Film Restoration

The Culture and Science of Audiovisual Heritage

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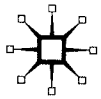

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Contents

Figures

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press from the 1910s and 1920s relating to early film preservation treatments shed valuable light on the origins and early development of the technical processes of archival film preservation and restoration.

It should be noted that the viewpoints and arguments expressed in this book – some of which, it has to be admitted, are a tad controversial! – are solely my own, and in no way the responsibility of anyone listed above.

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Introduction – Why Restoration Matters

On 2 December 2009, the British Broadcasting Corporation (BBC)'s flagship drive-time radio news programme broadcast a report on the centenary celebrations of what is claimed on its website to be 'the UK's oldest working cinema'.[1] The Electric Theatre in Birmingham was formerly a newsreel theatre, and a collection of prints of local topicals and other short films had survived in a rooftop film storage vault until their discovery by an archive film agency in the 1970s. Commenting on a screening of this material at the centenary event, the cinema's owner, Tom Lawes, told the BBC's interviewer: 'We've got some amazing archive film... They've managed to put it back onto DVD, digitise it, and it's pretty good, it's amazing to see the cinema in 1937.'[2]

That comment illustrates, in three short phrases, why this book is necessary. To start with, Lawes articulates a fundamental misconception as to the relationship between the technological specificity of the media to which he refers, and its empirical provenance. He talks of 'putting *back*' onto DVD content that was originated on 35 mm film, as if the act of making a relatively low-quality digital copy is a straightforward act of restoration. Secondly, he celebrates the idea of modernising archive film, opining that digitising is 'pretty good' and thereby implying that a viewing on a medium in which the film was originated is somehow second best. And finally, he expresses a conception of archive film as a surface-level entertainment spectacle, repeatedly using the adjective 'amazing' to emphasise the film's role as a commodified spectacle for uneducated consumers rather than an evidentiary artefact to be interrogated and understood by an informed audience.

As this story on a mainstream radio news programme, aimed at a non-specialist audience, indicates, critical and academic interest in, and attention paid to, our audiovisual heritage has ballooned in the

last 15 years or so. There are a number of reasons for this, of which two are of particular note: the emergence of computer-based moving image technologies and their effect on the cost and quality of distributing and exhibiting archival content (usually referred to colloquially by that catch-all word 'digitisation'); and a shift in the political climate in Europe and North America that has compelled its archive institutions to become far less inward facing and to prioritise access over all other activities. These issues will be discussed in greater detail in subsequent chapters.

It will suffice to note for the purposes of this introduction that the repackaging, remarketing and reinterpretation of archival moving images for contemporary audiences has, in a relatively short time, grown from almost nothing into a very big business. The scope of this activity can be represented by the widespread use, and in some cases misuse, of a single noun: restoration. The three approaches to archival film articulated in the Birmingham cinema broadcast – a misunderstanding of how the technology works and what it does, and the notions of modernisation and commodification – have, I will argue, dominated what little systematic debate in the public arena has taken place to this day on the subject of film restoration. The result has been a widespread misleading of the public as to how 'old' films are communicated to audiences by archive institutions (both taxpayer-funded and private sector), preservationists and curators.

Although this book is specifically concerned with archival practice, it is important to note the misunderstanding of the contribution of technology to the cultural practice of cinema in general terms, and the way it changed over time in specific ones, is the origin of the problem. This extends from the production and marketing practices of mainstream western cinema itself to the mainstream critical and journalistic infrastructures that grew up around them. Furthermore, it is not just mainstream journalists who are prepared to broadcast what I would argue is questionable information to their listeners (or more accurately in the case of the example cited above, to allow their interviewees to do so unchecked). It is not without justification that the few serious attempts to understand the role played by technology in shaping the function of moving images as cultural artefacts and historical source material have noted, to quote one recent example, 'the common resistance expressed by many scholars to handle technology matters'.[3] Writing in the British Film Institute (BFI)'s journal *Sight and Sound* in March 2011, a group of 26 full professors of film studies in British universities modestly described themselves as 'the root that has fostered

and sustained the UK's lively moving image culture'.[4] Their letter was protesting against the threatened closure of the BFI's reading room in Central London, claiming that this facility was vital to their fulfilling their self-appointed role as the leaders of public discourse and debate on the history and culture of the moving image in Britain – as the government report that proposed the establishment of the BFI in 1932 modestly put it, 'raising the standard of public appreciation of films, by criticism and advice addressed to the general public'.[5] If the professors' claim to being the root of British film culture is justifiable, it is highly problematic that they have enabled a situation to develop in which a national news programme produced by what its supporters would claim is an internationally respected broadcaster gave its listeners the impression that a DVD offers a superior viewing experience to 35 mm film.

In 1997, one of the signatories to that letter, Professor Laura Mulvey of Birkbeck College, London, published some criticism and advice aimed at the general public, also in *Sight and Sound*, on the contribution of Sam Warner to the invention of film sound.[6] It reproduces, uncritically, the myth that grew up, encouraged by the Warner Bros. publicity machine itself, that Vitaphone and *The Jazz Singer* (USA, 1927, dir. Alan Crosland) were the defining factors in the conversion to sound and that the core technologies they embodied became the industry standard. They were not and they did not. The system championed by Sam Warner was, in fact, one of three competing sound technology packages that emerged during the mid-1920s. It was by far the least successful (if judged by the criterion of market share) and shortest lived. The variable area optical recording method developed by the Radio Corporation of America (RCA), which was technically superior to both its competitors and was dominating studios and post-production facilities in America and Europe by the early 1930s, is not even mentioned in Mulvey's article. Her rationale for lionising Sam Warner was that 'there should be a place for acknowledging the contingent, almost accidental factors which affect history such as personal obsession or subjective choice.'[7] Empirical evidence as to how the technology worked, what it did, how it developed and why would have been more useful.

Another of the signatories to that letter, Professor Sarah Street of the University of Bristol, between May 2007 and September 2010 undertook a research project she called 'The Negotiation of Innovation', on the use of colour film technologies in British cinema. Her abstract claims that manufacturers of early colour film systems 'often faced fierce opposition from competitors who had vested interests in preserving the status

quo'.[8] Pre-chromogenic (dye coupler) colour systems were not widely used for precisely the same reason that synchronised sound was not used on any significant scale before the invention of optical sound-on-film in the late 1920s: compared to the *de facto* monochrome standard they were less flexible, more expensive, did not work reliably and in some cases all three. As the Phoebus Cartel demonstrated,[9] the protection of revenue by deliberately impeding the sale of newer, competing product lines that are perceived to be superior by their potential customer base is something that did occasionally happen. But it didn't in this case: the evidence suggests that as soon as colour film stocks that were almost fully compatible with equivalent existing black-and-white production workflows and imposed a negligible cost increase went on the market, the global film industry adopted chromogenic colour more or less wholesale for commercial feature film production within a few years.[10]

There has also been some misunderstanding with archival preservation and restoration, and it is here that the significance lies. In the first major output from her research project on colour, Street claims that 'it is seldom clear how the "look" of a DVD has been manipulated during the grading of a new print, or which decisions have been made in the transfer of the print to a digital format.'[11] Prints are not graded – intermediate elements during the film production or preservation workflow are. Except for showprints and other highly exceptional circumstances, release prints are printed 'one light'. Secondly, it wouldn't matter even if they were graded (i.e. the colour temperature and intensity of the printer light adjusted between shots during the release printing procedure), because release prints are almost never used in the digital capture process from which professionally made DVDs are derived. Being of much higher contrast than pre-print elements, they lack detail at the extreme ends of the visible spectrum that can be captured from earlier generations, and they are also likely to have physical defects from projection and handling. Fine grain interpositives are typically used in this process, and if they have been graded properly then only minimal (if any) further alterations to the gamma, contrast or chroma characteristics are needed in the preparation of DVD versions.

In August 2009, Professor Ian Christie of Birkbeck College, London, wrote an article on the restoration of *The Red Shoes* (UK, 1948, dir. Michael Powell and Emeric Pressburger). He claimed that 'film restoration today inevitably means going digital',[12] dismissing digital audio restoration as 'less controversial' than digital image manipulation. At the time Christie was writing, preservation projects still took place using entirely or primarily photochemical workflows on a widespread

scale. Even at the time this book was written, photochemical restorations were still taking place on a limited scale, though primarily in public sector archives.[13] The issue of *The Moving Image* published at around the same time as the *Sight and Sound* number in which he made that claim includes an article discussing the state of the art in photochemical restoration technique.[14] The *Journal of Film Preservation* issue from April 2009 includes an account of the photochemical restoration project of *Die Niebelungen* (Germany, 1924, dir. Fritz Lang) led by Anke Wilkening and largely carried out by PresTech Laboratories in London.[15]

Furthermore, certain practices in remixing audio elements for re-releases have proven every bit as ethically controversial as any digital restoration project, not least the standard industry practice of creating digitally synthesised 5.1 audio mixes of films that were originally distributed in mono final mixes only for DVD and BD publication, one that is a constant topic of discussion at archivists' conferences and technical symposia.

There are reasons for the misconceptions I have described. As I will argue in the concluding chapter, the academic study of moving images has had trouble dealing with the role of technology almost from its inception. This is somewhat ironic, given that cinema is virtually unique among art forms and recording media in the complexity of and extent to which it depends on the combination of technologies used in the creation, distribution and exhibition of its core product.

Literary narratives can be created, stored and communicated as theatrical performance using the human body alone (though the invention of the written word and subsequently the printed word vastly increased the scale on which this activity takes place). Drawing, painting, sculpture, basic forms of monochrome photography and other fine art practices are possible with chemically simple raw materials that do not require any post-Industrial Revolution technologies, and their reception requires no technological intervention at all. The same applies to musical composition and performance. Moving images and recorded sound are distinguished by the fact that they require an extensive combination of complex, post-Industrial Revolution technologies to create, store and communicate. These include inorganic chemistry, electricity, semiconductors, mechanical components cast from metal alloys, plastics, artificial light sources and more recently, microprocessors and mathematical algorithms. The cultural and evidential artefacts known as films and sound recordings require machines to create, and machines are needed to play them back. Unlike the written word, paintings, still photographs or music scores, moving images and recorded sound are

not natively 'human readable': they require a mediating technology at every stage of the way.

The dynamic of the interaction between the creators of the technology, the users of the technology, and the creation of cultural and evidential artefacts using the technology that results from this necessity is something that critics, theorists and historians of film have struggled to cope with ever since their emergence as a profession. With reference to sound recordings, the cultural historian Mark Sterne argues that the technology 'does not preserve a pre-existing sonic effect as it happens so much as it creates and organizes sonic events for the possibility of preservation and repetition'.[16] Theorists and philosophers have discussed the mediating role of technology in creating and reproducing records of human activity in even more abstract terms. When Marshall McLuhan infamously asserted that 'the media is the message', he was arguing that understanding the characteristics of communications technologies and how they were used revealed more about humanity than the content they were used to communicate.[17] More recently, Friedrich Kittler has suggested that the creation and use of media technologies to perform interactive processes is in itself important evidence of human activity: in essence, that there is little cultural difference between a novel and a computer program. Applying this to the cinema, Kittler writes, 'from film technology to film tricks, knowledge only extracted what it had invested in the studies of optical illusions since Faraday.'[18]

The systematic study of cinema, as practised in the humanities departments of universities and the infamous 'criticism and advice directed at the general public', tends to take the opposite extreme. Its practitioners have, since its emergence, tried to treat films in more or less the same way that classicists and literary scholars have treated books and plays, historians have treated sources and evidence, theorists have treated cultural phenomena and art critics have treated paintings. One of the dominant analogies of mainstream film studies is that of the film as 'text', directly comparable, using a series of metaphors, with the written word. Adapted from techniques in literary theory, notably semiotics, structuralism and psychoanalysis, the close textual analysis of films, as the author of one of the most widely published undergraduate introductory textbooks on the subject put it, is 'the activity of testing a film or group of films for specific, pertinent language-system codes... the cautious, semiotic labour of explaining just how a film makes meaning'.[19] The empirical development and use of technology in a film's creation and communication to the viewer is by definition not considered a part of how it makes that meaning.

For the first 70 years or so of the profession's existence, film scholars were able to make a pretty convincing case for all but ignoring technology: indeed, a number of institutional and ideological factors positively encouraged them to do so. The cinema began life as a lowbrow cultural form, integrated, both technologically and ideologically, with other working class entertainment practices, notably the fairground and music hall. At this point the medium and the message were completely intertwined: the film pioneers such as Edison, Pathé, Hepworth and Messter both manufactured the technology and made the films to exploit it with. The two roles diverged between approximately 1900 and 1920, with the creation of the technology and the creation of the films separated, but the lowbrow cultural associations remained. By the emergence of what Bordwell and Thompson termed 'classical' Hollywood in the 1920s, the dominant form of cinema had become firmly established as a potent combination of big business and low culture. Exceptions to that rule – Soviet agit-prop, German expression and the British documentary movement – were cast as explicit rejections of the Hollywood norm, and the 'serious' film criticism in which academic film studies has its roots was very much one of those exceptions. The first generation of film critics and historians, exemplified by Paul Rotha and Roger Manvell in Britain, or Iris Barry and Terry Ramsaye in the USA, saw their task as convincing a sceptical intelligentsia that film was more than just an ephemeral form of popular culture. The analysis of *technique* played an important role in this effort, but the analysis of *technology* did not. Rotha's *The Film Till Now*, for example, originally published in 1930 and generally acknowledged as the first significant monograph on film history to be published in Britain, organises the bulk of its coverage by country (USA, USSR, Germany, France and UK). Within these chapters, Rotha emphasises the ways in which American cinema pursued the mass audience, while European cinema 'discovered its aesthetic qualities',[20] attributing them primarily to the influence of contemporary fine and performance art movements. Manvell's *Film*, initially published as a 'Penguin special' in 1944 is divided into sections entitled 'The Film as a New Art Form', 'The Influence of the Film on Present-Day Society' and 'The Film Today'. In neither book is the role of technology really considered to be a source of that art or influence. Auteurism, the Marxism-inspired film theory of the 1960s and 1970s, the film and history movement in the 1980s and 1990s and the influence of postmodernism and media philosophy on film studies in the 1990s and 2000s all either consciously overlooked or failed to engage with the central function of technology in

the creation and communication of moving images and their associated audio recordings. The few who have tended to be economic and institutional historians, rather than researchers for whom the analysis of actual films forms the focus of their research. Notable examples are Douglas Gomery's research on the conversion to sound and John Belton's on widescreen.

There have been a small number of honourable exceptions to this paradox in which the overwhelming bulk of efforts by academics to understand the function and significance of a technologically dependent culture have either ignored or misunderstood the technology itself. Barry Salt's monograph *Film Style and Technology: History and Analysis*, originally published in 1983 and extensively revised in 1993 and 2009, provides the definitive exposition of an idea Salt originally proposed in 1974:[21] that of 'statistical style analysis', the object of which, in Salt's words, is 'that the form of films noticeably differ from one to another, and that the variables used to study this should be based on the concepts that film-makers actually use'.[22] In other words, Salt set out to show how the empirical circumstances of production determined what filmmakers did or didn't do, to which end the capabilities and limitations of the technology involved – cameras, film stocks, lighting – sound recording and mixing equipment – were carefully researched and examined alongside his 'textual' analysis of actual films. The development of this approach led Salt to become arguably the most trenchant critic of humanities-based film studies in print. The detailed and extensive attack on orthodox film theory which opens his book concludes with the assertion that knowledge of how the perception of the representational part of the film medium works will be produced 'by scientists, and not "theorists" sitting in armchairs in the humanities departments of universities'.[23] David Bordwell's work in *On the History of Film Style* followed in a similar vein, seeking to integrate the influence of technology with that of other cultural factors on the aesthetics of mainstream cinema.

This emergence of humanities-based film studies took place during a relatively settled period in the development of moving image technologies themselves. It could be argued that between the mid-1960s (when the conversion to colour and widescreen was more or less complete) and the early 1990s (when computer-generated imagery – CGI – made its first appearance), there were no fundamental technological changes that had an immediate or primary impact on the viewer's experience of the medium, comparable to the invention of cinema itself, the conversion to sound in the late 1920s or the earliest mainstream exhibition

of photographic three-colour films in the following decade. Technical standards developed and 'behind the scenes' evolution changed industrial practices (e.g. the introduction of polyester film base and the stereo variable area soundtrack in the 1980s). But none of these new technologies entered the public consciousness as technological phenomena and forced a widespread, mainstream debate that encroached on the academics' turf.

With the introduction of digital moving image technologies and the impending obsolescence of film-based ones in all but a few niche applications, that debate has now materialised. It has very significant implications, both for film scholarship and for more mainstream critical practice. Furthermore, it is a debate that those scholars and critics are ill-equipped to participate in, coming as they do from an almost exclusively humanities background. Yet, arguably for the first time since the transition to sound, its effect on filmmakers and the cinema-going public is so profound and immediately visible that the academic and critical establishment will lose all credibility if they fail to engage with it. The result is, as we have seen above, the assertions that all film restoration is now carried out digitally and colour grading only takes place at the DVD mastering stage.

The film studies establishment's response to the emergence of digital moving imaging technologies took a similar approach to the one it had used to marginalise and dismiss the role of technology in creating the cinema a generation earlier, only this time couched in the language of change and the new. It consisted primarily of identifying literary and/or ideological metaphors with which to argue for differences. Writing in the millennial issue of the journal which had been at the vanguard of the growth of film theory in the 1970s, *Screen*, Sean Cubitt downplays 'the distinctiveness of digital criticism', asserting that 'to some extent it is simply a call to expand existing paradigms in Film and Television Studies.' The difference, he argued, will come in understanding 'the semantic worlds in which the producers of digital texts operate'.[24] In another article in the same issue, Yvonne Spielmann proposes 'the reinforced concept of digital space', elaborated with some metaphors that quite simply defy empirical reality. For example, Spielmann argues that analogue cinematography consists of 'the automatic registration of light rays onto an image surface', whereas the digital image relies on 'calculation processes'.[25] Light focused onto a CCD by a lens is 'the automatic registration of light rays onto an image surface' in exactly the same way that light focused onto a photochemical emulsion by a lens is, and if the resulting data is stored uncompressed (which, in many high

end studio cameras, it is, or at least can be), no calculation takes place at the recording stage.

There were occasional lone voices in the wilderness, though it is indicative that, looking through some back issues of *Sight and Sound*, they are to be found in the letters pages rather than the editorial features. In July 1998, shortly after the first DVD video titles went on sale in the UK, a correspondent from Newcastle upon Tyne encouraged the magazine's editors to engage with what he predicted would be a profound shift in our film culture. Inadvertently, he articulated, once again, the extent to which the critical and intellectual efforts to understand and curate the significance of moving images by academics to the broader public ignored the role of technology. 'I'm not suggesting *Sight and Sound* develop a trainspotter's fetish for technical knowledge', he prefaced his call, before lamenting that 'in order to find out more about the advent of DVD, I had to buy a laddish, technophile magazine whose reviewer rated *Jumanji* [USA, 1995, dir. Joe Johnston] a better film than *Vertigo* [USA, 1957, dir. Alfred Hitchcock].'[26] In the following issue, the journal's editorial, mentioning DVDs in passing while lamenting the decline of repertory cinemas, reproduced a widely believed error as to what the initials stood for.[27] The implication here is clear: that people interested in and engaged with audiovisual culture can be divided into two, mutually exclusive camps. On the one side we have 'trainspotters', interested in and knowledgeable about moving image technologies, and in some cases operating and maintaining those technologies for a living; who, it is implied, are incapable of high level critical judgement and thus are likely to consider *Jumanji* a 'better' film than *Vertigo*. On the other, there are critics and theorists who are capable of discovering cultural meaning and significance within cinema and presenting that agenda to a broader, interested public, and whose approaches and methodologies draw them to the conclusion that *Vertigo* is the masterpiece; but who either consider the role of technology in the creation of that meaning and significance to be non-existent or who have profoundly misunderstood it.

A response to this letter in the following issue offers a rare flash of insight, and a quite surprisingly accurate prediction of what would be the state of play in a decade or so. Another *Sight and Sound* correspondent argued that the launch of the DVD 'brings one step closer a digital theatrical medium, which has implications for the preservation of films. Digital technology offers the possibility of the relegation of film to the level of an origination medium, and ultimately, its demise.'[28]

The academy struggled through the 2000s to make sense of the scale and extent of the technological revolution that swept through cinema. Indicative of this is a book published in 2009, in which Nicholas Rombes complained that 'the digital era inaugurates a new form of invisibility.' A film print, he notes, is 'linked to perceived reality by its materially identifiable and recognisable existence'. Moving images in the form of digital data, he claims, is 'unknown and invisible, a complex code known only to programmers and engineers'.[29] One could equally claim that the emulsion on a film print is a complex concoction known only to industrial chemists and photographers. And as for physical objects, DCPs (Digital Cinema Packages: the collection of files that are read by a digital cinema server and passed in decrypted form to a d-cinema projector) are usually transported to theatres on a hard disc drive inside a transit case, by the very same delivery drivers who previously carried 35 mm film prints. Rombes claims that 'in the past, they [moving images in analogue form] needed to be stored or archived',[30] thereby claiming that digital data does not have to be recorded on a non-volatile storage medium somewhere. In reality it does: the fact that this medium is physically separated from the end user, e.g. by the Internet, does not mean that it doesn't exist. There is a breakdown of logic in Rombes's claims. A film print, he claims, is materially identifiable: the audience never sees it (the print is kept out of sight of the viewer by the wall separating the auditorium from the projection booth), but yet he accepts that it exists. But he does not accept that digital data has to be stored on a 'materially identifiable' physical carrier at all, a claim that quite simply defies objective reality.

I have concentrated on the impact of digital moving image technologies on the academy in a general sense thus far, because this is a necessary context in which to cite the rationale for the remainder of this monograph. This is to address the emergence of film restoration in particular, and draw some conclusions as to the implications of this practice for everyone who makes, consumes and studies moving images intended for theatrical exhibition.

Film restoration is nothing new. Stripped to its basic essentials, film restoration means finding some way of reproducing the experience of viewing a film in the context and empirical conditions of its original production and/or reception, in circumstances when the film no longer exists in its original form, the viewing conditions no longer exist or both. 'Original' is a highly problematic adjective, referring to a complex and elaborate series of historiographical debates and issues, ones

which will be discussed in depth in subsequent chapters. Suffice as to say for present purposes that the technical principles involved have been applied for a very long time, and, true to form, largely ignored by the academy. The actual work of film restoration consists of either or both of two activities: modifying the technical characteristics of surviving film elements of the content undergoing restoration, usually in the process of copying; or assembling content from multiple source elements in which the sequence of content as originally assembled is known (or at least, can be estimated to a fair degree of accuracy), but does not survive in any surviving element in isolation.

