe : Un voyage incertain dans l’histoire d’un film suisse”, *1895*, under review (2022)

Academic Research Interests

Film Heritage, Technological History of Cinema, Archaeology of Cinema, Digital Media, Cultural Studies, World Cinema, History and Politics of Film Festivals, Television Industry and Aesthetics

CONFERENCES

May 2022 — Adviosry Board Member and Moderator of the: **Eye International Conference 2022 – Global Audiovisual Archiving** at the **Eye Filmmuseum**, Amsterdam, the Netherlands

May 2021 — Masterclass Organisation and Moderation: **Global Audiovisual Archiving** at the **Eye International Conference 2021**, online.
Link: https://www.youtube.com/watch?v=WWWcvMFDOFM
Participants: Aboubakar Sanogo (Carlton University), Karen Chan (Asian Film Archives), Juana Suarez (New York University, Tisch School of Arts), Giovanna Fossati (Eye Filmmuseum)

January 2020 — Paper presentation: **"Don't Throw Away Films"! The Dilemma of Analog-to-Digital Transition in Film Archives** at the international conference **Rethinking Digital Myths**, in **University of Lugano**, Lugano, Switzerland

September 2019 — Paper presentation: **"Film-Digital-Film": Digital Technology as an Intermediate Step in Archival Practices** at the international conference **Gestes singuliers, gestes collectifs: histoire et cinéma en pratiques**, in **University of Montreal**, Montreal, Canada

April 2019 — Roundtable Organization and Moderation: **Socio-political Diversity of Film Archives: Transitions from the Past to the Future** at the symposium of **FIAF Annual Congress**, at the **Cinémathèque suisse**, Lausanne, Switzerland

March 2019 — Paper presentation: **Description of Material Damages on Analog and Digital Film** at the international conference **Resisting Matter: Describing Archival Objects**, in **University of Lausanne**, Lausanne, Switzerland

May 2018 — Paper presentation: **Old Images of Iran Resurfaced: The Case of *Teheran Has No More Pomegranates!*(2007)**, at the **EYE International Conference**, in **EYE Filmmuseum**, Amsterdam, the Netherlands

December 2017 — Paper presentation: **L'image cinématographique en transition: une analyse technique de la représentation** at the international conference **Représenter/Interpréter**, in **University of Lausanne**, Lausanne, Switzerland

September 2017 — Paper presentation: **Small Nation, Big Archives: The Transnational Film Collections of Cinémathèque suisse** at the 8th edition of the **Small Cinemas Conference: Diversity in Glocal Cinemas**, in **University of the Basque Country UPV/EHU**, Bilbao/San Sebastian, Spain

June 2017 — Paper presentation: **"Let's Save *Our* Films!": National Film Heritage in the Transnational Context of European Film Archives** at the international conference **Exploring the "Transnational" in Film Studies**, in **University of Zurich**, Zurich, Switzerland

April 2017 — Roundtable Organization and Moderation **'Updating the Archives': When documentary makes use of archival images** at the international conference **Visions du Réel Documentary Film Festival**, Nyon, Switzerland
Participants: Michel Dind (Cinémathèque suisse), Martin Körber (Deutsche Kinemathek), Susana de Sousa Dias (Filmmaker), Werner Schwizer (Producer)

Workshops and Academic Stays

September 2021	Digital Archives Summer School at **Filmuniversität Konrad Wolf Babelsberg**, Potsdam, Germany
October 2018	Pordenone Collegium at **Giornate del Cinema Muto Festival**, Pordenone, Italy
March - May 2017	10-week research period at **EYE Filmmuseum**, Amsterdam, The Netherlands
March 2017	**FIAF Programming Winter School** at **Cinémathèque française**, Paris, France
November 2016	**The Politics of Film Archival Practice Workshop** at **University of Stockholm**, Stockholm, Sweden • International workshop organized by University of Lausanne, University of Udine and University of Stockholm as part of a research initiative on film archives • The workshop consisted of academic conferences and hands-on training at the archives of the Swedish Film Institute
September 2015	**The CICAE Art Cinema Management Workshop** at **Venice International Film Festival**, Venice, Italy
August 2014	**Documentary Summer Academy 2014** at **Festival del film Locarno**, Organised by the Università della Svizzera italiana Locarno, Switzerland
June - July 2014	**FIAF Restoration Summer School 2014** at **L'immagine ritrovata**, Bologna, Italy • **Analogue** film repair, printing and processing, film washing, film identification and study of materials • **Digital** scanning, digital image restoration, color correction, mastering, sound restoration, subtitling

Languages

Persian:	Mother tongue
French:	Bilingual
English:	Fluent (TOEFL IBT score 109/120)
German:	Good Knowledge (Zertifikat Deustch B1 from Goethe Institute)
Italian:	Proficient (B1)
Arabic, Azeri:	Notions

Computer Skills

General:	Windows – Mac – Microsoft Office – LaTeX - Web Programming (HTML, PHP, Wordpress) – Adobe Suite (Acrobat, InDesign, Photoshop) – Natural Language Processing – Image Processing – Matlab Programming
Film-related:	Final Cut – Première Pro – Digital Restoration (Phoenix, Revival) – Digital Cinema – Subtitling softwares – Film Encoding softwares