Arguably the earliest sustained examples of technical reformatting were not undertaken with restoration in mind, but rather with re-selling. Possibly the first was the widespread reprinting and distribution of 35 mm-originated mainstream feature films on 16 mm prints by the allied armed forces during the Second World War, an infrastructure that had been well established by Britain, Canada and the USA by the middle of 1942.[31] By the end of the following decade, the sale of back catalogue feature films to broadcasters for TV transmission had become an established business.[32] Significantly, this process frequently necessitated cropping of the broadcast image ('panning and scanning') in the case of films originated as widescreen productions, a practice that elicited widespread condemnation among technical purists at the time[33] and which studios would use to their advantage in marketing 'restored' (to their original aspect ratios) home video versions when the 16:9 ratio superseded 4:3 as the consumer television standard in the early 2000s, half a century later. Consumer video recordings, both for rental and outright sale, created yet another new market for archived films from the late 1970s onwards, one which the rights owners sought to regenerate with each new consumer and theatrical technology to materialise in the last three decades: digital sound for theatrical projection in 1992, the DVD in 1998, digital theatrical projection in the mid-2000s and the BD in 2007.

Alterations to the content sequence also go back a very long way, but again, do not have their origins in the practice of restoration. Quite the opposite, in fact: such alterations are frequently deemed to have caused the problem the restorers perceive themselves trying to solve. As early as 1912, the producers of newsreels covering the *Titanic* disaster, faced with the fact that hardly any footage of the actual *Titanic* had ever been shot before its infamous argument with the iceberg, cannibalised footage from earlier actuality films of another ship built a year earlier and to an almost identical design, the *Olympic*, and passed it off

to audiences as showing the *Titanic* immediately prior to its first and last revenue-earning voyage.[34] Several researchers and archivists (not to mention an army of amateur *Titanic* fans) have devoted hefty chunks of their careers to working out exactly what these filmmakers did and where their footage came from. A number of feature films that are now celebrated by scholars and critics as cultural masterpieces do not survive in their 'original' form, re-edited either because they were received as mediocre failures by the prevailing critical establishments in operation at the time of their initial releases, or because the studios that financed them did so to enhance their earning power, or because they were subsequently re-edited to fit television broadcast slots or the limitations of consumer media. Two of the most widely discussed films for which significant footage is still known to be missing are *Greed* (USA, 1924, dir. Erich von Stroheim)[35] and *The Magnificent Ambersons* (USA, 1992, dir. Orson Welles).[36]

Arguably the most extensively publicised, debated and seen subject of reconstructive restoration in western cinema history is that of *Metropolis* (Germany, 1927, dir. Fritz Lang). This is principally because it was celebrated by a succession of prominent writers and academics, from Iris Barry and Siegfried Kracauer onwards, as a defining example of the Weimar expressionist aesthetic and an icon of the German cultural achievements swept away by the Nazis; yet at the same time, the film was cut substantially almost as soon as its Berlin premiere was over (within six months, a significantly shorter version was on general release in Germany), and has almost certainly never been seen in precisely that form since. Major reincarnations of the film appeared in 1984, 1985, 2002, 2005 and 2010, the foremost provoking an intense ethical controversy for its replacement of the original intertitles with subtitles and a modern music score featuring the performances of prominent 1980s rock and pop stars. The most recent edition incorporated footage from a 16 mm element of the film that turned up in a museum in Argentina in 2008. News of the discovery was stage-managed by the German newspaper *Die Zeit*, which devoted an entire colour supplement to the story, characterising the rediscovery of 'the most important silent film in German history' as 'a worldwide sensation'.[37] Two prominent German archivists who had worked on previous restorations of *Metropolis*, Enno Patalas and Martin Koerber, told *Die Zeit*'s journalists that the Argentinian material included virtually all the footage believed to have been included in the 1927 Berlin premiere version but which had been missing ever since. This was probably the most dramatic, but by no means the only 'rediscovery of a masterpiece' narrative to be used

in the publicity for major restoration projects, and the prominence of this narrative raises some important questions as to the extent to which the archivists' agenda is set by the critical and academic establishment. Writing on the email discussion list operated by the Association of Moving Image Archivists (AMIA), a German film archivist working in the Netherlands sparked an intense controversy by questioning the value of yet another *Metropolis* restoration, even if the volume of new footage involved was substantial. He wrote:

> *Metropolis* is probably the most researched and best-documented (visually and written-down) film out there and I doubt that the new scenes will add any fundamentally new insight to the available (and I dare to say, vast) knowledge about *Metropolis*. I mean, the film is already on UNESCO's cultural heritage list. Isn't it time to move on? There is so much more to take care of.[38]

It is important, therefore, to realise that the issues raised by the practice of film restoration are not confined to the purely technological, even if the nature and extent of the misunderstanding of technical issues that surrounds the overall debate is a major impediment to addressing the wider questions meaningfully. These will be discussed further in subsequent chapters.

And these ethical and cultural debates have taken place. As I shall argue, a major problem is that they have mainly taken the form of an internal conversation among archivists and film preservation professionals surrounding the techniques, practices, aims and ethics of the practice of film restoration, both from the point of view of safeguarding original content and reformatting it for communication to the public using whatever is the dominant access technology of the day. They have not, on any meaningful or systematic scale, broadened out to incorporate the academic elements of film studies or media history, despite major early links between the two fields.

The film archiving movement as a sustained cultural force has its origins in the intellectual film culture of Europe in the 1920s, and materialised as actual institutions and collections during the following decade. Following the discovery in 1941 by the pioneer preservationist Harold Brown that cellulose nitrate film base decomposes over time,[39] thereby threatening the integrity of films in storage, the importance of preservation, and in some cases the deemed necessity of restoration, became one of the defining issues of that entire establishment and profession. The two largest representative bodies in the field, the International Federation of Film Archives (known generally by the initials of its name in French, FIAF), and AMIA, both started peer-reviewed journals dedicated, at least in part, to advancing the science and technique of film preservation and restoration: FIAF's *Journal of Film Preservation*, first published in 1993, and AMIA's *The Moving Image* in 2001.

In a foreword to the inaugural issue of the latter, AMIA's then president, Sam Kula, wrote that 'the level of discourse *among moving image archivists* on such topics as the ethics of restoration... have reached a point where a forum for the exchange of considered (and peer-reviewed) views was not a luxury but a necessity' (my emphasis).[40] Although changes in editorial direction towards the end of the decade increasingly drew the academic community into that debate, it remains to this day rooted primarily within the archiving profession, and conducted at a level that requires substantial technical and curatorial knowledge to participate in. Arguably the only monograph-length work on the wider implications of the profession, Ray Edmondson's *Philosophy of Audiovisual Archiving*, originally published in 1998 and extensively revised in 2004, is in effect a 'how to' manual for the evolution and implementation of ethically informed practices within the archiving profession.[41] No similar work exists aimed at engaging humanities academics and the broader public into this debate in the way that an extensive body of literature covers the wider cultural implications of conservation and restoration practices in other areas of cultural activity, notably restoration practices in art history and the period performance movement in classical music.

It is the aim of this book to make a start in doing that, and it is now vitally important that this be done. The prediction of *Sight and Sound*'s correspondent in 1998 has, 13 years later, been proven largely correct: the process of relegating film to the level of an origination medium is almost complete. At the time of writing, the major Hollywood distributors have all announced plans to cease theatrical distribution on 35 mm film, starting from the spring of 2013. As I shall argue in subsequent chapters, the practice of film restoration has existed since long before digital moving image technologies. But the emergence of those technologies makes it possible on a hitherto unprecedented scale, and furthermore risks creating confusion as to and misunderstanding of what its techniques and objects actually are.

Arthur Asa Berger wrote that 'Films are what might be called "finished texts". Once they are completed to the satisfaction of those making them, they cannot be modified without seriously affecting them.'[42] Film restoration is that modification, and it is very much open to question whether a lot of modification done in the name of restoration is actually

restoring anything, or modifying it to different ends. The emergence of digital imaging technologies enable that modification to take place on a far larger scale, in a far more diverse range of settings, with far less money and with far less curatorial and technological expertise and with far more of a commercial motive than was ever the case while the practice used exclusively photochemical technologies. The implications of this for the cultural status of 'restored' films and how they can be understood by the academy and beyond is too important to be left to either of two scenarios that have dominated thus far. On the one hand, we have *Vertigo* being celebrated as a creative masterpiece in comparison with a film such as *Jumanji*, but discussion of its restoration dismissed by an acclaimed film theorist as inconsequential 'quibbling about the remixing of the soundtrack and grading of the print'.[43] On the other, we have research that embodies fundamental errors as to what that remixing and grading actually involves.

The tendency for mainstream, public discourse that focuses on the art and culture of cinema to dismiss the role of technology has not gone away, despite the technological revolution of the first decade of the 21st century and the effect it had on the production, distribution and consumption of films. On 28 February 2011, as they had done 14 months previously, BBC radio's journalists once again demonstrated their belief that these issues are unworthy of significant discussion. That morning, the BBC's flagship current affairs programme, *Today*, broadcast a four-minute report on the previous night's Oscars ceremony, almost the entirety of which was devoted to the four awards won by *The King's Speech* (UK, 2010, dir. Tom Hooper), for Best Picture, Best Original Screenplay, Best Actor and Best Director. The piece concluded, almost as an afterthought: 'The science-fiction film *Inception* [USA, 2010, dir. Christopher Nolan] also won four awards, but these were mainly in technical categories.'[44] The message is clear: Oscars in 'creative' categories are considered of greater cultural significance than those in technical ones, despite the creativity being dependant on the technology for its very existence, and despite the fundamental changes in the core technologies used to create, distribute exhibit and preserve moving images in the mainstream. It is not the aim of this book to persuade readers to adopt a mindset that might judge *Jumanji* to be a better film than *Vertigo*, but hopefully to persuade them to engage with how both films were initially products of the technologies of their time, but which are usually seen today through very different ones.

1
Why Do Films Need to Be Restored?

Introduction – Articulating the original

Film restoration is a controversial practice. And it isn't. In May 2010, the British national newspaper the *Daily Mail* carried a report of the broadcast of an archive-based historical TV documentary series on the Second World War, claiming that 'Germans have been able to watch the war that changed their world forever in full colour', and that 'film footage and photographs restored and colourised using the very latest technology... allow people now to see the war as people then did'.[1] A year earlier and in a similar vein, another press report stated that recently discovered amateur film of Churchill and Eisenhower would be 'transformed into high definition footage using a state-of-the-art digital film format.'[2] In both cases, the archival footage being repurposed for contemporary access was processed in such a way as to add significant image information that was not captured at the original point of photography. Nowhere was it implied that this practice was curatorially problematic or ethically debatable as a general rule: it was mentioned towards the end of the former article that the producers of *Der Krieg* had refrained from colourising footage of Holocaust atrocities on the grounds that doing so would have been 'tasteless',[3] but the tone of the article was that in overall terms, the practice enhances the film's perceived authenticity as opposed to compromising it.

This raises a complex series of issues. Firstly, issues of authenticity and provenance in the physically recorded moving image and audio records that comprise a film have never been subject to the same scale of methodological and ethical debates in cinema criticism and scholarship as they are in most other cultural forms based on permanent records. If an art conservator had colourised Leonardo da Vinci's *Virgin*

and Child with St. Anne and St. John the Baptist, would its mainstream reception have been as uncritical as that of the colourised footage in a television documentary? Why do film critics and historians not routinely refer to the 1958 *Vertigo* compared to the 1997 *Vertigo* in a similar way to that in which classicists have conducted extensive debates as to the respective merits of William Melmoth's translation of Pliny the Younger's letters compared to that of Betty Radice? And why is there no established vein of scholarship on filmmakers whose works were subject to extensive alterations and revisions in the same way that for the last four decades, musicologists have debated what Deryck Cooke termed the 'Bruckner problem'?[4] Almost all the commercially published recordings of Bruckner's eighth symphony (for example) state prominently which of the five published versions of the score has been used for the performance, and many will be packaged with extensive essays by the conductor or a musical scholar justifying the choice through an analysis of the competing claims to authenticity made for each of them. Yet how many consumer video publications of *King Kong* (USA, 1933, dir. Merian C. Cooper and Ernest B. Schoedsack) incorporate comparable discussions of the multiple versions that were released in different territories and in different time periods since the initial screenings?

The object of film restoration means different things to different people. As I have argued in the introduction to this book, attempts have been made to define the combination of technical and historical specificity of the moving image medium by which it can be regarded as a discrete document, but these attempts have largely been confined to the archiving profession, with secondary input from historians. Central to this is the notion of originality, and implicit in that is the belief or assumption that there is such a thing as the 'original version' of any given film: in other words, a definitive form of the film from which others can be considered deviations and which, if it is not known to exist, it is the restorer's aim to recreate. The problem is that no-one is really clear what 'original' means. The International Federation of Film Archives' (FIAF) code of ethics requires its adherents to 'not seek to distort or change the nature of the original material',[5] while the AMIA charges its members 'to restore and preserve artefacts without altering original materials, wherever possible'.[6] Neither of these codes defines what is original and what isn't, and nor, to any useful level of objectivity, does the only monograph-length work on the subject, Ray Edmondson's *Philosophy of Audiovisual Archiving*. The closest Edmondson gets is in proposing two, mutually contradictory, definitions. The first is in a glancing reference in his proposed definition of a record: 'lasting evidence of transactions, decisions, commitments or process, often in the form of unique original documents'.[7] The second is 'a film negative or master recording'.[8]

The silent period: Incorporating exhibition

Defining 'original' as a combination of content-based and temporal (i.e. immediately following a film's initial production), to varying levels of specificity, is problematic. Early and mature silent cinema presents a particular challenge because, to adapt Edmondson's phrase, a major part of the 'transactions, decisions, commitments or process' this form embodies – the audio – is *not* contained within the 'unique original documents'; or at least, not in the same one and in the same way as the picture. That uniqueness is not self-contained and textual in the sense that it is embodied entirely within the audio-visual artefact itself. It was a common practice in early cinema exhibition in multi-purpose entertainment venues, notably fairgrounds and music halls, for a showman or lecturer to accompany the projection of a film, often explaining a filmic narrative with the aid of notes or a crib sheet supplied with the film print itself. During the period in which the techniques of continuity editing were still undergoing basic development and evolution, these notes provided elements of the narrative that were not understandable from the actual moving images, as in the case of *A Daring Daylight Burglary* (UK, 1905, dir. Frank Mottershaw), during the projection of which the audience was told that a telephone call had been made to arrange for a criminal's arrest.[9] The film makes no sense without this information, yet when it is screened today it is usually with a musical accompaniment and without any commentary. A claim could possibly be made to originality in respect of the sequence of film images in isolation, but not to the authenticity of the viewing experience.

Between approximately 1908 and 1915, a primitive version of what might now be called a music video emerged, in which films were made of a performer lip-synching to a pre-existing, commercially published music recording, and then exhibited using a proprietary method (there were several, each with their own branding, e.g. Cinephone, Vivaphone) of interlocking and synchronising an acoustic gramophone to a film projector.[10] In many cases the films survive but the audio recordings do not (or vice-versa), and today the films are sometimes screened with contemporary live musical performances of surviving scores. To what extent can this be regarded as original or authentic, especially if the situation is further complicated by the fact that upon such a film's

initial release, it may well have been screened with either recorded or live music, depending on the equipment and personnel available in the theatre?

After the combination of live musical performance and mechanically generated sound effects became the dominant form of accompaniment for mature silent cinema in North America and other countries that were significantly influenced by Hollywood's business and cultural practices (approximately from 1915 until the late 1920s), a number of variables informed how this took place. In some cases studios would provide scores, to varying degrees of specificity (i.e. ranging from a complete score to a loose framework that enabled significant improvisation by theatre musicians) and complexity, from a piano score to full-scale orchestral parts.[11] One school of thought among the archiving profession believes that 'a tour of important silent films without the original score [...] carries the message that half a restoration is good enough. No-one would accept this in the art world, [sic] why should it be acceptable in the world of early film?'[12] But 'the original score', if defined as an authenticated form of accompaniment dating from the film's initial screenings, meant something very different in a large, city centre theatre than it did in a small, rural one; a fact that needs to be borne in mind when considering the response to Anderson's injunction, offered by restorers such as Kevin Brownlow and Carl Davis, of synchronising high-quality recordings of full-scale symphony orchestras to the final release versions of their projects.

And furthermore, surviving evidence of the culture of film exhibition during this period is that it was a far more volatile and anarchic environment. For example, a comic record published in Britain in 1926, *Mrs.'iggins at the Picture House*, portrays a noisy projector, an out-of-tune harmonium, a customer who noisily reads out the film's intertitles, disinfectant being sprayed in the auditorium and a myriad of other distractions that created an exhibition context very different from the one in which the end result of archival restoration projects are typically seen today.[13]

The sound period: Multiple texts

Defining originality in the case of a sound film (and a silent one if the scope of coverage is restricted to the moving image component) would superficially appear to be easier, as there was usually a lot less inherent variation in the historical reception context. However, the definitions of originality commonly used by archivists have the potential to be every

bit as problematic as they do with silent films, both in evidential terms and in terms of the specificity of the film medium. Unique documents are often not 'original' in the sense of being an unmediated record of their content, e.g. if they are the end result of censorship, re-editing for commercial reasons or other alterations; and a film negative can often be two generations removed from the one exposed in a camera and incorporate substantial modification to the camera original's content during the post-production process. It may be the nearest (in generational terms) surviving element to that camera original, but be missing content that is present in other copies that are removed by further generations. In other words, a given physical element of a given film can be 'original' according to some definitions and in some contexts, but not others. As the historiographer Arthur Marwick points out, 'certain materials do not fit neatly into the categorisation as primary and secondary sources. Some are primary sources from one point of view, but secondary from another.'[14] The same health warning applies to the notion of originality in film. For example, the 1938 re-release of *King Kong*, in which scenes believed by censors to portray unacceptable levels of sexual violence were cut,[15] is 'original' in the sense of being a record of the effects of the Production Code half a decade after its introduction, but not of *King Kong* as it was initially distributed in most of the USA shortly after its production was completed in 1933. Or the British Film Institute's 'restoration' of *A Colour Box* (UK, 1935, dir. Len Lye) is original in the sense of revealing the aesthetic detail of its maker's hand painting onto film, but not of the subjective impression of seeing the film in the 1930s, as the two versions used entirely different colour reproduction systems and the theatre projectors in widespread use now use a different light source, with a slightly lower colour temperature, to those of the 1930s.[16]

Arriving at a definition is in fact easier said than done, the principal reason being that (with the arguable exception of home movies shot on reversal stock), audiences never in fact see an 'original' film, if one defines original as being the physical artefact that is exposed in the camera, i.e. on which the recording is actually created. Like the mass distribution of the written word, moving image media depend entirely on their ability to be copied. Indeed, it was the ability to create multiple physical copies from a single film element exposed in the camera that made the cinema a viable commercial enterprise: it is always worth remembering that the Lumières' *Cinématographe*, one of the earliest mass-produced piece of film industry hardware, was a machine that combined three functions in one: a camera, a printer and a projector. In other words, it embodied the three sectors of what would later form

the vertically integrated structure that enabled Hollywood's economic dominance: production, distribution and exhibition. The creation of multiple copies can be done at comparatively little cost (relative to that of the initial production, or the 'negative cost' in film industry parlance) and with little if any perceived loss of technical image quality by the lay viewer.

And furthermore, that copying is almost never a content-neutral process and is often integral to the creative one. In 2008, the inventor of a film scanner designed for archival use published a press release claiming that the machine offered 'non-judgmental preservation', by which he meant that it extracted image and audio information from the element being scanned and represented it in digital form without altering its subjectively perceived aesthetic or sonic properties.[17] The implication, of course, is that conventional film copying processes *do* incorporate some form of 'judgement' as to what the duplicate should look and sound like, which isn't necessarily the same as the source. The change can be deliberate, for example optical printing to incorporate dissolves, mattes or other special visual effects, or the incorporation of computer generated imagery (CGI) within a digital post-production workflow. In such cases, a 'non-judgmental' copy of the original camera negative will bear little if any resemblance to the finished product the filmmaker intended audiences to see on the screen, and in some restoration scenarios it may be deemed necessary to, in effect, recreate original post-production steps. A very simple example would be the practice of tinting and toning using coloured dyes. These colours were not captured at the point of photography, yet were routinely added in the processing of the final release prints. Some restorations incorporate colour tints and tones, either produced by authentic methods or simulations using contemporary technologies, whilst others have not, with the restored film being screened in black-and-white. Claims to originality could be made for either output.

Exhibition technologies in use following a film's initial release are likely to have been very different from the ones in mainstream use when it is subsequently restored, thereby raising further questions as to the nature of authenticity and originality. Technicolor is an obvious case in point: throughout the period in which it was a mainstream technology, the dye transfer printing method used to produce the copies shown in theatres was incapable of reproducing the definition or tonal range captured by the beam-splitting camera; so much so that many release prints dating from a three-strip production's initial release 'do not provide a true idea of the fidelity that the system was capable of [recording] at the time'.[18] The dye-transfer printing system was notoriously resistant

to quality control, producing release prints that varied from those that rival modern chromogenic ones to copies in which colour fringing, poor saturation and other defects resulted in them being treated as 'fly-over state' (USA) or 'north of Watford' (UK) prints, i.e. distributed to second-run theatres that charged lower admission prices. In some cases, Technicolor's technical characteristics were deliberately manipulated for artistic effect, effects that cannot easily or accurately be reproduced with alternative technologies in current use.[19] The final aesthetic variable that needs to be thrown into this mix is that during the period in which Technicolor dye transfer printing was a mainstream technology, the light source in most theatrical cinema projectors was the carbon arc lamp, which produces a colour temperature of about 5,000 kelvin. Between the late 1950s and early 1970s, carbon arcs were largely superseded by the xenon arc lamp, with a colour temperature of 4,000 to 4,500 kelvin (i.e. more towards the red end of the visible spectrum). Viewing a 1930s or 1940s Technicolor release print using modern equipment, therefore, will give a significantly misleading impression of what the cinematographer and grading technicians were trying to achieve.

A restored version can often reveal detail recorded at the initial point of photography that, due to shortcomings in post-production, printing and/or projection technologies used thereafter, were lost from the film's early screenings. Surviving release prints can provide evidence of this (subject to the health warning on illumination sources), thereby presenting the restorer with an ethical dilemma: does he try to recreate the 'original' exhibition experience, retaining what are now perceived as technical drawbacks, or does he use contemporary technology to correct them? When, in the 1980s and early 1990s, the former Technicolor employee Paul de Burgh was commissioned by the British Film Institute to undertake a series of restorations of three-strip titles held in (what was then called) the National Film Archive, critical responses to his work frequently pointed out that compared with surviving dye transfer prints from the initial releases, many of the restored versions offered substantially greater definition, contrast and saturation.[20] In crude, subjective terms, they 'looked better'.

And finally, individual textual elements can incorporate visual or sonic elements that were not created at the point of initial production, often because those original components either do not survive or are regarded as compromised in some way, and thus are perceived by the restorer to need replacing. An indicative example would be the audio components of *Lawrence of Arabia* (UK/USA, 1962, dir. David Lean) that were junked as the result of cuts made to the film following its initial screenings. For the 1988 restoration, members of the original

cast re-performed parts of the dialogue in a new studio two and a half decades later.[21] The film's restorer, Robert Harris, defended his actions on the grounds of fidelity to the director's 'original' vision, and indeed the result was endorsed by Lean himself. But the 1988 version of the film incorporates material that simply cannot be defined as 'original' by any evidential criterion: these recordings were simply not part of the film as screened following its initial completion, and because those that were no longer exist, it will never be possible to form even a subjective view of how accurately they reproduce the film as it was seen by a very small number of people before the distributor started to edit it down for more widespread distribution. Nevertheless, this has not prevented the 1988 *Lawrence* from being distributed in new 70 mm prints and published on consumer video media with claims of fidelity to the technical integrity of 'the original'.[22]

A minority of practitioners simply don't care whether the end result of their work is focused on the originality of the technical attributes of the surviving physical artefact or the authenticity of its initial exhibition context at all, e.g. the producers of *Der Krieg*, for whom their source footage was simply a starting point in an attempt to evoke their imagination of what *its subject* (as distinct from a reproduction of the original media) in wartime might have looked like. However, they tend to be the exception. The majority of archives and restoration practitioners both seek to validate their activity and to articulate as its goal the recovery of something lost, that something being related, to varying degrees, to the concept of originality. They rarely get as far as defining precisely what they mean by that, and as we have seen, there is a wide range of definitions, and combinations of definition, on offer.

The remainder of this chapter will detail the principal scenarios, the perceived existence of which has led to the decision that an 'original' film does not survive and that restoration activity is warranted. These can broadly be placed into two categories that I will term the physical and the political – or in other words, loss of the original caused by the shortcomings of the medium itself, and those caused by human activity, both accidental and deliberate, conscious acts and those of neglect. Of course, the two categories frequently overlap, often in the form of one invoking the other.

Physical loss 1: Chemical decomposition of the film base

Nitrocellulose and cellulose acetate-base photographic film, which account for all but an insignificant fraction of moving images originated on film, is an inherently unstable medium. Its chemical composition is such that it is slowly destroying itself from the moment of its manufacture. When combined with human neglect, the result is loss by default. Stored in unregulated temperature and humidity conditions, these film bases will decompose to the point at which the image and audio information on them can no longer be recovered within roughly 20 to 100 years, depending on the climate and other variables.

Cellulose film bases have been mass-manufactured since 1889. The basic procedure is to dissolve wood pulp in acid (either nitric or acetic), and process the resulting brew into the solid material offering the three vital properties needed of motion picture film: flexibility, a high tensile strength capable of withstanding extreme mechanical stress and transparency.[23] Or at least, it offers them in the short term, and therein lies the problem. Film was originally conceived as an ephemeral medium, and no systematic, institutionalised thought was given to preserving moving images, either as commercial intellectual property or as public records, until the 1930s. Formal preservation activity did not take place on any significant scale until the 1960s, and the chemical processes that cause nitrate and acetate film decomposition – and thus, how to manage and inhibit them – were not fully understood until the early 1990s. Even today, substantial debate and disagreement exists within the archiving profession over the optimum preservation strategies for different sorts of film element in different circumstances, and the fact that the scientific principles which inform that debate were not accepted as being fundamentally definitive until film had been in use for almost a century indicates the extent of loss and damage due to film decomposition that has taken place during this period.

Nitrocellulose film base, more commonly referred to as nitrate, was the industry's mainstay from its invention in the late 1880s until the middle of the 20th century. During this period, the primary emphasis of its use and management was on short-term health and safety, not long-term preservation. One thing that was immediately understood by almost everyone who worked with nitrate film was that, with the possible exception of liquid fuel, it was arguably one of the most dangerous chemical products to be used routinely in the presence of the public. Nitrate was highly flammable, impossible to extinguish once alight (because the combustion process generates oxygen as a by-product[24]) and produced highly and acutely toxic gases during combustion. As the author of one of the first histories of the film industry, published in 1926, put it, 'public and official opinion holds a most positive opinion that motion picture film is a deadly explosive. The reputation of

nitro-glycerin is trivial beside it.'[25] The period in which nitrate film was in widespread use was punctuated by a series of highly publicised fires, costly both in lives and money.[26] Nevertheless, the cost of the safety precautions needed to keep the risk within what were regarded as acceptable limits was exceeded by that of using the less flammable alternatives that were available at the time.[27] An article written in 1939 noted that 'nitrate film is used by theatrical picture producers because when used promptly after development it is less expensive and better able to withstand the heat and mechanical wear of theatrical projection than is acetate film.'[28]

What was a lot less well understood was the process of nitrate film decomposition. In crude terms, the chemical action of the nitric acid during the manufacturing process does not cease when it is complete: it continues to attack and weaken the polymeric structure of the base thereafter. The first visible symptom is shrinkage, followed by moisture leaching from the film base, dissolving of the emulsion (the coating on the base of the film that actually carries the photographic image), adhesion between layers and eventually wholesale decomposition of the film into a highly volatile solid with similar properties to gunpowder.[29] A review of the technical literature produced by the film industry before the emergence of the film archiving movement in the mid-1930s reveals no significant evidence that this phenomenon had been observed, documented or commented on. By the end of the decade, evidence of awareness of the problem begins to emerge: for example, the observation that 'the life of nitrate film is not definitely known; but even when correctly stored, it is thought not to retain the best of condition more than thirty or forty years' in 1939.[30] But the earliest systematic descriptions of the stages of nitrate decomposition that I have been able to find in print date from the early 1950s, i.e. well after the British archivist Harold Brown is generally credited with having discovered the phenomenon in 1942. Even then, the discussion was focused either purely or primarily on the discovery that in the later stages of decomposition, nitrate becomes even more volatile (i.e. easier to ignite and prone to explosion) than when it is mechanically intact, with the consequent safety issues, rather than the implications for the long-term preservation of content originated on the medium.[31]

The commercial launch of cellulose triacetate film base in 1948[32] was not only celebrated by the film industry as a low-cost replacement for nitrate that took the fire problem off its hands, but also by archivists who believed that it took the decomposition problem off theirs. This resulted in an almost dominant and universal preservation strategy

being adopted by the world's film archives from the 1950s until the 1990s, that which is encapsulated in the title of Anthony Slide's 1992 book *Nitrate Won't Wait*.[33] This consisted of making copies of nitrate elements onto triacetate base stock, to varying levels of technical quality, depending on the laboratory infrastructure, expertise and money at their disposal. Disposal of the nitrate originals after copying was commonplace during this period, as it was believed that they would inevitably decompose beyond the point of recovery within a relatively short timescale, and therefore that there was no point in spending money on their continued storage.[34] Unfortunately, it quickly became apparent that triacetate film decomposed in much the same way as nitrate, the only difference being the absence of the nitrate-specific fire and explosion risk. Acetate film decomposition is widely claimed to have been first observed in India at some point during the 1950s,[35] due to the high ambient temperature and humidity there, and in northern hemisphere archives from the mid-1970s. 'Vinegar syndrome', as it was quickly termed by archivists due to the strong acetic acid smell of stock in an advanced state of decomposition, worked, in the words of a scientist researching its effects, by 'a mechanism which involves the acid catalysed hydrolytic deacetylation and degradation of the polymer structure.'[36] In other words, the acid used in manufacturing the film base attacked other components of it just as it does in nitrate, causing the overall breakdown of its molecular structure. Once again, the film industry had chosen its mainstay production medium with short-term operating costs in mind, not long-term preservation.

From the early 1980s, most release printing and some intermediate stocks began to be manufactured on a polyethylene terephthalate (polyester) base. Being a synthetic as distinct from an organic compound, it is widely believed to be unaffected by decomposition.[37] However, its very high tensile strength has resulted in polyester being considered unsuitable for camera and some intermediate use, due to the equipment damage that would result from a film jam or other mechanical failure (acetate film would simply break). And so the sorts of film element that from a preservation standpoint are most desirable to be originated on polyester base stock – camera negatives and fine-grain interpositives printed from them – are still normally originated on acetate. Another development during the 1980s was the discovery by researchers, principally at New York's Image Permanence Institute and Manchester Metropolitan University in the UK, that the decomposition of nitrate and acetate-based films can be inhibited to a large extent by storage in atmospherically controlled vaults maintained at a constant

and significantly lower temperature and humidity level than is usually found in the normal atmosphere.[38] This presents the modern archive with the same dilemma as it responded to in the 1970s by copying and then disposing of nitrate holdings: original (or the closest surviving generation to original) film elements that they have been caught in the early stages of decomposition can be preserved for an extremely long time (accelerated aging tests indicate a useful lifespan of several centuries in optimal conditions), but at relatively high cost. Although the most recent generation of archival science has identified effective methods of best practice, they do not come cheap and in any case, chemical decomposition has already had a major impact on a significant proportion of the world's overall film heritage.

Film base decomposition can be judged to necessitate restoration activity when it has resulted in the total or partial loss of the original, or closest surviving generation to original, element of a given title. This is most likely to have happened in cases where a rediscovered film element has been stored in sub-optimal atmospheric conditions, either in private ownership for a substantial period prior to its acquisition by an archive or in archival storage since significantly before the importance of temperature and humidity control to preservation was fully understood. A chemical test, developed by the Image Permanence Institute, exists to predict the rate of future decomposition in acetate film (the use of acid-detection strips[39]), though for nitrate collections visual inspection is necessary. Many archives do not have the workforce or budget needed to monitor their collections as closely as is needed to catch the decomposition process before the point of no return, i.e. when it has caused a significant impact on the image and sound information embodied within a film reel, such that at the very least, remedial treatment is necessary. One archivist, interviewed in 1983, recalled opening a reel of nitrate to discover that 'there weren't more than two frames that had an image left. You have to junk the film outright. There is powder, gel, but no film.'[40]

In such cases, where the original or best (defined in this context as the generationally closest to the original) surviving element has been totally lost due to decomposition, the essential response is the same one as in the case of total loss for other reasons: lower quality elements have to be used to create the restoration master, possibly with more extensive treatment to address the generational loss of image quality than would have been the case had the camera negative and/or other elements that embody the definition of originality the restorer is trying to achieve been available. Restoration activity can also be necessitated

by partial loss due to decomposition. Shrinkage is a common aspect of both nitrate and acetate decomposition, resulting in unsteadiness of the projected picture; as is discolouration of nitrate and lateral deformation ('buckling') of acetate. Both photochemical and digital methods exist of copying the content from affected elements, to varying perceived quality of result according to the individual scenario. A restorer has to judge whether to use a decomposed best surviving element or one that may be further generations removed but in physically better shape as the basis for a restoration master.

Chemical decomposition of physical media is not a problem unique to the preservation and restoration of films. The decomposition of paper, made from wood pulp, caused by acids used in the manufacturing process has been systematically described, understood and managed by document archivists and librarians since the mid-1930s – within a decade of the discovery of nitrate film base decomposition.[41] The process quickly acquired a nickname as ubiquitous in the document archiving field as vinegar syndrome is to film archiving: the 'slow fire', a phenomenon which inspired a documentary film, *Slow Fires: On the Preservation of the Human Record*, made in 1987.[42] However, there are some important differences between the way the problem has been perceived in the two professions, ones which shed important light on the reasons why factors are deemed to exist that necessitate film restoration. Like cinema, the printed word depends on copying for dissemination. Analogous to the way in which an uncut roll of original camera negative represents the raw material from which the (or in some cases a) final version of a film is prepared in the form of an intermediate generation for mass-duplication, so an author's manuscript is the initial input into an editing and production process, the end result of which is a paperback on the library shelf. However, loss of information in the (analogue) copying process is usually not considered as significant an issue when dealing with document conservation as it is with film, and therefore any method of copying that preserves the legibility of the written word, including simple photocopying onto acid-free paper, is considered sufficient for the majority of preservation purposes affecting slow-fire-affected printed documents. Facsimile editions using high-quality photography are sometimes produced in the case of documents when the aesthetic properties of the original artefact are regarded as significant primary source material in their own right, for example in the case of the conservation, photographing and rebinding of the Domesday Book in 1984–1986.[43] But such projects are the exception that proves the general rule of document archiving: that preserving

the content is usually more important than the form. With film, the distinction between the two is made a lot more complex due to the inherently analogue nature of the photographic image and the loss of image information that results from copying it; hence one facet of the 'originality fetishism' that drives many decisions first to undertake restoration projects, and then within them, is the emphasis within modern film archiving of saving best surviving (defined as generationally closest to original) elements from decomposition.

Physical loss 2: Physical damage to the film base or emulsion

This category of damage is distinct from chemical decomposition of the base itself in referring to man-made, physical damage to the film. It can be subdivided into abrasion (scratches), failed splices, perforation damage, edge damage, foreign bodies and foreign agents on the film base or emulsion surface. While laboratory processes to minimise such damage to pre-print elements during the post-production process existed by the late 1920s,[44] such damage was generally regarded as routine, unavoidable wear and tear in the case of release prints. Research carried out by a Kodak scientist in 1948 indicated that a typical nitrate print had a lifespan of 644 projections before mechanical failure.[45] In cases where pre-print elements are not known to survive, therefore, the decision to undertake restoration work based on significantly damaged release print elements may be made. A number of factors can inform the choice of elements used (where a choice exists), as some forms of damage can be mitigated more effectively than others. Physical damage that compromises film transport through a copying device such as a printer or scanner, principally perforation damage and failed splices, can often be repaired without leaving any visible trace on the duplicate. The same applies to dirt and abrasion on the base side of the film, though on the emulsion side, where abrasion has actually removed some of the image information, there are limits to what can be achieved, both with photochemical and digital techniques.

In some cases such artefacts have been created, allowed to accumulate or even digitally simulated deliberately, either as part of an artistic statement embodied in the film,[46] or as a visual device intended to convey an impression to the audience that the footage is 'old'.[47] The mere existence of this convention presents the restorer with a dilemma. In strict technical terms, film footage should not be scratched or dirty, however old it is: that damage can only have been caused by incompetent film handling practices, and/or running the film through a poorly maintained or faulty

mechanism. However, the standard of film handling and equipment maintenance required to keep film elements totally clean is very high. It is least likely to be maintained in the case of release prints, because cinema projection booths by their very nature are very unforgiving environments for film. In such an environment the film is repeatedly wound at high speed, subjected to high levels of heat and run on equipment with fast moving parts and sharp edges. Projection booths are habitually the dirtiest and dustiest parts of a theatre building, as they are one of the few parts to which the public is not admitted.

A heavily used release print, therefore, is likely to contain a lot of physical damage, much of which can be mitigated, either by remedial treatment to the element itself or in the copying process. Yet it is a common and widespread misconception among those who know little about moving image technology that such visual artefacts are an inevitable symptom of film's aging process and that their absence indicates the film to have been made relatively recently; so much so that restoration projects that painstakingly remove them have resulted in complaints that the restored film looks too clean, and thus lacks authenticity. Occasionally, archives decide to leave evidence of physical damage in place in copies of films intended for public access, either because no restoration technology in current use can effect a satisfactory mitigation, because it could be done but the archive cannot afford it or even as a curatorial statement. A notable example would be a DVD compilation of classroom sex education films published by the British Film Institute (BFI) in 2009, in which several of the titles are transferred from actual 16 mm release prints that had previously been in distribution before their acquisition by the BFI.[48] Deep emulsion scratches and heavy dirt is visible in some passages, typical of the damage caused by the poor operation and maintenance of the portable 16 mm projectors used extensively in schools and other non-theatrical settings from the 1930s to the 1980s. The principal reason for the decision to leave the visible defects in was financial: the budget was not available to carry out full-scale restoration work on these titles in preparation for their inclusion on the DVD.[49] Correction of colour dye fading was carried out during the transfer process, however, as it could be done at very little extra cost. So although in one respect the restoration process was inconsistent (one form of damage was mitigated, but another was not), a strong argument could be made that the resulting digital copy gives viewers a more subjectively authentic impression of the experience of viewing a 16 mm classroom film in its original context than would have been the case if the visible artefacts from physical damage had been removed (because the

film's initial classroom audiences would have seen dirt and scratches resulting from mishandling but not the dye fading, which takes several decades to become visible). In the case of restoration projects involving affected elements, such decision-making should be an integral part of the process.

Physical loss 3: Loss of colour information

As with physical damage, colour information in film also falls essentially into two categories: that which is captured and reproduced photographically, and that which is introduced independently of the photographic process. The end product is the same in both cases: a visible dye contained within the film's emulsion. There are a number of scenarios in which the colour information found in surviving elements used for a restoration project differs substantively from that which would have been seen by audiences in the past.

Until the 1930s, the dominant form of colour in the cinema was tinting and toning. Tinting involved applying a uniform colour dye to the entire image, either by applying it to the film base before the photosensitive emulsion is coated onto it or by immersing it in a tinting bath after exposure and processing. A toning dye was absorbed by the silver image only, meaning that in a monochrome image the 'black' became another colour, but the 'white' was unaffected. Tinting and toning could be carried out to varying degrees of complexity, ranging from a single tint applied to an entire release print, to different colour combinations of tints and tones, changing between scenes or even individual shots. Different combinations of tinting and toning were achieved by compiling all the shots to be given a specific tint and/or tone into a single reel of negative, which were then printed, processed and dyed. Each release print, therefore, had to be assembled individually from the processed and dyed reels, meaning that this method of colouring films was potentially a very labour-intensive one. The tints and tones used were often not identical in all the release prints made of a given title: Paul Read notes that 'there is anecdotal evidence that some distributors used many colours for a few show prints, but the majority of prints had fewer and cheaper colours, or were simply black-and-white.'[50] The technique could be used to create highly elaborate and time-specific effects, as in *At the Villa Rose* (UK, 1921, dir. Maurice Elvey) in which tints and tones were 'used for precisely timed effects such as the switching on of a light, and in another scene a combination of blue toning with a pink tint was used to indicate the last flush of a rosy sunset as night descends'.[51]

The diversity of tinting and toning practice that took place requires a restorer to decide the extent to which they should attempt to reproduce it and what sources of information they should use in order to determine what to reproduce. If evidence exists that the same film was shown in prints ranging from black-and-white to the elaborate and precise tinting and toning found in a surviving initial release print of *At the Villa Rose*, what should be the end result of a restoration? A case could be made for the authenticity of a number of different approaches. In practice, the tints applied to surviving release prints are often used to guide restoration strategies, though in cases where only uncoloured elements survive, restorations are sometimes tinted and toned on the basis of written evidence found elsewhere. In a restoration of *Die Niebelungen* (Germany, 1924, dir. Fritz Lang) carried out in 2006–2008, evidence from the surviving elements suggested that most of the prints shown outside Germany were tinted orange almost throughout, and that the German domestic prints were coloured rather more elaborately. One release print discovered in Uruguay was black-and-white.[52]

Other non-photographic colour systems were used throughout the silent period, notably hand colouring and stencil colouring (and its semi-automated variant, the Handschiegl process), though all of them on a far smaller scale. In many cases the colour information present on release prints screened contemporaneously with the film's initial distribution does not survive in preservation material held by archives. Various techniques are available to recreate them or simulate their appearance in the final output of a restoration project. Which, if any, to use will be determined by the aspects of originality and authenticity that determine the objectives of a restoration, as well as more pragmatic factors, notably financial and the limitations of what current restoration technology can achieve.

Photographic colour systems – those in which the recording of colour information is integral to the process of creating the photograph, as distinct from being added later in a separate process – can give rise to the need for restoration. This is usually judged to be the case in either or both of two scenarios: when a system, or a significant component of it, is obsolete (i.e. the equipment, consumables or services needed to make it work are no longer commercially available), or if the colour dyes cannot be reproduced accurately without substantive technical intervention in a copying process, either because of incompatibilities

between surviving elements and equipment currently in mainstream use, or chemical decomposition affecting colour dyes.

An example of the former would be the short-lived Kodacolor process, a lenticular system marketed for amateur filmmaking between 1928 and 1935. It was necessary to attach filter glasses to both the camera and projector, and these interacted with the embossed lenticules on the film base to record and reproduce the three primary colours.[53] Neither the embossed panchromatic film stock nor the filters are in production anymore, and therefore the only viable way of recovering the colour information from surviving elements is to use a modified filtering system on an optical printer or digital capture (datacine) device. This can be considered an active restoration, as distinct from preservation, as a significant technical intervention is needed to retrieve the colour information. Simply ensuring that the surviving elements are maintained in the condition that an archive received them (preservation) will not in itself enable the colour content to be viewed.

The vast majority of photographic colour systems that pre-date chromogenic dye-coupler technologies present the obsolescence issue to varying degrees, mainly because the colour information recorded on the films as shot and processed is not visible to the naked eye without an additional process taking place either in the production of release prints, or in projection itself. Gaumont Chronochrome, Kinemacolor and Technicolor are all major examples. The latter presents an especially complex challenge for the restorer. On the one hand, the film elements created during the production process are generally acknowledged to be the most chemically stable of any colour system that was in mainstream use. Yet on the other, the colour information is very difficult to reproduce as part of the copying process for preservation and access. As a prominent preservation scientist noted, 'Technicolor is often characterised by a colour saturation that is difficult to reproduce using modern film stock, let alone electronic media.'[54] In approaching the restoration of surviving Technicolor elements (either three-strip negatives or dye-transfer release prints), therefore, the restorer has to judge the extent to which the contrast, gamma and colour balance should be manipulated in the copying process, sometimes based on a mainly subjective conception of the original viewing experience.

The biggest problem with substantive dye-coupler technologies is colour dye fading. Throughout the first half of the 20th century, the development of photographic colour processes had as its commercial objective the perfection of a system that added little if any cost to production in black-and-white, and specifically no requirement for special

equipment, processes or services to make the system work. The technology that eventually enabled this involved, in crude terms, three layers of photosensitive emulsion on the raw stock, each sensitised to one of the three primary colours. After exposure, chemical 'couplers' were activated in processing, which turned the latent image into a visible dye of the corresponding colour (or its subtractive negative). The earliest viable mass-production system was the German Agfacolor, initially launched in 1936 and exported extensively following the Allied occupation at the end of the Second World War.[55] But it was the launch in 1952 of a negative–positive coupler process by Eastman Kodak that enabled colour cinematography in the mainstream film industry to become the norm and, within a decade and a half, black-and-white the exception. Eastmancolor stock required no modification to equipment in either the studio or theatre: the only infrastructural investment needed was in the laboratory. As with nitrate and acetate decomposition, the drawback with this technology was only recognised and understood a quarter of a century after it ended widespread commercial use: the first generation of coupler stocks was prone to dye fading, to the extent that much of the colour information in surviving elements has been lost. A high-profile campaign in the late 1970s[56] led to the introduction of a 'low fade' coupler stock range by Eastman Kodak in 1982, and research later discovered that as with cellulose ester film bases, storage in cool and dry conditions substantially inhibited the fading process.[57] But many surviving elements of films made from the 1950s to the 1970s have already suffered significant dye fading. There are a number of ways in which restorers can attempt to mitigate these, which will be discussed in subsequent chapters.

Physical loss 4: Format obsolescence

A related problem to that of some obsolete photographic colour processes, format obsolescence occurs when image and sound information has not been lost from surviving film elements, but the hardware needed to reproduce them is no longer being manufactured or in mainstream use, and therefore the film cannot be shown in its 'original' form. This can be as fundamental as the film gauge itself, as in the case of 28 mm and 9.5 mm. Films shot using short-lived widescreen systems that necessitated the use of bespoke hardware, e.g. Fox Grandeur[58] and VistaVision[59] can now only be screened (apart from in a very small number of museums and cinematheques that may operate restored original equipment, as with the Cinerama installation in the National Media

Museum at Bradford, UK) after the content has been copied to what the restorer judges to be an equivalent medium, but which is currently supported and in widespread use. The same applies to sound-on-disc audio systems, and even some sound processes that failed relatively recently, e.g. Kodak's Cinema Digital Sound (CDS) in the early 1990s.[60] Where systems, formats and processes have been used in a film's initial production that are now obsolete, a restorer is faced with having to decide how best to reproduce the aesthetic impression of the obsolete technology using modern replacements.

Political loss 1: Lost films

Human activity, or inactivity, can often result in the total or partial loss of a film. It goes without saying that as long as the film, or part of it, remains lost, no restoration is possible. The issue is what happens when rediscovery occurs: thus, the phenomenon Darragh O'Donoghue called 'the lure of the lost film' is a relevant one in considering how the agenda for restoration activity is set.[61] In many cases the loss of a film is caused by the interaction of a physical and a political factor, namely chemical decomposition and the 'erratic archiving that saw material lost due to poor storage.'[62] This will be explored in greater depth in the following chapter, which considers the role of institutions and prominent individuals within the film archiving movement in setting the agendas that drive film restoration. It will suffice to note here that a canon of lost films has emerged, on which researchers and archivists have devoted significant resources to rediscovering, almost all of them the work of critically celebrated and/or commercially successful directors or stars, e.g. *The Mountain Eagle* (UK, 1926, dir. Alfred Hitchcock) or *London After Midnight* (USA, 1927, dir. Tod Browning). Others survive only in incomplete form, e.g. *Greed* (USA, 1924, dir. Erich von Stroheim) or *The Magnificent Ambersons* (USA, 1942, dir. Orson Welles). As the former curator of Britain's National Film and Television Archive put it, 'another legend (this one beloved of journalists) says that there are dozens of lost and neglected films lying in dusty vaults or attics waiting to be rediscovered – a *Greed* here, a Griffith there, the Hitchcock that never was.'[63]

In the occasional cases when rediscoveries occur, the lost film myth can, in some circumstances ensure that they go straight to the front of the queue for restoration work. Two prominent examples deserve a mention in this context. *Beyond the Rocks* (USA, 1922, dir. Sam Wood), a release print of which was deposited with the Nederlands Filmmuseum following the death of a private collector in 2001, was probably the first all-digital restoration by a major European archive. The project received extensive publicity, partly on account of this and partly because the film featured two major and well-remembered Hollywood stars (Rudolph Valentino and Gloria Swanson). Mainstream media reports emphasised Valentino, Swanson and the nature of the film's rediscovery.[64] In archiving and cultural circles the project cemented the reputation of the 'innovative spirit' of the Nederlands Filmmuseum,[65], positioning it at the leading edge of curatorial (the decision for a Dutch publicly funded cultural institution to invest major financial and political capital in an American film) and technological practice, and established its leader, Giovanna Fossati, as a 'starchivist' film restoration practitioner. Subsequent restorations of other rediscovered early Hollywood features from the same collection, e.g. *The Floor Below* (USA, 1918, dir. Clarence Badger) in 2007, have passed virtually unnoticed.

The Life Story of David Lloyd George (UK, 1918, dir. Maurice Elvey) illustrates another set of circumstances through which lost film mythology can inform the agenda as to which films warrant immediate and extensive restoration work and which do not. Once again, a combination of unique factors combined to make the project especially newsworthy. The film's subject was a highly controversial political figure, its production was abandoned during the editing stage (it is hypothesised due to political intervention), it was rediscovered in the form of unedited camera negative rolls, in very good condition, in Lloyd George's grandson's attic (thereby enabling both a 'resurrection' narrative in the mainstream media coverage, and restoration to a high technical quality), and it was the first, and so far only, high-profile restoration project undertaken by a small and previously little-known archive institution. There were both political and academic factors in play, too. Researching the film's mysterious production circumstances was ideally suited to the empirical research methods that had been established and developed by the media and history movement in the 1980s and early 1990s,[66] and, for a lay audience, 'will always bring an added frisson to the images', as a press release for the DVD put it.[67] The director of *David Lloyd George*, Maurice Elvey, had a well-established reputation among film scholars as a prolific but minor talent: as Charles Barr notes, his output has been 'dismissed as negligible' by biographers of his contemporary, Alfred Hitchcock.[68] But *David Lloyd George* prompted a re-evaluation of this view with its epic structure, special effects ahead of their time and convincing, large-scale crowd scenes. The restoration process itself was groundbreaking, consisting in effect of recreating post-production techniques from the 1910s. And finally, the re-released film was marketed as a cultural symbol of

Welsh national identity at the precise moment this was becoming a significant political issue (the referendum to establish the Welsh Assembly took place in 1998, while the roadshow re-release was taking place), and promoted extensively as a calling card for the archive that undertook the project.

Political loss 2: Poor quality or orphaned surviving elements

A related problem to outright loss is the known survival only of elements considered to be of compromised technical quality, and thus where restoration work is deemed necessary to reproduce an impression of prints produced in a conventional post-production workflow. Generally accepted best practice among the archiving profession dictates that original camera negatives, or the closest generation of element to them that is known to survive, be used as the raw material for restoration. But it will be recalled that the technological feature on which the commercial viability of cinema depends is the ability to create multiple copies of a completed film. These release prints are considered inferior for preservation and restoration purposes, because they are usually at least three generations removed from the camera negative: as Kevin Brownlow somewhat brutally put it, 'in the silent days, film stock was sharp and clear, but the moment you copied it the sharpness and clarity vanished.'[69] But they are also the category of element that is most likely to survive, for the simple reason that a lot more of them existed to start with. This scenario falls into the category of political (i.e. caused by human activity) loss, because in many cases production-generation elements were lost either through neglect or deliberate destruction. Until the advent of television and home video created a significant aftermarket for mainstream feature films, studios and production companies were notoriously reluctant to preserve their own master material, and sometimes even destroyed it as an anti-piracy measure. Universal destroyed a large proportion of their camera negative holdings from the silent period in 1948,[70] and many of the other studios had done likewise in the preceding decades. Neither was the problem restricted to the studios. A series of major nitrate fires in both private and public sector repositories have destroyed preservation master material, from the Cinémathèque Française in 1959 to Universal Studios in 2008. Almost all can be attributed to inadequate fire prevention measures, although in fairness it should be noted that it has never been proven conclusively whether or not nitrate is capable of spontaneous ignition.

This scenario is a lot less likely to generate headlines and thus provide the catalyst for major restoration activity in itself, and it also presents the restorer with two dilemmas. The further removed, generationally, a surviving element is from the camera original, the greater the scale of the technical intervention (and hence cost) needed is likely to be, and the lower the subjective quality of the restoration output. The second is principally a political issue. As a result of studios' and production companies' reluctance to preserve their own output in the past, many surviving elements are likely to be in the hands of public sector archives, or other bodies that do not own or control the copyright to the content embodied therein. The inability to exploit or provide access to a restoration output without paying substantial royalties to a third party can act as a major disincentive: *Beyond the Rocks* would probably not have been chosen for a high-profile restoration project if it had not lapsed into the public domain as the result of Paramount failing to renew its copyright registration (on the assumption that the film was lost and would stay lost, and hence that there was no point).[71]

Political loss 3: Incomplete surviving elements

There are a number of reasons why the complete form of a film, in which it is known or believed to have once existed, does not survive in any one surviving element, but may be possible to reconstruct from multiple sources. The two most common are when shots or scenes have been cut from a film for commercial reasons (of which *Lawrence of Arabia*, discussed above, is a prime example), or when censorship or other political issues have resulted in significant cuts being made. As with the rediscovery of a lost film, a reconstruction project, even if it is not predicated on a single rediscovery, can attract headlines, cultural kudos, TV licensing and home video sales on the back of a 'labour of love' narrative using an archaeological metaphor for recovering something previously thought lost to philistinism.

Robin Hardy, director of *The Wicker Man* (UK, 1973), commented in an interview that he thought it unlikely that the film would have acquired the status of a popular cultural icon if close to a quarter of the film's initial cut had not been excised from its eventual theatrical release and the negative deliberately sent to landfill as an act of spite following a change of management at the film's production company. This prompted prolonged speculation among enthusiasts for over two decades as to whether or not the missing footage survived in any form.[72] When it was eventually discovered in the form of a 1 inch videotape

transfer, a reconstruction was undertaken, incorporating footage from the tape with the existing film version onto a new video master, and subsequently published on DVD in 2002.[73] Despite the aesthetic mismatch between the two sources, the reconstruction was considered justified by the iconic status of the content. The same rationale was applied to the latest restoration of *Metropolis*, in which the decision was consciously made not to use any type of image manipulation technology to attempt to disguise the aesthetic differences between footage from the existing, preserved 35 mm version and the missing material recovered from the 16 mm negative in Argentina. The restorer, Martin Koerber, justified this decision both on the grounds of inherent limitations in the source material and the ethical belief that viewers should be aware of the film's disparate provenance.[74]

Arguably the most widely celebrated reconstruction project of all, that of *Napoléon* (France, 1927, dir. Abel Gance) was started in 1955 and resulted in the screening of a series of progressively extended versions from 1969 to 2000. Again, the story has all the elements guaranteed to grab the public imagination. *Napoléon* first came to the attention of its restorer, Kevin Brownlow, as a teenager, who devoted a large part of his career to its rediscovery. The film and its director had been largely forgotten, the latter retired and living in obscurity. As a result of its extended length (almost five hours) and largely indifferent reception on initial release, heavily cut versions were produced for a number of markets, ranging from arthouse theatres in the USA to domestic consumer sale and rental on 9.5 mm film prints. Brownlow would become the world's first 'starchivist' film restorer on the back of his four-decade quest both to reconstruct *Napoléon* and to promote the cultural significance of European silent cinema, working largely independently and raising money as he went. Primarily in recognition of his work on his 'most famous and long-gestating rescue', Brownlow was awarded an honorary Oscar in 2010.[75]

The existence of incomplete films, therefore, and the selection or rejection of them for restoration, is more significantly a cultural and political process than it is a technically led one. It is defined by the conception of authenticity and originality a restorer aims to recreate, and the restoration of incomplete films is often foregrounded as an archival practice as a result in changes of cultural attitude shifting the commercial boundaries, e.g. the poor box office performance of *Metropolis* in 1927 compared with its status as a widely acknowledged masterpiece today.

Political loss 4: Modernisation

The cultural perception of a film or filmmaker can change over time: indeed, this fact is one of the main reasons for film restoration being judged necessary and/or desirable. The cultural perception of restoration itself (and, by extension, archival and curatorial practice in more general terms) can also change, and cases frequently occur in which a re-released version of a film at some point in the past is now considered unacceptable, and further technical intervention carried out. The UCLA Film and Television Archive's restoration pioneer, Robert Gitt, argues that 'there is preservation, there is restoration and then there is modernisation.'[76] The distinction between the latter two is that whereas restoration aims to recreate, at least implicitly, the subjective experience of a film's technical and aesthetic properties in a condition for which claims of originality and/or authenticity are made, modernisation does not necessarily invoke such claims: the object of the exercise is simply to make the content acceptable to a contemporary, mainstream audience. The competing cultural imperatives of the commercial media industries and ethically led archiving practice frequently lead to a situation in which an act of modernisation in the past is held to be no longer desirable and appropriate, and restoration is deemed necessary. In such cases, the act of restoration may consist of little more than the re-release of an earlier, preserved version of the same film.

Arguably the most widespread modernisation practice is the reformatting of film images in cases where their original aspect ratio is incompatible with that of a contemporary release medium. This practice is known as panning and scanning, and involves cropping the original image so that the remainder fits the modern display device. It has been embroiled in an 'art versus commerce' controversy almost since its emergence in the late 1950s, when television broadcasters started to purchase the rights to films that had been shot and released using one of a number of emerging widescreen formats.[77] The process has also been carried out in reverse: one of the most infamous examples was the re-release, in 1967, of *Gone With the Wind* (USA, 1939, dir. Victor Fleming et al.) in which the 1:1.38 image was cropped to 1:2.20 and optically enlarged for distribution on 70 mm prints. The resulting re-release was commercially very successful, and the loss of image information resulting on the reformatting process elicited hardly any negative comment at the time. Four decades later, the decision to modernise the film in this way is routinely condemned by critics, historians and lay enthusiasts as an act of cultural

vandalism and indefensible. Performing a Google search on 'Gone With the Wind' and '70 mm' at the time of writing, the top two hits were articles on relatively knowledgeable fan sites condemning the 'bone head idea to blow up *Gone With The Wind* to 70 mm and screw around with the sound'[78] and 'that monstrous 70 mm abortion'.[79] When the film's current owners, Warners, carried out a restoration based largely on contemporary archiving ethical principles and re-released the result, in the original aspect ratio, in 2004, the mainstream critical response was essentially to congratulate them on correcting a mistake. Interestingly, the panning and scanning of 1:1.38 (4:3 television equivalent) into the 16:9 widescreen television ratio that replaced it as the broadcast standard in most of the developed world during the early 2000s, is gradually becoming more widespread, though more in the case of actuality footage used in documentaries than in fictional feature films, which are usually broadcast in their original ratio with an area of the widescreen display 'windowboxed' out of use. When one of the best known and pioneering archive footage-based historical documentary series, *The World at War* (UK, 1973–1974, pc. Thames Television, prod. Jeremy Issacs), was re-released on BD in 2010, its publicity website claimed that 'each frame has been painstakingly restored' into a 'new widescreen presentation'.[80] If one accepts Gitt's distinction between restoration and modernisation, then this is certainly not the former, as all of the original 4:3 content has been vertically panned and scanned into 16:9. But just as the practice passed without significant comment when it was initially used in a previous generation of technologies, so it has again when done in reverse following the emergence of 16:9 as the new television standard.

Colourisation, remixing mono audio tracks into multi-channel ones, and more recently, the reformatting of conventional footage into 3-D using digital processes that simulate the Pulfrich effect, have all followed a similar pattern of initial acceptance followed by rejection on cultural grounds as the result of a combination of legal disputes, a better educated mainstream audience and the emergence of ethical frameworks within the archiving profession. Returning to that old favourite, *Metropolis*, in 1984, the rock musician and film composer Giorgio Moroder acquired the US rights and 'restored' it, principally by replacing the intertitles with subtitles and adding a music score consisting mainly of 1980s pop staples. At the time of its release, the Moroder *Metropolis* elicited both support and condemnation,[81] but the weight of cultural, legal and archival opinion has not come down on its side in the quarter of a century since: a prominent intellectual property academic pronounced it 'a questionable work from the point of view of aesthetics and ethics',[82] and the Moroder *Metropolis* joined the 70 mm *Gone With the Wind* in the history books and the Internet as object lessons in how not to do film restoration.

Where a film is only known to exist, therefore, at least in widespread dissemination, in a previously modernised form, the justification for which is now largely rejected, this can form the grounds for the decision to restore.

Conclusion

In 1992, the British Film Institute published a book entitled *Missing, Believed Lost*, intended to draw attention to the issue of lost films. It consists mainly of descriptive accounts of 100 fictional feature films made between 1914 and 1945,[83] which at the time of publication were not known to survive in any form in any established archive or documented collection. The overwhelming majority are 'quota quickies' produced during the early and mid-1930s: very low budget comedies and melodramas that were made purely to satisfy a protectionist legal requirement introduced in 1927 for British cinemas to show a set proportion of British films.[84] Most made hardly any critical or commercial impression upon their initial release, and have since disappeared without either physical or cultural trace. Fifteen of those films have since been rediscovered and preserved, though some of them in incomplete form,[85] and although preservation work has taken place, none has been given as high profile a restoration project as *Metropolis* or *Beyond the Rocks*. It is interesting to note that those which have rediscovered more or less intact tended to have been those in which a widely celebrated actor or director was involved, e.g. *The Constant Nymph* (UK, 1928, dir. Adrian Brunel) and *His Lordship* (UK, 1932, dir. Michael Powell).

As I have argued above, the total loss of a film is simply the endgame of a process which in many cases doesn't get that far, and which in its intermediate stages gives rise to the perceived desire and justification for film restoration. That process starts with the absence of any legal requirement or commercial imperative to preserve, and is catalysed by the perception that a film is of little cultural quality or significance. The restorer is then faced with defining the object of the exercise. Is it is originality, based in an empirical conception of what the film once looked and sounded like? Is it authenticity, e.g. to the director's personal vision, even if that is at odds with originality? Or is the activity modernisation as distinct from restoration? Political and cultural factors also play a major role: a rediscovered apprentice piece by a celebrated *auteur* or star

vehicle, or a film that has major political and cultural significance is more likely to be restored than a routine melodrama made by a studio full of what historians and film scholars have since judged to be minor talents.

The following chapter will consider the organisations and individuals who carry out film restoration work, and their contribution to its form and identity as a cultural practice.

2

Where Are Films Restored, Where Do They Come From and Who Restores Them?

> Very many of these films are frankly amusing, and would find no place in a national historical repository.[1]

Introduction

The production, distribution and exhibition of cinema films is a relatively young set of practices – they have taken place on a systematic scale for little over a century – and the preservation and restoration of them even younger. The question could legitimately be asked why, therefore, film restoration is necessary at all. As we saw in the preceding chapter, the perceived necessity is due to a unique combination of technological, economic and cultural factors. The medium is fragile, prone to chemical decomposition and colour dye fading, and for the first half-century of its existence, highly inflammable. Systems and processes that require the integration of specific film and hardware components (e.g. lenticular Kodacolor or VistaVision) often do not survive in their original form; either one may have survived in isolation, but not both together. Until the arrival of television in the 1950s, the producers of commercial films had no economic motive to preserve them, as their perceived cash value was negligible after their initial release and distribution, so much so that some studios operated a policy of recalling and destroying as many extant release prints as they could in order to prevent piracy.[2] And finally, cinema was regarded by the political establishments in the developed world as lowbrow, ephemeral and a threat to be managed rather than an emerging form of cultural memory to be preserved. Indicative of this is the fact that when governments first started to interact with the film industries under their jurisdiction, it was to restrict and regulate. In Britain, for example, the first systematic intervention was the 1909

Cinematograph Act, which brought the exhibition under the regulatory jurisdiction of local authorities in the same way as other mass leisure activities (e.g. sports events, theatres and pubs) and established the legal basis for censorship.[3]

The history of systematic moving image preservation is essentially one of the transition from a fringe activity, undertaken largely in isolation from both the commercial industries that made most films and the state-sanctioned organisations that preserve archival documents as a public record, to one that has become fully integrated into both commercial business models and public policy. The time taken for this transition to mature is largely responsible for the fact that the emergence of film restoration as a distinct element of archival practice did not take place on any significant scale until the 1960s, and could not really be said to represent a professional methodology, related to but distinct from other technical archive operations, until the 1980s. It is a history of the institutions (both public and private), prominent individuals, technologies and processes that have shaped the practice as it is now understood – and in some quarters, ignored, overlooked and/or profoundly misunderstood.

The suggestion that films should be archived was made almost as soon as the first films had been. Historians of the film archiving movement repeatedly cite an article written by a Polish émigré cinematographer working in Paris, Boleslaw Matuszewski,[4] as being the earliest proposal in print for the establishment of a moving image archive. In 1912, the German cinema owner Franz Goerke published an article calling for the establishment of a state-funded national film archive with legal deposit powers ('Just as publishers are required by law to send a copy of each of their publications to the Königliche Bibliothek'), basing his argument on the cultural significance of moving images as historical source material.[5] Similar calls were made by prominent film industry and cultural figures throughout the first three decades of the cinema's existence, almost all of which had one important aspect in common: the argument for the establishment of film archives emphasised the risk of political loss (as defined in Chapter 1), but in most cases did not even mention physical loss.[6] Arguably the closest the pre-1930s literature gets to making the case for film preservation on the grounds of technical integrity can be found in another essay published in 1912, the British author of which acknowledges the likelihood that incomplete surviving elements might eventually become a problem ('Films for showing are frequently cut down; for instance, the Durbar took about 8,000 feet of film, but this is rarely shown complete.'),[7] and describes a preservation regime not dissimilar to the passive conservation approaches in use today, based essentially on cool and dry long-term storage.[8]

But apart from acknowledging the fire risk presented by nitrate, there is no evidence that the chemistry of film decomposition was formally investigated or understood in any meaningful way until the first generation of moving image archives established in the 1930s began to observe symptoms within their collections towards the end of that decade. Before that point there was no perceived need for restoration, or even scientifically informed preservation practices: the emphasis was simply on the prevention of loss or destruction, both deliberate and through neglect.

The film archives: Public sector

Shunned by both the commercial film industry and the political establishment (early articles calling for the establishment of film archives such as the one cited above are notable for their infrequency), therefore, the origins of organised film archiving can be found primarily in the alternative film culture of 1920s Europe. This catch-all term has been used to refer to a large number of filmmakers, studios, movements, critics and writers: Soviet agit-prop, Weimar 'expressionism', the French avant-garde, the emergence of the British Documentary Movement and activist filmmakers on the political left being but five examples.[9] The strand that links them all is oppositionality, and to two things. Firstly, they were in opposition to what their participants perceived to be the dominant political regimes, and in particular the extensive political censorship of films (throughout Western Europe, but especially in Britain and Germany). Writing in the alternative film culture's Switzerland-based house journal, *Close Up*, the leftist filmmaker and activist Ralph Bond attacked the authorities' repeated refusal to allow the screening of Soviet films imported by the London Workers' Film Society during the late 1920s,[10] one of many such skirmishes to illustrate the movement's belief that the establishment sought to suppress culturally important films, and especially European ones.

Secondly, the alternative film culture opposed the perceived cultural hegemony of the emerging classical Hollywood cinema resulting from the surge in American film exports to Europe, which from the early 1920s they accused of forcing indigenous cinema off the screen. This reaction is not to be confused with the nationalism-inspired moral panic that the internationalist expansion of Hollywood precipitated and which has been documented extensively elsewhere.[11] Rather than

a 'trade follows the film'-based argument, which resulted in protectionist legislation throughout the continent being enacted at various points between the two world wars, the alternative film movements believed that the imposition of an export-led and rapidly standardising set of film forms and aesthetics (later to be dubbed 'classical' cinema by Bordwell and Thompson) developed in Hollywood threatened to drown out the indigenous film cultures in countries that received the full force of the American imports. It was partly in response to this that the first generation of European film archivists were motivated to establish their nascent institutions, as a means of preserving the output of minority film cultures they believed were under threat. By the same token they also emphasised the acquisition and preservation of pre-Hollywood American films, interest in which can be seen in the space devoted to early American cinema in the first generation of critical literature on film to emerge from Europe, most notably Paul Rotha's *The Film Till Now*, published in 1930.

The alternative film culture was understood both at the time and by historians since as being divorced, both socially and intellectually, from mainstream, popular cultural cinema, both Hollywood and indigenous. The author of a 1932 book on the impact of the conversion to sound characterises the 'highbrows' as

> inoffensive enough. They form a little coterie, they think it is shocking to have something else to do on Sundays than attend the Film Society's shows, they use the handy, though alien, word *montage* when they mean editing or cutting, and they wear black hats.[12]

To sum up, the two camps that had hitherto resisted calls to establish film archives – European national governments and the Hollywood-led commercial film industry – were the same ones that the alternative film cultures, broadly speaking, regarded themselves as being in opposition to. They also saw film archiving as an act of resistance to what they regarded as cultural philistinism, and to a more limited extent, political censorship.

The birth of the modern film archiving movement is generally understood to have taken place in the mid-1930s, with the formation of four public sector institutions: Britain's National Film Library (NFL; now, after many changes of name later, known as the BFI National Archive), the Cinémathèque Française in Paris, the film department at the Museum of Modern Art (MoMA) in New York and Nazi Germany's Reichsfilmarchiv (dissolved at the end of the Second World War). These

institutions were in turn the founder members of the International Federation of Film Archives (known by the acronym formed by its initials in French, FIAF), in 1938.[13]

The three that still exist were shaped by and closely associated with their founding curators, all of whom, to varying degrees, were products of the inter-war European minority film culture. It is worth considering their background and motivations in some depth, as between them they established the ethos, cultural priorities and principles of moving image archiving, which persist intact to a large extent today: indeed, one of the most notable aspects of the introduction of digital technology into film preservation is the extent to which the leaders of world's major public sector archives today have emphasised the application of the movement's founding principles to what is arguably the most profound evolution in moving image technology since organised film archiving began.

It is also worth noting the widespread and often-repeated misconception that the emergence of the public sector film archive movement took place in isolation from any established film culture at all, and was motivated by political factors, principally nationalism. Although it has popped up regularly in histories of British cinema and film archiving over the years, probably the most recent example is in Caroline Frick's book. She begins by asserting that the establishment of the BFI and the archive under its jurisdiction was inspired by 'the United Kingdom's global imperial role, and its corresponding concerns',[14] justifying this with out-of-context quotes from *The Film in National Life* (bringing civilisation to backward races and so on – see below), which had virtually no bearing on the policies or priorities pursued by the organisation founded as a result of its publication.

The evidence suggests the exact opposite: that the BFI and the archive founded under its umbrella were noted more for their links to the European oppositional and art film cultures, and to Hollywood, than to anything related to the British Empire. Less than a year after the BFI had come into existence, it was criticised in a widely circulated pamphlet for modelling itself on the national cinemas of Germany, Italy and the Soviet Union,[15] and also of subordinating itself to (largely Hollywood-controlled) commercial interests.[16]

Furthermore, Frick does not acknowledge the fact that at the time the BFI was founded, Britain's global imperial role was in rapid and terminal decline, that the UK itself was in the depths of the most severe economic depression in its history and that even its film industry was in the grip of a boom-and-bust cycle – factors that have been explored thoroughly in

a huge volume of literature dealing with the period (Ronald Blythe's *The Age of Illusion* or Piers Brendon's *The Dark Valley* being but two examples), and survey monographs on Britain's film industry and culture in order to place the inception of the BFI into a broader and more accurate cultural context (e.g. Kenton Bamford's *Distorted Images* or Jeffrey Richards's *The Age of the Dream Palace*). The impetus to establish film preservation (and later, restoration) as first and foremost a public sector, taxpayer-funded, activity was rooted far more in the oppositional and alternative film cultures of the 1920s, the fleeting popularity of Soviet and European art cinema and the desire of the political left (which, under the 1929–1931 Labour and 1931–1937 National governments, had a meaningful voice in government for the first time) to establish a media presence through projects such as the BBC and the Documentary Movement, than in anything to do with nationalism or imperialism.

Frick asserts that the inception of the NFL was inspired principally by nationalist, imperialist dogma, thereby implying that Ernest Lindgren was to a significant extent informed by the anti-American sentiment and accusations of cultural imperialism[17] that inspired the 1927 Cinematograph Films Act and all that followed.[18] This position could be challenged by the fact that, between its inception and Lindgren's death in 1974, the organisation he founded preserved over 2,000 Hollywood feature films, on the grounds that their distribution in the UK made them a part of British cultural history; one dramatic example being that, following the destruction of the original camera negative in a laboratory fire in New Jersey in 1972, almost all the film prints and DVDs of *Citizen Kane* (USA, 1941, dir. Orson Welles) now in circulation worldwide derive ultimately from a fine grain positive that Lindgren acquired (see below).[19] When the NFL was created, the principal criterion for acquisition adopted by the BFI's board of governors was that films should be 'notable either for some outstanding excellence or for their influence on the development of the cinema'.[20] As early as 1950, Lindgren cited *The Birth of a Nation* (USA, 1915, dir. D.W. Griffith) and *Battleship Potemkin* (USSR, 1925, dir. Sergei Eisenstein) as indicative examples of the cinema that his organisation preserved and made available – hardly artefacts of British cultural imperialism![21]

Frick claims that, in effect, Britain tried to colonise the world with Lindgren's model of film archiving. She refers to FIAF as 'his' (Lindgren's), claiming, with no supporting evidence (and despite claiming later in the book that it was initially Olwen Vaughan, not Lindgren, who was the British protagonist involved in founding FIAF[22]), that he single-handedly determined FIAF's policies and priorities throughout his later career, and by implication that his emphasis on preservation over access had a generally negative effect on the development of the profession by impeding relations between the public and private sectors. Frick's articulation of this narrative is not helpful in trying to understand how institutional histories and cultures inform the contemporary practice of film restoration, for which a more evidence-based approach is needed.

Lindgren was an English literature graduate, initially employed in 1934 as a librarian by the nascent BFI, a publicly funded advocacy body established by Royal Charter two years earlier following the publication of the report that had proposed its creation by a group of educationalists (none of whom had anything to do with Britain's film industry and culture in the long term, as Frick implies), *The Film in National Life*.[23] Though he was not directly involved in the inter-war minority film culture and comparatively little is known about him (unlike his counterparts in France and the USA, no monograph or biography has been devoted to Lindgren's career), surviving accounts of his work emphasise his affinity with it: Lindgren's successor, David Francis, recalls that 'he believed the art of the cinema was vested in the great European film directors of the silent cinema',[24] while the author of a survey of the BFI's activities published in 1971 notes that while a student, Lindgren 'had been a frequent visitor to the specialised cinemas in the West End, finding there a type of film excitingly different from the family houses he had so far known'.[25] His reputation was largely that of the civil servant or bureaucrat of the pioneer archivists. The NFL under Lindgren's leadership established a reputation for emphasising the importance of selective acquisition and preservation over access and curatorship, and has attracted sustained criticism for this stance. Characterised as 'Fortress Archive' in what many have come to regard as the standard history of the film archive movement,[26] Lindgren's regime is generally remembered today for the rigid implementation of two policies: a strict preservation policy in which access to films was frequently refused until full-scale copy-to-preserve photochemical duplication had been carried out,[27] and the infamously idiosyncratic nature of the NFL's selection committee, which, stripped to its bare essentials, evolved a *modus operandi* of making highly subjective value judgments as to what was worth saving and what was not.[28] Here the influence of the European alternative cinema tradition was very much in evidence: for example, Penelope Houston (a former member of the Selection Committee) recalls that meetings consisted of 'arguing about whether the new film by Godard and Buñuel should be elevated to category A', and that the one

and only film, a print of which was actually purchased for preservation, was *Les Dames du Bois de Boulogne* (France, 1946, dir. Robert Bresson).[29]

The Cinémathèque Française under its founding curator, Henri Langlois, shared the same emphasis on the cultural importance of European art cinema, but set about promoting it in an entirely different way. Langlois believed that the most effective means of preserving films was to screen them, as prominently and as often as possible,[30] and bitterly opposed Lindgren's position (and that of the NFL's preservation officer, Harold Brown, of whom more below) that film elements designated as preservation masters must not be run through any machine except a printer for the purpose of copying, due to the risk of accidental damage in viewing, and that preservation should be given priority over access for funding and resources. As Karel Reisz recalled, Lindgren and Langlois were 'totally opposed in character and methods. Lindgren never wanted to show his films except when he was absolutely forced at gunpoint... Langlois's policy was to show everything.'[31] Their oppositional stances on this have been dubbed 'the Lindgren-Langlois debate', one which continues to inform discussions of the ethical relationship between preservation and access in film archives to this day. In the same way that Lindgren's selection committee was informed by the canonisation of inter-war European art cinema, so was Langlois's extensive screening programmes in Paris, the most loyal attendees of which were the group of filmmakers and critics who founded the magazine *Cahiers du Cinéma* in 1951 and who would go on to cement the artistic supremacy of the director and the centrality of the alternative film cultures both within academic writing and archival policy,[32] a process that informs decision-making as to which films the public sector archives choose to restore and promote to this day.

The British archivist Iris Barry made her initial reputation as a film critic in 1920s London, most notably for the *Daily Mail* between 1925 and 1930. She emigrated to the USA in 1930, and in 1934 founded a film library at MoMA in New York. As with Lindgren and Langlois, the archive Barry founded was, in the words of its biographer, 'not ideologically neutral'.[33] Barry's approach to archived films was as museological artefacts. Lindgren believed that it was not his job to second-guess who the future audience for his archive would be, Langlois used his archive to train a future generation of filmmakers, whereas Barry used hers to train a future generation of critics and aesthetes: in her own words, her objective was to 'study the growth, technique, aesthetics and sociological content of the most popular and liveliest of arts'.[34] Her screenings at MoMA were characterised by scholarly essays handed out as programme notes, an insistence on high technical presentation standards (one that MoMA maintains to this day: it will refuse to lend its prints to screening venues that, for example, cannot reproduce the correct speed or aspect ratio) and a curatorial approach that emphasised the study of the evolution and development of film style and technique. As with Lindgren, Barry prioritised preservation: but whereas Lindgren was essentially concerned with the 'historical value'[35] (i.e. cinema as primary source material) of the films in his care, Barry sought to preserve their technical integrity as works of art.

There are two notable exceptions to this general rule that emerged in the 1930s, of not-for-profit archivists establishing their institutions as an act of resistance to Hollywood hegemony and local political repression: the Department of Film at London's Imperial War Museum (IWM), and the state film archive established in Nazi Germany. The IWM's collection, established in 1920, came into existence because the British government had engaged in film production for the first time on any systematic scale during the final years of the First World War. Given that the film output of the first Ministry of Information had the *de facto* status of a public record, the founders of the IWM regarded it as their task to preserve them along with all the other evidential documents of armed conflict that fell within their remit. As a subsequent curator pointed out, the IWM's operation began 'some fifteen years before the date normally recognised for the birth of the film archive movement',[36] and throughout the nine decades of its existence has emphasised the importance of ethical curatorship in the preservation of and access provision to its holdings, many of which constitute evidence of war crimes and atrocities.

The Nazi Reichsfilmarchiv, founded in Berlin in 1934, was the last of the four founding member institutions of FIAF, and the only one that does not survive as it was originally constituted (for somewhat obvious reasons). Created as the result of initiatives both by the national censorship office and the films division of the propaganda ministry, it was intended as a national collection that would both preserve officially sanctioned material as a public record, and banned material for use in training Nazi officials.[37] Little is known about the operation of the Reichsfilmarchiv and its curator throughout all but the first few months of its existence, Frank Hensel; indeed, Rolf Aurich's article represents about the only serious research on him to have been published. One complicating issue is that Hensel was, from all accounts, an ideologically committed member of the Nazi party since the mid-1920s; yet he and Langlois are widely believed to have collaborated to ensure the

preservation of 'degenerate' films (i.e. primarily those made by Jewish actors and directors) that the Nazis ordered to be destroyed, as a result of which much of what is now regarded as the canon of Weimar cinema ended up in the Cinémathèque Française.[38] Given the political sensitivities in researching the collaboration between a Nazi official and someone who has come to be regarded as an icon of French cultural history, it is hardly surprising that very little work has been done in this area, especially by European film historians.[39] At the end of the Second World War, the Reichsfilmarchiv's Berlin premises fell under Soviet control, and much of the archive's holdings were seized by the Russians and taken to Moscow. Describing the search for missing *Metropolis* footage during the multiple attempts at reconstructive restoration that took place from the 1960s to the 1980s, the head of the East German state film archives at the time, Wolfgang Klaue, recalls protracted and sensitive negotiations with the Russians for the repatriation of elements that had been seized from the Reichsfilmarchiv at the end of the war.[40] Therefore, even though the Nazi film archive was a state-sanctioned institution in the way that the other three FIAF founder institutions were not (or at least, they were only at arm's length), and Hensel certainly did not influence the profession personally in the way that Lindgren, Langlois and Barry did, its history illustrates in a different way the contribution made by the early history of the movement to the contemporary film restoration landscape. In a nutshell, this is an emphasis on European art cinema and alternative, oppositional traditions, diverging curatorship models but sharing a public service imperative in common, and a legacy of films cropping up in unexpected places.

And these attributes were embodied in the constitution of FIAF itself. From its inception in 1938 until the formation of the Federation of Commercial Audiovisual Libraries (FOCAL) in 1986 and the Association of Moving Image Archivists (AMIA) in 1990, it remained the only professional and representative body concerned with moving image preservation and restoration. From its outset, FIAF saw its goals as twofold: to facilitate the transfer of materials between member archives for preservation and access purposes, and to set standards of professional practice for archivists and ethical methods for archive operations.[41] Its house journal, initially the *Film Bulletin* and subsequently the *Journal of Film Preservation*, has in the four decades of its existence published articles on individual preservation and restoration projects, as well as more polemical pieces and proposals for standards and codes of conduct.[42]

FIAF was from its outset, and remains, militantly public sector and non-profit. Its core mission and principles are enshrined in its code of ethics, a linchpin of which is that member archives 'must not make any commercial use of their films'[43] (employees of these institutions working on FIAF commissions and projects are not allowed to continue doing so if they change jobs to one in the for-profit sector). FIAF embodies the founding principles of the four archives that established it: the preservation of film as a public service, the status of archives as independent 'honest brokers' with the commercial sector, lacking any vested interest in the commercial exploitation of material in their custody, and a curatorial approach that treats film as art, a source of record or both.

The number of publicly funded national film archives around the world grew significantly during the three decades following the end of the Second World War. FIAF grew to 35 member institutions by 1970 and 83 by 2008. The next major moving image archives to open in the USA after MoMA did so during this period: the Motion Picture Division of the Library of Congress in 1946, George Eastman House in 1949, and the University of California at Los Angeles (UCLA) – the first of the major university-based film archives – in 1965.

The public sector and the origins of preservation science and education

As has been discussed in Chapter 1, surviving written evidence suggests that there was a general awareness before the mid-1930s that the shelf life of nitrate film could be optimised by storage in cool and dry temperatures, but that it was not indefinite. But it was not until the establishment of the film archive movement that systematic research began to take place into the chemical processes of film decomposition, the subsequent development of storage conditions to inhibit them and the techniques and equipment for preservation copying. As early as 1920, the newly established IWM approached Eastman Kodak for advice on long-term preservation of master status film elements, and in reply were warned that they would shrink and become brittle with age if not stored in a cool and dry environment.[44] Interestingly, the authors of *The Film in National Life* appeared to be unaware even of this rudimentary principle, declaring that 'the difference [between storing film and other forms of archival record] is only one of degree, except in so far as the inflammable nature of the film makes special precaution necessary.'[45] Immediately following the establishment of the BFI, Lindgren approached the British Kinematograph Society (BKS, later the British Kinematograph, Sound and Television Society), a recently formed technical standards body, which made a detailed set

of recommendations for film storage, notably that 'upon the occurrence of signs of deterioration, the films should be copied by photography and the copy stored in place of the original.'[46] The BKS report articulates the essential principles that were later researched and understood in far greater depth and to far greater precision by the Image Permanence Institute and others in the 1980s: that 'the vapours it [nitrate] gives off' was the principal cause of base decomposition, that black-and-white emulsions were relatively stable compared to nitrate base, that regular inspection of archived films should be undertaken and that master status materials should not be used for access.[47]

The BFI's founding head of preservation from its inception until his retirement in 1984 was Harold Brown, an instrumental figure in the development of film archive technical operations. Described by a subsequent curator of the BFI as 'the most important and enduringly influential technical film archivist of his era',[48] Brown's achievements included designing and constructing some of the earliest printers for damaged and partially decomposed elements, establishing a systematic storage and inspection regime and standardising the technique of film inspection and repair. The technical manual he wrote in 1990 for FIAF, *Physical Characteristics of Early Films as Aids to Identification*, was the culmination of almost three decades of film conservation work, much of it as the head of FIAF's preservation commission, and remains in print and a standard reference work today. He is also widely credited with having invented the phrase 'vinegar syndrome' to describe the deacetylation of cellulose triacetate film.[49]

Similar technical pioneers were to be found in the other public sector archives worldwide. In the USA, for example, Robert Gitt at UCLA developed standardised procedures for preservation copying,[50] while Kemp Niver invented and refined a technique for copying the paper print collections (copies of 35 mm negatives duplicated onto paper for copyright registration purposes) in the Library of Congress during the 1960s.[51]

And it was also from within the public sector film archiving movement that the formal education of moving image archivists began. In Britain, the emergence of the public sector film archive movement took place more or less in parallel with the emergence of film studies as an academic discipline in universities. The first academic post in film at a UK higher education institution was created in 1960, and, along with the network of regional moving image archives, the first generation of undergraduate and masters' degree programmes in the subject were launched in the early to mid-1970s.[52] It is hardly surprising, therefore, that the first formal programme of education for film archivists to

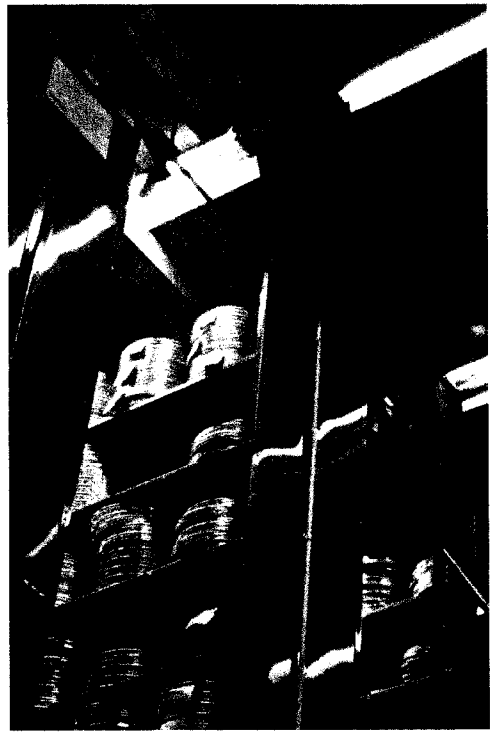

Figure 2.1 An atmospherically controlled vault at the British Film Institute's conservation centre near London. Air that has been treated to achieve a consistent temperature and humidity is pumped into the space through the one-way membrane mounted on the ceiling above the fluorescent lights. The BFI's Harold Brown discovered that cool and dry storage inhibits the decomposition of nitrate and acetate film base, and dye-coupler colour film emulsions, thereby enabling their long-term storage in a passive conservation approach.

be offered should seek to bridge those two fields. It was launched at the University of East Anglia (UEA) in the 1990–1991 academic year, with a syllabus that combined elements of the MA degree in British cinema that had existed since 1978 with vocational training in the technical, curatorial and administrative operations of a moving image archive. This included basic film handling and examination, identification of technical characteristics and provenance, physical repair of film elements, storage, duplication, acquisition and legal deposit, approaches to access, copyright law, management, administration and fundraising. Interestingly, the inaugural syllabus is said to have included 'the practice and

ethics of film restoration',[53] even though at the time, the literature on the subject was virtually non-existent (the *Journal of Film Preservation* was in its infancy and *The Moving Image* and the first book-length work on the subject – Read and Meyer's – would not be published for another decade). The UEA course, which ran until 2011, was the only one of its kind in the world for over a decade, until UCLA established a similar programme in 2002: like UEA, UCLA hosted a major film studies department and an archival collection within its organisation, and used the resources of both to teach its film archiving students. By the end of the first decade of the 21st century, postgraduate education programmes devoted in whole or part to film archiving had also been established at the universities of New York, Amsterdam and the George Eastman House museum in Rochester, New York. Graduates from these programmes have formed the bulk of new entrants into the professional ranks of non-profit archives in North America and Europe, and this second generation of film archivists is in many ways the most visible manifestation of a field making the transition from the pioneering establishment of basic knowledge, principles and procedures undertaken by archivists such as Harold Brown and Robert Gitt, to the structured application, regulation and refinement of that body of skills and expertise that is the defining characteristic of a mature profession.

The public sector – Conclusion

It was from within the FIAF-affiliated public sector archives that the set of practices that would now be recognised as the activity of film restoration effectively emerged, though the formal distinction between preservation and restoration would not be made in any systematic way and on any significant scale in terms of the institutionalised working practices of archives until the 1980s. Indeed, Roger Smither (writing in 2000) notes that Foxen-Cooper's work in establishing the IWM's archive was 'alien to the current emphasis on restoration'.[54] However, preservation and restoration both involve the same core activities, principally the examination and assessment of the technical characteristics of surviving film elements, followed by their duplication to produce copies that, for one or more of a number of reasons, are regarded as more suitable for long-term storage and/or access purposes. The earliest published work I have been able to find that makes a sustained attempt to articulate an objective, conceptual framework for what film 'restoration' actually is and is not was published in 1986,[55] and a widespread professional dialogue in this area was not in evidence until a decade later.

It is therefore necessary to look at the cultural and technological legacy of the public sector film archive movement in more general terms in order to understand how it informed film restoration once it did become widely understood as a discrete activity in its own right.

The two essential points to take from this history is that public sector film archiving grew directly from the inter-war intellectual/minority film culture, and that the basic technical practices that constitute what we now understand as being film restoration evolved within this movement. As with John Reith and the BBC, the pioneer film archivists were ideologically antipathetic to the popular cultural mainstream, a mindset that influenced both what they preserved and how they preserved it. As Haidee Wasson puts it in her biography of Iris Barry, 'old films and foreign films were seen as appealing alternatives to unsatisfying, undistinguished, banal, or objectionable film programming.'[56] To a certain extent this mindset was engendered by a problematic relationship between Lindgren's generation and the commercial film industry, which viewed the emerging archives as an irrelevance at best and a threat to their intellectual property at worst. It was further entrenched by the avowedly non-profit stance of FIAF's initial constitution, which has been maintained to the present day. Although a significant amount of preservation and restoration work now takes place in the private/for-profit sector, commercial archives and their employees remain barred from membership of FIAF, and the organisation regularly takes stances that oppose any commercialisation of any aspect of film archiving. For example, in the body's 'Declaration of Fair Use and Access', published in 2007, affiliate archives 'declare their right to engage in... exhibition [of their holdings] on their premises' and 'use in their own publications and promotional activities', even where this is in breach of copyright legislation.[57] Added to this, FIAF's 'non-restrictive definition of national heritage'[58] has encouraged its member archives to develop unique and culturally informed definitions of their collecting remits, which in turn came to inform decisions to what films are worth restoring and what not.

From a technical perspective, the pioneer archivists also saw themselves as fighting a rearguard action against industry philistinism. It is certainly true that the essential problem they faced – and still face today – is that the basic technologies of cinema were invented and developed for short-term use, not long-term preservation; the most fundamental one being film base itself. The essential problem was one of preserving a raw material that is inherently very fragile (i.e. handling in normal use will inflict significant physical damage), and chemically

volatile in long-term storage. The economies of scale of film archiving never permitted the research and development needed to produce technologies that were specifically designed for the needs of preservation, and where media have been developed that have proven stable and durable (e.g. the Kodachrome emulsion and polyester film base), this was the result of luck rather than intent.

Caroline Frick argues that Houston's 1994 history of the public sector film archive movement, *Keepers of the Frame*, 'narrativizes the field by celebrating the "victories" of nonprofit or government archives against significant obstacles'[59] Both Houston's articulation of this dichotomy and Frick's essential validation of it oversimplifies the inherent paradox whereby these collecting institutions, both public and private, apply a set of practices that is in effect a combination of public records management and museum curatorship to the custodianship of material, the majority of which was conceived to be commercial and ephemeral. There is no simple either/or headline to distinguish public and private sector archiving practice: both have influenced each other in subtle and complex ways.

The film archives: Private sector

As with film restoration itself as a recognised and discrete process within the field, the archiving of moving images either as a profit-making activity in its own right, or as a back end function to support the business activity of a larger for-profit concern, was not in any way systematic or widespread until the 1980s. The one major exception was the newsreel industry. Unlike in virtually every other sector of the film industry, newsfilm had a resale value after its initial release in its production companies' own reels, both as stock footage for use in feature films and for use in later issues that covered further developments in an ongoing story, hence the commercial incentive to preserve it. By the mid-1940s, Fox Movietone in the USA had already amassed a collection of 42 million feet, which, like those of its competitors, was maintained primarily in order to generate footage sales revenue.[60] Little if any preservation work was carried out, but unlike in the case of many feature film production studios before the advent of television, there was a commercial incentive for meeting the cost of storage space. When television news began, it drew on the footage gathering infrastructure that the cinema newsreel industry had already developed, and their working collections for stock footage.[61] Many of the television news agencies based in the USA and UK that would eventually form a major source of actuality footage for broadcasters worldwide grew out of the newsreel companies' library collections.[62]

The emergence of television brought with it a need for content, and the consequent creation of an aftermarket for studio feature films. As the author of an essay on the introduction of home video notes, 'until the 1950s, there was only one variable the domestic distributor needed to be concerned with: the theatrical run.'[63] After that theatrical run was complete, the market for a feature film was virtually non-existent. Although most of the Hollywood studios and production companies elsewhere in the developed world did not intentionally destroy the master elements (usually the cut camera negative and final mix sound negative), except in a minority of cases where this was required by contractual arrangements with a writer or star, neither did they invest substantially in their preservation, as, before the arrival of television, there was no prospect of making any return on their investment. There is evidence that in the pre-television era the Hollywood studios themselves regarded preservation as a job for the public sector, and not an overhead that they should be saddled with, on the grounds that it is the job of private industry to create commercial value, not preserve cultural value. Iris Barry's successor at MoMA, Richard Griffith, stated in 1955 that 'Hollywood feels – and with some logic, it seems to me – that preservation work should be carried on by some publicly supported institution.'[64]

One significant source of tension between public and private sector film preservationists is that, many years after the event, private sector studios and distributors can and do assert their intellectual property rights, even in the case of titles that have been physically preserved by public sector archives, following the emergence of aftermarkets that have added commercial value to films that the public sector had preserved on cultural grounds. One frequently cited case in this ongoing controversy is that of *Citizen Kane*, the cut camera negative of which was destroyed in a commercial laboratory fire in the 1970s. Thereafter, subsequent restoration work undertaken during the 1990s and 2000s by the copyright owner used as its principal source a fine grain interpositive exported to the UK from which the original British release prints were derived, and which was eventually deposited and preserved in the BFI.[65] Yet the BFI itself is restricted by copyright law in its provision of access to this material, even though the copyright owner failed to preserve it. This situation has manifested itself in a number of ways, one of which is FIAF's militantly anti-commercial constitution. Another is that if we accept Frick's position, that the history of film archiving in general has tended to be written in a way that privileges the role of the public

sector, then the studios' role (or more accurately, lack of one) in the years before they developed full-scale preservation operations is characterised by 'contemporary film preservation histories that pit early film archivists against studios'.[66] A third, as we shall see in the following chapters, is that the studios apply what is in many cases a radically different approach to restoration practice than that of the public sector archives.

The television broadcast of 'old' feature films began to take place on a systematic basis in the late 1950s. Progress was initially curtailed by resistance and restrictive practices on the part of film industry bodies,[67] but a combination of the convergence of ownership in cinema and broadcasting in post-Paramount Case Hollywood and the fact that the film industry was about the only major source of back catalogue to occupy the many hours of off-peak content needed by an industry that had not been producing its own content for long enough to fill the gaps with repeats, ensured that this did not last long. Warner Brothers was a pioneer in the sale of back catalogue films to broadcasters, establishing a regular programme of licensing between 1952 and 1960 alongside the development of new drama productions specifically for TV, with the owners of the other major Hollywood collections following suit shortly afterwards.[68] Other, smaller but significant aftermarkets emerged during the 1960s and 1970s, notably specialist cable television channels, the exhibition of films on airliners,[69] the growth of the film society movement and the emergence of formal film study in universities, creating an audience for non-theatrical screenings on campuses.

Home videotape enhanced the value of studios' back catalogues even further. In its first phase, from approximately the late 1970s to the mid-1980s, the industry concentrated on marketing new, mainstream titles for rental through high street retail outlets and minority interest titles, e.g. horror, pornography and special interest non-fiction material, through specialist outlets. From the mid-1980s onwards the home video market entered a phase of consolidation: competition between incompatible consumer systems was over, with VHS as the dominant format, and sales of equipment and media had grown to the point at which the potential customer base supported the publication of archive titles. In response to this the video publication arms of the major studios developed a two-tier pricing structure, whereby recently released mainstream features continued to be distributed on a rental basis, but legacy titles began to be marketed for outright sale to consumers in much the same way and at a similar price to music albums and paperback books.[70] The launch of the DVD, in different parts of the world between 1996 and 1999, grew this market significantly further. From the late 2000s, the sale of digitised archival films to consumers for direct Internet download was in its embryonic phase, and is at the time of writing undergoing rapid growth.

By the turn of the century, therefore, 'the ability to resell established properties, whether classic or contemporary, [...] is an essential economic strategy for the studios',[71] with the result that they now invest heavily in the preservation and restoration of their back catalogue. Most have now built atmospherically controlled vault facilities and carry out full-scale conservation and restoration operations in-house. Few would argue that this process is more commercially led than in the case of public sector archives, and the legacy of the 20th century – of private-sector rights owners being reluctant to foot the bill for preservation until a market for their archival collections became available, and then subsequently of marketing them aggressively – has created a certain amount of tension between the major public and private sector collecting institutions. But the private sector is now a significant player in the film preservation landscape.

Private film collectors

Private film collectors have traditionally formed an important route by which titles have passed into the collections of public sector (and, far less often, studio) archives, and elements held privately have frequently formed the basis of restoration projects. The role of film collectors in preservation and restoration overall is difficult to quantify, because, with a relatively small number of exceptions (principally the small quantities of 8 mm and 16 mm prints that were manufactured for outright sale to consumers for domestic viewing), their activity was and still is technically illegal. The emergence of the classical Hollywood economic model brought with it a system whereby prints of feature films were not sold to theatres, but supplied on a rental basis along with a licence that specified the terms of exhibition. When the run was complete, the print was supposed to be either returned to the distributor or 'crossed over' direct to another theatre, and remained the legal property of the distributor at all times.

By the mid-1920s, this system of distribution had become virtually universal in the developed world. However, given the sheer number of prints in circulation, it was not watertight, and prints could and did escape from it in a number of ways. Firstly, they were stolen from the distribution chain by pirates, often to be exported and screened

commercially in countries in which the studio or distributor did not have a significant presence, and/or with ineffective or non-existent copyright law.[72] Secondly, prints intended for non-theatrical use (e.g. screening in schools, prisons or on airliners) fell into unauthorised hands through lax security procedures, and passed from there into private collections. In the late 1940s, for example, organised criminal gangs were alleged to be screening 16 mm feature film prints commercially in non-theatrical venues throughout Britain that had originally been supplied to the army and had, in the words of a private investigator testifying at the trial of one of the illegal exhibitors in 1946, 'just vanished, like so many of the forces' stores did'.[73] Thirdly, prints could be abandoned at the end of their commercial lifespan and subsequently fall into private hands. Probably the most widely celebrated instance of this was the discovery in 1978 of 533 reels of release prints made between 1913 and 1929 in a former swimming pool in Dawson City, near the border between Canada and Alaska. Being a remote and isolated location, it received films at the very end of their commercial distribution chain (usually between two to three years after their initial release), and neither their distributors nor the town's theatre owner was willing to pay the cost of return shipping.[74] As a result they were dumped in a disused swimming pool and left there until their accidental rediscovery and archival accession nearly half a century later.

Many of the prints that escaped from the distribution system through these routes ended up in the hands of private collectors, who over time have proven an important, though problematic, group of participants in the preservation process. Most do not have any commercial motivation. Before the advent of mass-market consumer media formats, film prints were the only media on which copies of feature films could be owned at all. Many collectors saw themselves as the custodians of material, especially the more minor and lesser-known examples of Hollywood's output, that they regarded their owners as having abandoned. Furthermore collectors saw the public sector archives, with their emphasis on European art films and reputation for making access difficult (as late as 2001, these were characterised in one film studies journal as 'specialised spaces into which only certain people are allowed to venture'[75]), as being antipathetic to such material. After consumer video technology became widely available in the 1980s, the private film collector survived, though more as an enthusiast of the legacy technology than motivated by content.

As a general rule, studios and other rights owners have tolerated the existence of private film collectors, because they hardly ever attempt

to exploit their prints commercially and they have formed an important source of rediscoveries. But there have been times when concerted attempts have been made by law enforcement agencies to curtail the practice, most intensively in the late 1970s when the emergence of home video precipitated fears that privately held film prints might be used as the source material for pirate videotapes. Legal action against collectors was usually predicated on the fact that 16 mm and 35 mm prints were almost never sold outright to consumers, and therefore that anybody collecting them had to be in possession of stolen goods. In the 1977 prosecution of a man accused of selling 35 mm prints of *The Exorcist* (USA, 1973, dir. William Friedkin) to collectors, 'the government made no attempt to establish the source from which the prints had been acquired, but relied on testimony from studio executives that no prints had ever been sold.'[76] Although, writing in 2006, a prominent American film historian asserted that 'the FBI gave up prosecuting film collectors two decades ago' (though without citing any substantive source),[77] memories of the period in which they were regarded essentially as criminals by copyright owners and the authorities remain a significant part of the reason why film collectors tend to regard themselves as a subculture, and the transition of material from their care into legitimate archives for preservation and restoration is often a protracted and tortuous process.

Another complicating factor in the relationship between collectors and archives is that the latter are usually keen to take custodianship of the former's films as quickly as possible, conscious that the collector probably does not have atmospherically controlled storage facilities, and due to the institutional nature of their operation, to observe copyright restrictions scrupulously thereafter.[78] Nevertheless, there have been committed amateur film collectors who, throughout the last century, were instrumental in rediscovering titles that neither the public sector archives nor the studios had previously been able to acquire and preserve.

The service sector

Just as the transition from early to classical cinema saw the change from a business model in which release prints were sold outright to exhibitors to a rental system, so the manufacture of hardware and consumables used by the industry shifted from being integrated to fragmented. Pioneer filmmakers such as the Lumières in France, Hepworth and Paul in Britain, Messter in Germany and Edison in the USA manufactured equipment and made films. Within a decade of the first commercial film

screenings, however, the two activities were starting to undergo an institutional split. About the one original player in the industry that stuck exclusively to the manufacture of a commodity and did not attempt to diversify into film production – Eastman Kodak – rapidly emerged as its most economically successful. The failure of the last significant attempt to vertically integrate the production of the technology with the production of the films, that of the Motion Picture Patents Company in 1917, effectively enshrined that separation to the present day.[79] Manufacturers of cameras (Bell and Howell, Mitchell and Arri), film stock (Kodak, Fuji and Agfa), sound technology (RCA, Western Electric, DTS and Dolby), theatre projectors (Christie, Cinemeccanica) or digital imaging systems (Sony, Barco and Red) all compete to supply producers, distributors and exhibitors of films, but these two areas of business activity do not, as a general rule, overlap.

Film preservationists, therefore, purchase products and services from this sector in the same way that the mainstream film industry does. Until the closing period of the 20th century, technical archivists were conscious that the products they had to work with were designed with short-term performance in mind, not longevity – nitrate film being the classic example. The emphasis of their research and development work, therefore, was in adapting what was on the market, and had been put there for a customer base with fundamentally different needs, to the requirements of film preservation and restoration; hence the research that established the effect of low temperature and humidity storage in retarding the decomposition process of cellulose film bases described in the previous chapter.

The emergence of products and services designed specifically for the archival market in many ways mirrors the emergence of for-profit film archives themselves. When the size of the market grew to the point at which the development of specialist products and services became commercially viable, they started to emerge. Before then, adaptation was necessary. In archival duplication, for example, the Debrie Matipo contact step printer, launched in its original form as early as 1913, became highly sought after by archivists from the 1950s onwards due to a unique feature that most laboratory printers used in routine post-production operations lacked: the ability to remove registration pins from the film path, thereby enabling the duplication of significantly shrunken originals without causing perforation damage.[80] Duplication as part of the preservation and restoration process had to be done using film stocks designed for feature film and television post-production, not archiving. Most camera negative stocks remain unavailable on a

polyester base. Despite the fact that cellulose triacetate is more chemically volatile in long-term storage, its use in film production is necessary because polyester cannot be cut and spliced without leaving a visible mark in the frame area, and will cause serious damage to a camera in the event of a film jam. The potential volume of sales of these emulsions on a polyester base for archival use is insufficient to justify their manufacture. In fact, Eastman Kodak did not develop and market a film emulsion that was specifically and exclusively for archival use until the launch of its separation master stock, type 5238, in 1992.[81] In the meantime, archivists had to battle on with products intended for mainstream production use. When it became clear in the mid-1970s that the type of colour film stock that had superseded three-strip Technicolor two decades earlier was prone to catastrophic dye fading, Kodak (its principal manufacturer) was accused by the protagonists of a campaign launched in April 1980 and spearheaded by the American, then independent, filmmaker Martin Scorsese of being disinterested in the problem, and in effect of not caring what happened to its products after their initial use. One of the campaigners even argued that a solution 'doesn't belong to private enterprise. It's a cultural heritage. I think the government should provide funds.'[82] With the possible exception of state-owned broadcasters, there has never been an instance of the public sector funding the research and development of new media technologies directly, and it is therefore unsurprising that this suggestion fell on deaf ears. In the event, more fade-resistant colour stocks were on the market within a few years, but this was largely because the business case for them had been made, not the cultural case.

The 1990s and 2000s also saw the commercial emergence of film laboratories geared (or re-geared) mainly or exclusively to provide duplication services for archival preservation. PresTech in Britain, Haghefilm in The Netherlands and the Film Technology Company in the USA are prominent examples. These businesses take on specialist work subcontracted from the major archives, both public and private sector, that it would be uneconomic for archives to maintain the expertise and infrastructure to undertake in-house.

The withdrawal from production and sale of obsolete products also poses a major problem for preservationists. Equipment and consumables that were a crucial part of the production and post-production processes used in films that are now undergoing restoration are now no longer available, forcing archivists to seek alternatives that simulate their aesthetic properties. When the last London laboratory serving the production sector ceased to make 16 mm release prints, the decision

prompted an article by a Berlin-based artist/filmmaker predicting it would become impossible to preserve examples of the genre in which she worked.[83] Though her article contains errors and misconceptions[84] (not least in its headline – she was 60 years too late to 'save celluloid', which had ceased to be sold in the UK as a moving image film base in 1951[85]), it raises an ethical issue that archivists will have to face on a far larger scale before much longer, when the conversion process to digital cinema exhibition is complete and film stock for release printing is no longer manufactured as a result of its core market disappearing.

The archivist as auteur

The final major constituency from which film restoration activity originates is that of the prominent individual, or, to put it in somewhat crude terms, the celebrity archivist, or 'starchivist'. As a profession, moving image archiving is both young and small in comparative terms. At the close of 2009, its principal professional representative body, the AMIA, had 962 members worldwide.[86] As has been noted above, no formal education programme existed for new entrants into the profession until 1990, and the pioneering work of the first generation of film archivists in establishing the basic knowledge and techniques of film preservation and restoration (some of whom, at the time of writing, are still alive) is still fresh in the memory of the current one. It is therefore hardly surprising that the influence and recognition of the field's professional leaders is profound and significant, and as the film industry itself is very much a public-facing one, that prominent archivists should play a major part in the re-launch and promotion of major film restorations. Some have spent their careers as the employees (and in some cases, the founders) of major archive institutions, while others have operated on a self-employed basis, working on individual projects to commission from archives, studios and broadcasters.

Arguably the first such individual to achieve significant name recognition beyond film archiving and related academic circles is that of the historian and curator Kevin Brownlow (b. 1938), who initially established a reputation as an independent filmmaker and prominent private film collector in 1960s London before publishing what was arguably the first cultural history of mainstream western silent cinema written from a post-classical perspective, *The Parade's Gone By*, in 1968. It is for his reconstruction of *Napoléon* (France, 1927, dir. Abel Gance), that Brownlow became an internationally recognised authority on film

restoration. The story of the project has been heavily mythologised, not least by Brownlow himself. He began it as an enthusiastic teenager, was motivated by an antagonistic relationship with the BFI (Brownlow recalls that Ernest Lindgren 'detested' private film collectors, and regards the BFI as having overly canonised European high art cinema[87]), his search for elements of missing footage took decades and extensive international travel, he was constantly struggling to raise money and the justification for the project in itself was one of proving a sceptical establishment wrong, as exemplified by *Napoléon*'s dismissal in Rotha's *The Film Till Now*. Brownlow himself stated that his motivation to work on *Napoléon* grew out of a desire to rehabilitate the work of a filmmaker who 'suffered in France as Erich von Stroheim suffered in America'.[88] The wider curatorship projects with which Brownlow followed the *Napoléon* restoration, the 'Thames Silents' series of (mainly 1920s Hollywood) features prepared for the London Film Festival and subsequent television broadcast with specially commissioned orchestral scores, launched in 1980,[89] and the documentary series *Cinema Europe: The Other Hollywood*, broadcast in 1995,[90] established him as arguably Europe's leading authority in the mainstream cinema between the end of the First World War and the conversion to sound, and in recreating the authenticity of the exhibition context of these films.

Since Brownlow set this precedent, prominent individuals in the field tend to be distinguished by expertise either in a specific genre of cinema, the output of individual filmmakers, restoration involving specific obsolete technologies or the curatorial missions of collecting institutions with whom they are associated over a long career (often their founders). Lindgren, Langlois and Barry are obvious examples of the latter, as are James Card at George Eastman House and Roger Smither at the IWM. Focus on specific technologies or technological challenges has been the career emphasis of a significant proportion of many of the sector's leading professionals. In a recent interview, the independent film restorer Robert Harris (himself a specialist in recreating obsolete large film formats) acknowledged the expertise of David Shepard in reconstructing silent film intertitles, and Robert Gitt in working with three-strip Technicolor and early sound.[91] João de Oliveira's work at the BFI and subsequently at the commercial film laboratory he founded in 2004, Prestech, has concentrated on improving the quality of sensitometry and densitometry in duplication, and recreating original formulations of tinting and toning dyes used in early cinema.[92] More recently Giovanna Fossati at the Nederlands Filmmuseum has pioneered the use of digital post-production technology in treating visual defects on surviving

elements, most prominently in her 2006 restoration of *Beyond the Rocks* (USA, 1922, dir. Sam Wood).

Conclusion

The practice of film restoration evolved, and is carried out within a relatively small group of institutions and individuals. As a distinct activity with its own techniques, methods and ethos, it has only really existed for three decades. The political, cultural and commercial shape of these groupings, therefore, has had a profound effect on how film restoration is carried out, with what aims and for what audiences; of which more in the following chapters. Although the technical, professional and academic literature related to the field of film archiving has grown exponentially since around the turn of the 21st century, when its two principal journals, *Journal of Film Preservation* and *The Moving Image*, were established, it was very small before then, and that nucleus has had a profound impact on the way the field is understood. In particular, Anthony Slide's *Nitrate Won't Wait* (1992) and Penelope Houston's *Keepers of the Frame* (1994) have become established as canonical texts that feature prominently on the reading lists of the postgraduate film archiving programmes, and far beyond. This initial canon of literature and a generation of subsequent authors, notably Caroline Frick, who have accepted its narrative largely uncritically, have enshrined a characterisation of the profession that pits custodians of public heritage against commercially philistine studios and technology manufacturers, emphasised the importance of European minority film cultures and the dedication of amateur enthusiasts such as film collectors, and celebrated the achievements of early technical archivists such as Harold Brown in developing the basic scientific principles of preservation and restoration. The following chapters will consider what the process actually involves.

3
The Technique of Film Restoration

Introduction – Defining the original

The restoration of audiovisual records is a relatively young set of practices, compared to those used to restore comparable cultural artefacts, notably archival written documents, works of fine art, sculptures, museological artefacts and buildings. Its proponents also claim that it is a fundamentally unique one. A 'charter on film restoration' endorsed by FIAF in 2011 claims that it is

> different from all restoration in other fields, where a tradition is already established. Whereas those traditions typically imply work on an original artefact, film restoration implies duplication and/or reconstruction.[1]

In fact the issue isn't as simple as that, as the process usually involves work on an original artefact *and* duplication. What is certainly true is that the restoration of moving images and sound recordings is distinguished from most other cultural restoration practices apart from print media (e.g. the publication of facsimile editions of historically significant manuscripts or editions), in that access to the end result does not involve direct contact with the original artefact: the output is always a duplicate or surrogate.

However, this is simply the reflection of a basic technological principle on which cinema itself depends for its cultural and economic viability, namely the ability to produce multiple copies from a single film element exposed in the camera. A significant proportion of film restoration activity is in fact the recreation of steps undertaken in the initial

post-production process, as the result of the outputs from those process having been lost or otherwise compromised for one or more of the reasons discussed in Chapter 1.

But the fact that there is no 'original' film that can be defined using comparable objective criteria to those used to define originality in a museological artefact makes determining this definition a crucially important step to be undertaken at the outset of any film restoration project. In the case of the former, producing this definition is generally regarded as straightforward and unproblematic. In the introduction to his book on museological conservation, for example, Andrew Oddy discusses the case study of a bronze statue in the Roman baths museum at Bath Spa, UK in relation to what he calls 'non-original restoration', usually carried out due to 'changes in fashion, taste or politics'.[2] The statue is currently on display in the conserved state in which it was recovered by archaeologists, with gold leaf gilding worn away and corroded in places. Oddy notes the existence of evidence to suggest that the piece had been regilded at least six times during the Roman period, presumably due to wear and tear. That raises the methodological question as to what the object of any restorative activity should be – to display the piece in the preserved aesthetic condition that it was discovered by the modern curator, or to recreate the physical maintenance and exhibition context of the piece that we have evidence to suggest was intended by its creators?

In some ways this scenario is comparable to the practice of film 'modernisation' discussed in Chapter 1. Empirical knowledge exists as to the condition in which a cultural object was seen and experienced in the immediate wake of its original creation, and a deliberate decision has been made not to recreate that in the curation of access to this object two centuries later. By the same token, anyone who sets out to colourise *Citizen Kane* or add a soundtrack of 1980s rock music to *Metropolis* knows full well that they are creating something not envisaged by the creators of the source material and not experienced by those who saw the film immediately following its completion. As with preserving a Roman statue in a state of comparative disrepair, the only rational justification for doing that can be in relation to the cultural expectations of a contemporary audience, not the experience of the contemporaneous one.

But in the case of the Roman statue, the decision-making required is limited to the nature and extent of physical work carried out on the one object and the setting in which it is displayed. The latter is important, as the curator has complete control over the physical environment in which it is displayed (there is only one) and in which access takes place. In contrast, defining the object of film restoration consists of aiming at several, moving targets. Certain factors lie within the restorer's control: the sequence of images (and, if applicable, synchronised audio recordings) being restored, if any, what technologies are used to reproduce image characteristics that were originally created using now obsolete ones, what steps are taken to reverse the aesthetic evidence of physical damage or decomposition, if image and sound information recorded at the point of initial creation but not published in the original release is to be included in the restored output (an example would be the stereo recording of the music score for *Vertigo*, heard for the first time in Robert Harris's 1996 restoration[3]) and whether the final output is photochemical, digital or both.

But others are not, most importantly the technical and cultural environment in which the end result will be exhibited. Most film viewing now takes place in the home: as Barbara Klinger puts it, 'America's film past is preserved in the realm of *domestic* leisure',[4] despite the fact that most filmmakers working before the 1950s would not have imagined or conceived that their work would be seen in any setting other than the communal one of a theatre. And not only is the social context of reception fundamentally different from that of the film's initial reception, but so is the technology: photochemical in the case of a film produced and initially screened theatrically before the turn of the 21st century, and televisual and/or digital when screened in the home. Archival purists argue that the reformatting process involved in reproducing the former by means of the latter (i.e. the telecine or data/cine process) affects such a fundamental change to the aesthetic experience of reception that this in itself compromises any attention to provenance that might inform a restoration itself. Their detractors would point out that such objectivity is fundamentally impossible, given the extent of the evolution that has taken place in photochemical imaging technologies during the 20th century, and that copying is and always was an integral part of all film distribution, for whatever market.

Paolo Cherchi Usai has gone as far as to declare the term 'restoration' fundamentally misleading, suggesting that 'simulation' is a far more accurate description of what the archivists who produce new versions of old films are actually doing.[5] And furthermore, in the case of many, if not most, mainstream feature films produced since the mid-1970s, domestic viewing *was* part of the original business plan and cultural experience: as the author of the standard history of the consumer VCR as a distribution medium notes, theatrical and home video distribution

were considered to be of equal importance in the production planning of many 1980s blockbusters,[6] and therefore reception contexts of equal cultural significance for the viewer.

Ultimately, however, just as the restorers of our Roman statue can only work on the object itself, so film restorers can only work on what literary theorists and critics, and those who adapt the metaphor for use in academic film studies, would call the text. This has led one writer to suggest that essentially, the role of the archivist/restorer (who works on the film itself) should be regarded as a fundamentally separate role from that of the curator, who determines the conditions of its reception. He writes:

> The archivist does not need to know how to interpret what he keeps in the archives and the programmer does not need to have knowledge of a film's origin. The curator, on the other hand, interprets the collection to the audience and staff of the institution. To curate at film museums is to translate and interpret, says Horwath.[7]

His opening statement – that an archivist does not need to know how to interpret what he keeps in the archives – is surely a problematic one, given that without a certain degree of interpretation, he (or she) will be unable to arrive at a definition of originality, or at least of the physical condition in which a film previously existed and which is the goal of the restoration. But this idea does propose a useful distinction: that ultimately, the restorer has little if any control over the circumstances of reception, either in the past or in the present. An archivist working on a 1930s Busby Berkeley musical cannot rebuild 2,000 seat picture palaces in every major town in the developed world, which is where most people would have seen it in the immediate aftermath of its production, or do anything much about the fact that most people will see the result of his or her work on a 42-inch screen in the company of two or three other people at most. Therefore, the two chapters in this book that cover the techniques and technologies of film restoration divide the issue into two halves: work on the films themselves in this chapter, and on their exhibition and reception in the next.

Initiating the project

A restoration project will usually start in one of three ways. The first is when an unexpected discovery of major commercial and/or cultural significance occurs, prompting the immediate decision to undertake

whatever restoration work is necessary to enable accessibility. An indicative example would be the Mitchell and Kenyon films in Britain, a collection of some 800 reels of actuality footage from the 1900s to early 1910s, which had been abandoned by its production company in the basement of its former premises and rediscovered by chance when the building was being refurbished almost a century later. The route by which these elements eventually arrived in the care of the BFI was, in the words of the curator who oversaw the project, 'a complex interaction of individual and institutional behaviour with pure luck'.[8] Once there, the cultural case for full-scale restoration work was immediately established to be urgent and compelling. No other regional, non-fiction early cinema collection so extensive or complete was known to survive or be archived anywhere in the world, many of the elements were actively decomposing and there was no guarantee that the technical or curatorial expertise or the money needed to restore and interpret the collection would continue to be available in the long term.

Other instances of rediscovery-led restoration include *The Life Story of David Lloyd George* (UK, 1918, dir. Maurice Elvey) by the National Screen and Sound Archive of Wales in 1995–1996,[9] and *Beyond the Rocks* (USA, 1922, dir. Sam Wood) by the Nederlands Filmmuseum in 2004–2006.[10] Such projects traditionally attract the most prominent headlines and favourable publicity for an archive undertaking them, informed in part by lost film mythology (see Chapter 1) and the consequent perception that the rediscovery is of major significance – the embryonic work of a later-to-be prominent director, or a controversial film lost to censorship, for example.

As a result archive institutions tend to give such discoveries high priority, and in the opinion of this author can be tempted to make exaggerated claims for their cultural importance. *Beyond the Rocks*, for example, received indifferent reviews and performed relatively poorly at the box office upon its initial release, and from a viewing of the restoration it does not require a leap of the imagination to understand why. A satirical and prescient comment on this tendency can be found in a spoof television documentary made in New Zealand, *Forgotten Silver* (dir. Peter Jackson and Costa Botes, tx. 29 October 1995), in which Jackson claimed to have made the chance discovery, in a garden shed, of the entire output of a forgotten pioneer of the nation's cinema. The programme followed the restoration and curatorship of material from the collection, satirising both early cinema (intentionally) and archivists' obsession with 'back from the dead' rediscoveries (probably unintentionally) as it went. While most of the critical reaction and debate

elicited by the broadcast concentrated on questions of cultural and national identity in relation to New Zealand's history,[11] it also raises some pertinent questions about the ways in which archives tend to celebrate and emphasise rediscoveries by prioritising them for extensive restoration work.

The second catalyst for film restoration activity is what might be termed film search initiatives. This is when an individual or organisation searches, often in the form of public appeals, for films that are outright lost, or for missing or higher quality elements relating to a specific title. As Ray Edmondson notes, these initiatives, as with 'back from the dead' rediscoveries, act as important shop windows for the archive institutions that conduct them. The Australian National Film Archive's 'Last Film Search' project in the early 1980s 'garnered immense free publicity in the press, and on television news and chat shows. It ultimately yielded two one-hour television documentaries.'[12] Another Australian example was the search conducted in the early part of the last decade for high quality pre-print elements of the controversial and critically acclaimed 1971 horror film *Wake in Fright* (dir. Ted Kotcheff). While poor quality release prints and video transfers circulated to limited audiences throughout the 1980s and 1990s, the film's editor spent almost a decade searching for the cut camera negatives, which were not formally archived following the completion of the original post-production work. He eventually found them in the USA in 2004, shortly before the commercial storage facility in which they were housed would have destroyed them. Even though *Wake in Fright* was not a lost film in the sense that, say, *David Lloyd George* was, its rediscovery, restoration and eventual re-release was greeted in the press as a 'great find', and 'for cinema historians, like winning the Melbourne cup.'[13]

The final way in which restoration work is initiated is when the planned decision is made to restore a film that is already extant and archivally preserved in some form, but which it is believed does not communicate the cultural integrity of the original (however this is defined). This is usually triggered by the availability of new elements, knowledge, technologies and/or money providing a realistic prospect of further work on the film resulting in an output that is judged to be significantly closer to an archivist's vision of the original's cultural integrity, or sometimes for primarily commercial reasons. Unlike in the case of back-from-the-dead jobs in which claims are often made for the cultural significance of discovered material, the distinguishing feature of a planned restoration is that it is not triggered by the discovery of new material, but by a new reason for working on extant material. Of course,

no discussion of this category of restoration project can pass without yet another mention of *Metropolis* (Germany, 1927, dir. Fritz Lang), which, as stated in the introduction, has a strong claim to being the world's most frequently and extensively restored film (or as a colleague of mine put it somewhat more colloquially, 'restored up the ass'), with at least five full-scale projects having been carried out on the basis of surviving material since the 1970s.

The example of *Metropolis*, though an extreme one, illustrates an important point, namely that the subjects of what one might call revisionist restorations tend to be films that have become canonised, either critically (e.g. by the writing and teaching of film studies academics), commercially (the phenomenon of 'cult films') or both. Canonisation is an ideologically charged process, characterised by what Janet Staiger terms 'the politics of admission' and 'the politics of selection'.[14] Because the public film archive movement grew to a great extent out of what might be termed 'highbrow' cultural activity (see Chapter 2), the critical canon has informed all aspects of moving image archiving, and not just restoration. It is hardly any coincidence, for example, that only one of the 58 feature films directed by Alfred Hitchcock is considered lost (*The Mountain Eagle*, 1926), which incidentally, the BFI launched an 'international campaign' film search to find in 1997;[15] whereas most of those directed by his early contemporaries, notably Graham Cutts and Maurice Elvey, are not known to survive, a fact that is rarely mentioned in any national newspaper.

Another notable example of revisionist restoration is that of *The Red Shoes* (UK, 1948, dir. Michael Powell and Emeric Pressburger). Preservation and restoration of this film was originally carried out by the BFI in the late 1980s, as part of a major project to preserve the entire surviving collection of British Technicolor features. The work, carried out mainly by a former Technicolor employee subsequently employed by the BFI as a colour expert, Paul de Burgh, 'undoubtedly played a major part in the rehabilitation of [Michael] Powell's reputation', according to the BFI's biographer.[16] A literature review would certainly support Houston's claim that the BFI's decision to, in effect, begin the canonisation of Powell and Pressburger themselves, provided the catalyst for that process's ultimate conclusion: the first monograph length study of their films was published in November 1985,[17] seven years after the BFI's first Powell and Pressburger restoration (*The Life and Death of Colonel Blimp* in 1978) was premiered. Over a dozen have followed it.

The BFI's restoration of *The Red Shoes* was prepared during the 1980s, using entirely photochemical techniques. At the time, this and the other

Powell and Pressburger Technicolor restorations were hailed as having, in Christie's words, enabled the films 'to age into the condition of art'.[18] It is worth keeping in mind that, as with *Wake in Fright*, these films were not lost. Furthermore, no archival master materials were even considered missing: these elements were already in the care of a FIAF-affiliated archive institution at the time the restorations took place. Rather, the decision to undertake the 1980s restoration was informed by the belief that the filmmakers who produced *The Red Shoes* were important cultural figures, and the resulting effect of its screenings was to create the impetus for the 2009 restoration to take place. At the time of its completion, the BFI's restoration was considered to have achieved its technical objective, namely to create preservation master elements and release prints of the film that effectively communicated its original technical integrity.

The essential reason why the 2009 restoration took place was the enthusiasm for *The Red Shoes* of the director Martin Scorsese, inspired by his friendship with Powell's widow, the campaign he led against colour dye fading in the early 1980s and his consequent belief that the BFI restoration had not restored the film to the extent that digital methods, which had emerged during the intervening two decades, could now achieve. [19] It should be noted that this was the second, large-scale and highly budgeted restoration project to be done on a film which had already received substantial work and which was in no danger of outright loss. It therefore demonstrates that critical canonisation is a crucial factor in determining which films are selected for restoration activity, especially of films that are not essentially rediscoveries; and in some cases, even of repeat restorations.

The workflow – Photochemical, digital or both?

Until approximately the turn of the 21st century, film restoration consisted essentially of three activities, all of them taking place in the photochemical and analogue domain. These were physical conservation and repair work on surviving film elements, the assembly of those elements into a sequence of shots that amounts to a version of the 'original' film, however that is defined (if applicable), and the duplication of the prepared elements to create the element (usually a negative or fine grain positive) that will become the preservation master element of the restoration, from which access copies are made. In short, the technical processes in use were essentially the same ones as were being done commercially as part of everyday post-production work in laboratories and facilities houses, with slight adaptations for the specific requirements of preservation and restoration work.

The emergence of computer-based technologies for storing and manipulating moving images originated on film enabled the development of digital film restoration. These technologies began to appear in the early 1990s, designed principally for the creation of CGI, and the integration of photographic and CGI elements within the same filmic image. Two mainstream feature films that featured, and were prominently marketed on what at the time was considered the groundbreaking use of CGI were *Terminator 2: Judgment Day* (USA, 1991, dir. James Cameron) and *Jurassic Park* (USA, 1993, dir. Steven Spielberg). It was not long before the manufacturers of these systems realised that they could also be used to carry out equivalent image enhancement techniques in the digital domain that archivists were using in film restoration as part of the photochemical duplication process, and, potentially, to do them more effectively and more cheaply.

The first major fully integrated digital post-production system, Kodak's Cineon, was first marketed in 1992 and was used to carry out what was possibly the first full-scale digital restoration project on a feature film, that of *Snow White and the Seven Dwarfs* (USA, 1937, dir. David Hand) the following year.[20] By the middle of the 1990s, digital restoration was being widely discussed as an alternative to photochemical methods, but the cost of using the technology was beyond the reach of all routine archival work. Writing in 1996, the independent expert Paul Read noted that 'the price of using the present equipment and service is quite unacceptable' for all but a tiny fraction of restoration projects (he gave the typical usage cost of a digital scanning and editing system charged by a post house as being £650 per hour).[21] Discussing the restoration of *Vertigo* in 1996, Robert Harris expressed the belief that he could have achieved better results with certain shots and sections of the film using a fully digital workflow, but was unable to do so on account of the cost.[22] The following year, a representative of the FIAF Technical Commission noted that a major factor driving the cost of digital restoration beyond what public sector archives could afford was the relatively slow speed at which the then current generation of scanners and film recorders operated (and thus the volume of film they could process in a given time) – about 20 seconds per frame – relative to their cost.[23]

A decade later, by the middle of the 2000s, the cost of digital restoration had reduced to the point at which the technique was accessible for non-profit archival use, albeit restricted to prestigious projects or work for which photochemical methods were judged to be a significantly

inferior option. The hardware was being produced by a range of third party manufacturers, software designed specifically for restoration applications had entered the marketplace (much of which ran on standard Windows PCs or Macs with only minor hardware additions) and larger archives had the realistic choice of outsourcing digital restoration work to post houses or carrying it out in-house.[24] At the time of writing, hybrid photochemical and digital workflows for film restoration were also in widespread use.

By the start of the present decade, the commercial use of film as an imaging medium was in rapid and probably terminal decline. The use of digital cameras for high resolution image capture began in the late 1990s, gathered steam throughout the following decade, extended to independent filmmakers following the launch of low-cost cameras such as the Red One in 2007 (which was priced at a comparable level to that of professional 16 mm cameras during the format's heyday and was aimed at an equivalent market), and became almost universal following the emergence of D-SLR cinematography at the close of the decade. By this stage film had also disappeared almost entirely from television production workflows, with HDV digital camcorders replacing Super 16 mm for high-end origination.

By 2008, fears were being expressed that the conversion to digital projection in theatres, a process that by this stage was well underway, would force independent cinemas that could not afford the new equipment out of business.[25] These concerns were largely addressed by the emergence of the Virtual Print Fee (VPF) model at around the same time, whereby the up-front cost of digital projection equipment is borne by a third party (usually an equipment manufacturer, film distributor or venture capitalist) and then repaid by the exhibitor over a number of years as a proportion of the box office gross.[26] By April 2011, the *Los Angeles Times* reported that at least one major Hollywood distributor was planning to discontinue the supply of feature films on 35 mm release prints altogether, meaning that theatres would be required to screen DCPs.[27] At the time of writing, rumours were circulating that Eastman Kodak, the manufacturer of most of the world's film stock, was on the verge of bankruptcy following a failed attempt to restructure the business in order to focus on consumer inkjet printing technologies.[28] On 9 November 2011, the distribution arm of 20th Century-Fox sent a letter to all exhibitors in the USA on its books that had not installed digital projection, to 'remind you that the date is fast approaching when TCF and Fox Searchlight will adopt the digital format as the only format in which it will theatrically distribute its films'.[29]

It is probable, therefore, that in the foreseeable future a film restoration workflow based on photochemical duplication and a final output to film will simply no longer be possible, because neither new, unexposed film stock, nor the laboratory services needed to print or process it, will be commercially available anymore. Leaving aside debates as to the viability of economies of scale needed to maintain the availability of film as a niche product, and ethical questions related to film restoration using digital methods (which will be addressed in the concluding chapter), it is sufficient to note for the purposes of this chapter that at the time of writing, photochemical, digital and combined methods are potentially available to the archivist embarking on a film restoration project.

In making the decision as to which to use, the restorer has to address a number of factors. These are, in essence:

1. Whether both routes are realistically possible at all. A non-standard film format, for example, may not be supported by any photochemical printer or digital scanner with the other features needed in the duplication processes required by the project. In some cases it is determined that technical characteristics in the source elements that are considered to be defects are so serious that either they can only be corrected using digital methods, or that the relative cost of the two methods effectively makes the decision. Colour dye fading is a common example,[30] as is the shrinkage of nitrate and acetate stock beyond the tolerances of any photochemical printer available.
2. The comparative cost of digital versus photochemical workflows.
3. The timescale of the project, e.g. a completion deadline imposed by a prominent anniversary (for example, of the film's original premiere), film festival, broadcast or other event to publicise the project.
4. The equipment, infrastructure and expertise available to the organisation and individual(s) carrying out the restoration.
5. The technical characteristics and condition of the source element(s) from which the restoration master will derive. For example, a film element with extensive perforation damage can be passed through a sprocketless scanner as is, whereas to print it extensive (and expensive, in terms of staff time) physical repair and preparation will be necessary first.
6. Ethical considerations. Sometimes less (objectively) efficient duplication and processing technologies will be used if it is believed that doing so will result in a more (subjectively) accurate aesthetic impression of the original viewing and/or listening experience in the copy. Writing in 2002, a leading archival film sound expert described

himself as 'possibly the last person on this planet to re-record using a variable density sound camera',[31] using what is regarded by today's film industry as obsolete equipment in the restoration process in order to preserve the impression of sonic authenticity.

An evaluation of these factors may lead to the decision to use photochemical technologies for some components of the workflow, but digital for others. For example, the restoration of a silent film may be carried out by wet-gate printing of the surviving source elements to produce a new master negative or interpositive for preservation. However, it may then be decided to produce only digital surrogates for access with tinting and toning colours applied in the digital domain, perhaps to circumvent the cost of chemically tinting and toning a 35 mm release print, or to be able to synchronise a recorded music score and eliminate the difficult and expensive technical challenges in projecting a 35 mm silent print in the correct aspect ratio and at the correct speed in a typical modern theatre installation.

The restoration process

Technical selection

Regardless of whether photochemical or digital copying techniques are to be used, the first practical stage in a restoration project – and in some cases, the one that determines whether the project is considered viable at all – is technical selection. This consists of identifying and examining all the extant elements of the film to be restored in order to decide which will be duplicated (i.e. will be used as the source material) in order to form the master element of the restored film. The nature and extent of this initial phase of the project can range from non-existent to large scale. If, as in the cases of *The Life Story of David Lloyd George* and *Beyond the Rocks* (restored 2005–2006), only one element of the footage is known to exist, then that will be the element from which the restoration derives, without any technical selection being needed. At the other end of the scale, some projects begin with multiple elements of the same footage, ranging from the camera negative to release prints, with only unreliable provenance information available for some of those elements, if any (as was the case with *Vertigo*) (Fig 3.1).

Each generation of photochemical duplication, even contact printing, changes the aesthetic properties of the photographic image. Some would characterise this as degrading it, though once again it must be borne in mind that a film's audience never saw the camera original projected:

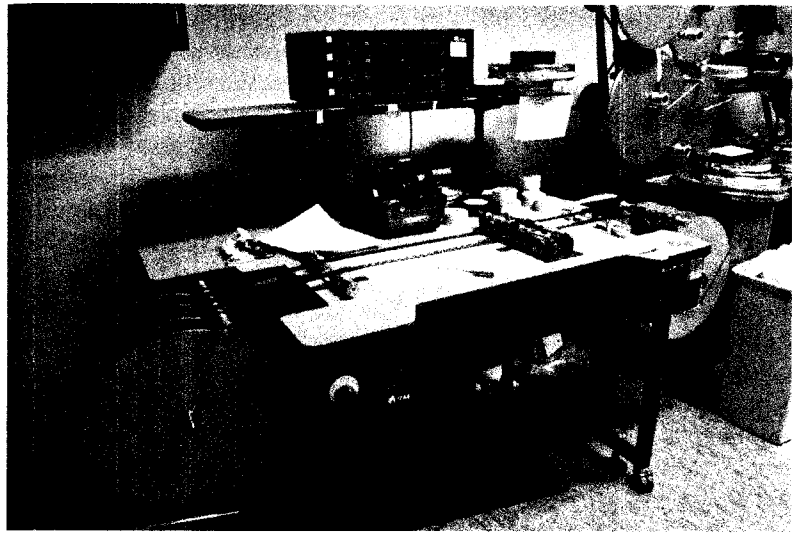

Figure 3.1 A film examination bench used for technical selection. It enables up to four 35 mm film elements to be wound in synchronisation with each other (the motors being controlled by the pedals, leaving the operator's hands free to handle the film and make notes) while being examined above the light box in the middle. The meter unit at the top (indicating here that both elements are positioned 2,911 frames from the start of the reel) allows the operator to record accurately the position of film sections being compared.

multiple generations of duplication were part and parcel of the 'original' production process, and should not always be considered a threat to authenticity. Nevertheless, the restorer will, as a general rule and as a starting point, try to use either the camera negative or the closest generation to it as possible. Pragmatic as well as ethical factors can work against that baseline. When Robert Harris began work on *The Godfather* (USA, 1971, dir. Francis Ford Coppola) in 2006, for example, he discovered that the cut camera negative was 'filthy and riddled with scratches, rips and tears, some of which broke into the image area; in some sections, parts of the image had actually been torn away.'[32] In such a situation, where the closest generation extant to the camera original (in this case, the original itself) has extensive and irreparable (the image torn away) physical damage, a higher quality restoration master can be obtained by using another element, even though this will be at least one generation removed. In other cases, the camera original is not an accurate representation of what the filmmaker intended to be seen, as significant

image manipulation took place in subsequent post-production, which has to be recreated in the production of the restoration master. One dramatic (though unusual) demonstration of this can be found in Bill Douglas's debut feature *My Childhood* (1972). The filmmaker's intention had been to shoot in black-and-white, but he was overruled by a funding body because black-and-white was 'allegedly redundant'.[33] The camera negative was therefore in colour, but Douglas was able to impose his artistic preferences in post-production and the initial release prints were made on black-and-white stock. This decision has been interpreted as culturally significant by critics, one of whom wrote, for example, that it resulted in Douglas's early work being 'linked to the tradition of British realism'.[34] It would therefore be impossible to restore the film (at least, according to the director's vision and in the form it was screened upon its initial release) by straightforward duplication of the camera negative.

In some scenarios, curatorial and technical considerations can be interdependent. For example, until the introduction of intermediate duplicating stocks in the 1920s, it was common practice within the Hollywood studios to shoot each scene in the studio or on location with two cameras simultaneously. The 'better' angle shot was typically used for the domestic (US) release prints, with the inferior negative being assembled to print the overseas version.[35] If the cut camera negative of the foreign version survives in relatively good condition but the US version is only available in a poor contrast, second generation dupe negative, which should be used for the restoration? The former is preferable when judged by the criterion of technical quality alone, whereas the latter is a closer content representation of the viewing experience intended for the film's primary audience.

Physical repair of film elements

One of the aims of technical selection is to identify film elements in the best possible physical condition for duplication. It is generally accepted best practice that the need for technical intervention designed to remove the visible appearance of decay or damage should be avoided, which in turn mandates the selection of elements that have not decayed or been damaged, if available. However, that imperative can sometimes conflict with others, and in technical selection the restorer may have to decide between, for example, a heavily worn camera negative and a first generation, fine grain dupe in near perfect condition. In other words, which imperative is the more important – sticking as close as possible to the original element that was exposed in the camera, or avoiding the need for remedial treatments? There is no definitive answer, and in practice a number of factors will have to be evaluated in order to arrive at a decision. Is the gain in image information offered by the camera negative sufficient to justify the cost and risk of repair? Would that repair necessitate known to be or potentially irreversible treatments that might compromise the effectiveness of duplication technologies that may become available in the future? Would the cost and speed gain from using the dupe enable higher quality work to be performed in other aspects of the project, e.g. the soundtrack?

Once the need for repair processes to be undertaken has been invoked by the technical selection of film elements that require them in order to achieve optimum results in duplication, the procedures necessary can be subdivided into two categories: repairs that are necessary for the element to withstand the mechanical strain of being passed through a printer or scanner, and those intended to improve the quality of the printed or digitally captured image. The former consists essentially of the reconstruction of damaged splices and perforations, and repairs to tears that encroach into the picture area. The adhesives used in both cement and tape splices (the two methods of joining nitrate and acetate film) degrade over time and eventually fail, even under optimum storage conditions. They are repaired by manually scraping away the adhesive residue and remaking the splice. Perforations that have become deformed and/or torn away at one or more edges are normally repaired by the application of pre-perforated adhesive tape. The approach taken in photochemical and digital workflows varies significantly at this stage. An analogue printer will transport the film using sprocket teeth that engage the film's perforations, in the same way that a camera or projector will. Those perforations therefore need to be intact, to enable the film to be transported through the printer without jamming or other mechanical failure. The latest generation of digital film scanners, however, include models that are totally sprocketless. The film is in effect dragged through the mechanism by the take-up reel, with only mild tension being applied in the gate area where an even surface is necessary. Film elements with significant perforation damage, therefore, can be scanned without the need for physical repairs first. Furthermore, in the event of a film break or other transport failure, the element can simply be rethreaded and scanning resumed from the break point, without spoiling any of the expensive raw film stock receiving the duplicate image in an analogue printer. The inventor of one such scanner claims that it enables 'non-judgmental preservation', in that avoiding the labour cost and in some cases the irreversible treatments associated

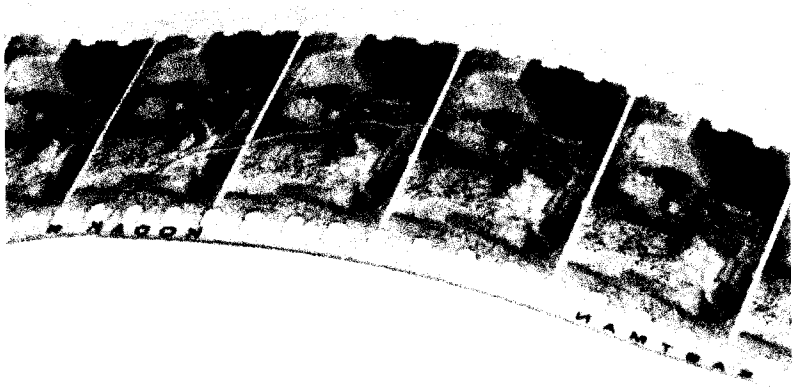

Figure 3.2 A section of 35 mm nitrate negative, in which a lateral tear across four frames has been repaired with adhesive tape.

with full-scale film repair prevents the need for archives to make a cost-based judgement as to what is worth saving and what is not before materials are lost to decomposition (Fig 3.2).[36]

Image enhancement repairs can be further subdivided into two categories: the mitigation of scratches, and the removal of dirt and artefacts. While both scratching and dirt/artefacts exhibit similar visual characteristics in the projected moving image – they manifest themselves as visible image information that was not recorded at the point of photography and was not intended to be present by the filmmaker – there are two crucial differences between them which determine how they are dealt with by restorers. Firstly, the visual presence of dirt and artefacts will be largely random: for example, fingerprints caused by film poor handling or contamination with projector oil are unlikely to affect the same place in a sequence of frames. Scratching, by contrast, is likely to be the result of mechanically inflicted damage and thus will follow a consistent pattern from frame to frame. For example, arguably the most common form of scratching is the so-called 'tramline', which is applied by passing the surface of a film in contact with an abrasive object, perhaps the flange of a roller as the result of incorrect threading in a projector. The resulting lateral scratch will be visible in the reproduced moving image as a continuous vertical line over successive

frames. Secondly and as a general rule, dirt and artefacts can usually be removed from the film's surface by means of a cleaning process, whereas visible evidence of scratching can only be obscured during the photochemical copying process (i.e. it cannot be removed from the original element) or by digital manipulation of the image after scanning. And if the scratching is on the emulsion side of the film, then part of the image information itself will have been scraped away: the missing part cannot actually be 'restored' at all, only its loss concealed.

Film cleaning

Film cleaning is almost certainly the oldest technique to which the term 'restoration' has been applied. As early as 1915 the technical column of Britain's leading film industry trade paper, *The Bioscope*, noted that a proliferation of chemical products were already being marketed for the removal of surface contaminants and as preventative treatments to make film 'less liable to be scratched and, in the case of cleaned films, with a view to prevent dirt from again collecting in scratches'.[37] These included 'a pad of cotton wool dipped in Benzoline and worked over the film, one side at a time' – in other words, the use of an organic solvent to lift contaminants from the surface, and the automated application of a proprietary substance that was designed to leave a permanent, protective residue on either or both sides of the film element.[38] The Clairal process, introduced in 1919, consisted of a proprietary solvent that was applied to both surfaces of a release print in the film path of a projector. Its promoter claimed that 'the action of the fluid on the film is such as to render any badly scratched subject equivalent to new when it appears on the screen',[39] presumably through a similar action to modern wet-gate printing. Systems for coating release prints with a proprietary cleaning solution (usually an organic solvent with a variety of additives) immediately before projection have remained in continuous use to the present day, with products such as FilmGuard, Renovex, Filmrenew and Solvon all being on the market, in variants for both manual and automated application, at the time of writing.

In 1923 the Henderson process was launched, and its initial success financed the establishment of the film laboratory in South London of the same name, that eventually became one of the world's leading archival preservation facilities until its closure in 2004. This was one of the earliest systems intended not only to maintain or enhance the quality of release print projection, but also to remove and prevent visible defects in pre-print elements in preparation for duplication

('negatives are reconditioned without interference with contact when printing').[40]

Restorers today tend to regard these treatments as problematic, as their reversibility and long-term effects are often unknown, or in some cases, are now known to cause irreversible damage themselves. Probably the most widely reported example of this is the 3M Photogard process, marketed from 1978 (and renamed Scotchgard in 1993), in which a permanent lacquer is applied to both sides of the film surface. Photogard worked by 'filling in' abrasions in the film base with a substance that had an almost identical refractive index to the film itself, thereby rendering them invisible in projection or duplication, and leaving a permanent coating that was significantly more resistant to further damage than the untreated film. Claimed by its manufacturer to be 'a permanent protection that will not crack, yellow, delaminate or fade with age',[41] it has nonetheless proven problematic after long-term storage in many cases, notably when the cellulose triacetate film base underneath it has shrunk after application, thereby causing mechanical deformation. Removal is often impossible.[42]

If the principle of doing nothing that is or could be irreversible to original film elements is to be maintained, therefore, the application of proprietary chemical treatments (i.e. ones for which a full formula is not published by the manufacturer) is ruled out. While their use is often considered acceptable on duplicate film elements that are replaceable and/or not intended for long-term preservation (e.g. release prints or the internegatives from which they are struck), the widely accepted ethical best practice dictates that only chemicals that are known for certain to leave no trace or permanent effect (apart from aiding the removal of contaminants) on the film after use may be applied to irreplaceable, one-of-a-kind elements.

For this reason, restorers today will generally use either or both of two non-invasive treatments to clean unique elements in addition or as an alternative to cleaning by the application (manual, using a non-abrasive cloth, or automated, in a film transport mechanism of some description) of a chemical solvent.

Ultrasonic film cleaning dates from 1979, when a patent was granted for 'an ultrasonic liquid film cleaning device having means for moving a film strip at high speeds between a pair of oppositely moving cleaning strips'.[43] The film is immersed in a heated chlorinated solvent as it passes through the machine, which in turn is agitated by ultrasonic energy. Cleaning is achieved through a dual action, with the ultrasonic-induced agitation of the solvent separating contaminants from the film's surface, and the circulating reservoir of solvent then suspending or dissolving

them. Like so many technologies used in the archival preservation and restoration of motion picture film, ultrasonic cleaning was not invented or developed specifically for this application: rather, it was initially marketed to laboratories and post-production facilities for use in the initial production process, for cleaning film elements immediately before printing or telecine transfer, primarily in order to maximise the number of release prints that could be produced from a single internegative without significant loss of image quality.[44] It was soon discovered that the technical characteristics of the process made it ideal for archival use, both practically and ethically. The mechanical process by which contaminants are separated from the surface of the film is significantly more efficient than that of any hand-cleaning process used previously (in crude terms, it gets more crud off). It is also less dangerous to the film than hand or basic mechanical cleaning, because the film is not passing in direct contact with a surface that could already be contaminated by sharp objects that had been lifted from the film previously. And crucially, the solvent evaporates totally from the surface of the film during the drying process that follows ultrasonic cleaning: it does not leave any residue and is not capable of being absorbed by the film emulsion. [45] Except in a small number of cases in which ultrasonic cleaning can damage attributes it is desired to leave intact (e.g. some types of magnetic stripe soundtrack and tinting dye), the ultrasonic process thus conforms to the ethical principle of doing nothing that is or risks being irreversible (see below).

The major drawback of ultrasonic cleaning is environmental. As an executive of the world's largest manufacturer of these machines elegantly put it, 'the history of film cleaning seems to be so much a history of the use of rather nasty chemicals'.[46] The solvent of choice for use in many pre-ultrasonic, mechanised film cleaners was carbon tetrachloride from the 1950s until the mid-1970s, was discovered to be a cause of several serious diseases in humans (in fact it is probably one of the most potent poisons ever devised, discounting nerve gases), damaging to the ozone layer and a greenhouse gas. The first generation of ultrasonic cleaners used 1,1,1 Trichloroethane, which, by the late 1980s, was recognised as being similarly dangerous. The use of both solvents was phased out by the Montreal Protocol of 1989, an international agreement to withdraw environmentally destructive chemicals from mainstream industrial and consumer technologies.[47] Since the 1990s, tetracholoethylene, known colloquially as perchloroethylene, or 'perc' (and more widely used in the dry cleaning of clothing), became the standard. Although it is not as destructive as its predecessors, perc still has significant environmental and health dangers. A number of

alternatives have emerged since the early 2000s, ranging from the use of distilled water to proprietary solvents.[48] But it is generally accepted among archivists that none are as effective for film cleaning as the earlier, more dangerous chlorinated solvents. The inescapable rule of thumb is that the more dangerous to human health and the environment the chemical is, the better it is at cleaning film. This problem is cited by advocates of digital restoration (including technology vendors) as evidence for its preferability, given the ability to scan dirty film and then remove the appearance of artefacts in the digital domain (Fig 3.3).

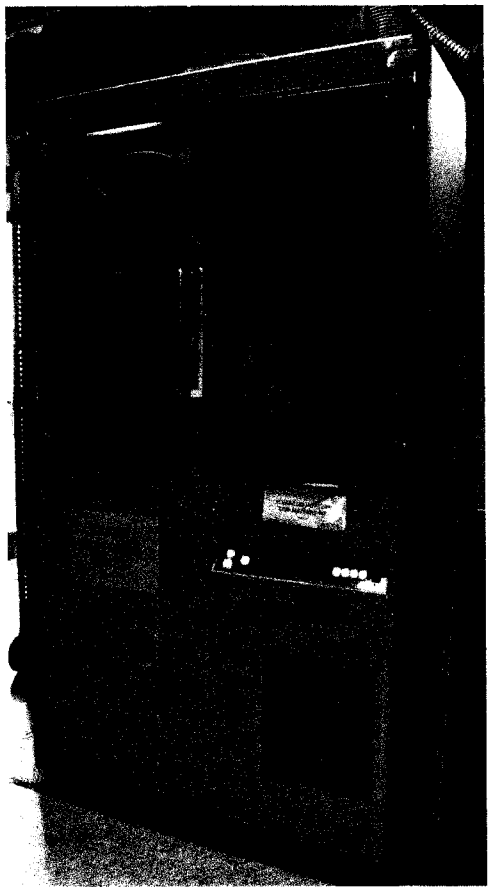

Figure 3.3 An ultrasonic film cleaning machine.

The other non-invasive technology widely used in film cleaning is the particle transfer roller (PTR). As with ultrasonic cleaning, it was not developed specifically for archival use. The PTR consists of a cylindrical roller coated with a mildly adhesive, polyurethane-based substance. A number of rollers are placed in a film path, usually between the feed reel and the point at which an image is read in a projector, printer, telecine or scanner. At least two are needed (one for each side of the film), although in some configurations, multiple sets of rollers are used. The surface of the roller is formulated to be adhesive enough to transfer contaminants from the film surface to that of the roller, but not sticky enough to impede the film's motion over the surface. After each pass of a given reel, the rollers are removed and cleaned, often using nothing more than tap water. The PTR was developed by Eastman Kodak and first sold in 1989. It achieved rapid success in the cinema exhibition sector, where is proved effective at keeping relatively new prints clean in repeated daily projection over an extended time period.[49] From an archival perspective, the PTR, like ultrasonic cleaning, has the ethical advantage of being non-invasive. It is also more environmentally friendly than any cleaning method that involves the use of chemical solvents, and requires no special health and safety precautions to protect the technicians operating them. However, the PTR's cleaning action is nowhere near as effective as that of chemical-based methods, and is generally regarded as a method or prevention rather than cure as far as dirty film is concerned (Fig 3.4).

Scratch reduction

The cleaning methods described above will only remove foreign objects and substances that are present on, and in some cases have adhered to, either or both of the surfaces of a film element. Once removed, the image information on the emulsion underneath is revealed and can be reproduced in photochemical reproduction or digital scanning. Cleaning cannot repair damage caused by abrasions, indentations or the complete loss of the film base or emulsion itself (referred to as scratching here for the sake of brevity); in other words, the complete loss of image information (damage to the emulsion side) or damage that introduces unwanted artefacts into the visible reproduction (damage to the base side). Several techniques exist to address this problem in the preparation of elements for copying and in the copying process itself.

Relatively light scratches in the emulsion side of a film can to a limited extent be 'healed' by a process known as rewashing. In essence, this

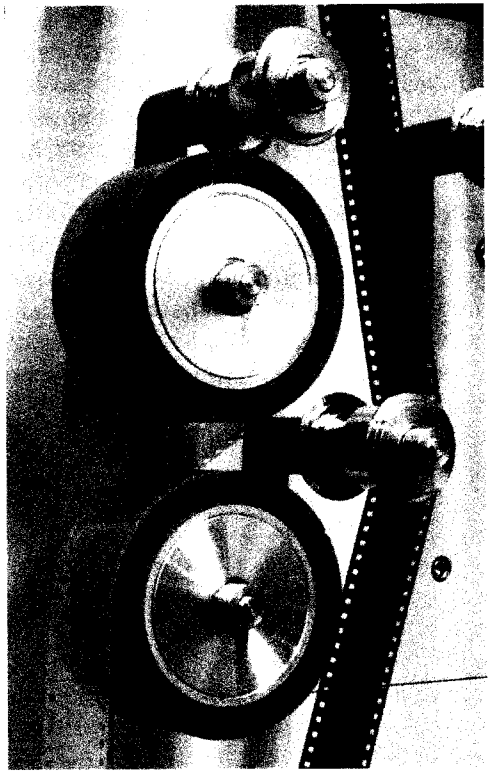

Figure 3.4 Particle transfer rollers (PTRs) in the film path of a contact printer. One roller passes in contact with the base side of the film, and the other with the emulsion. While PTRs are not considered as effective as solvent-based film cleaning, they are often used to augment it by being positioned immediately before the gate (imaging device) in printers, scanners and projectors to keep the surfaces of the film free from dirt and other contaminants.

consists of repeating the procedure that washes the residual chemistry out of the film emulsion after it is initially processed. The moisture content introduced into the emulsion causes it to swell slightly, reducing the gap left where emulsion has been scraped away by abrasion. Repeated rewashing may cause permanent changes to the dyes present in the emulsion, and so is not entirely risk-free. Eastman Kodak has developed a codified rewashing procedure, the RW-1 process, which is designed to minimise this risk.[50]

Relatively light scratches in the base side of nitrate and acetate film can be treated by polishing. In this procedure the film is passed

over a rotating glass wheel while immersed in a reservoir of acetone. The buffing action of the wheel removes a minute layer of the film base, such that a light scratch no longer forms a visually reproducible indentation.[51] The particles of film base removed by the polishing action are suspended in the acetone. While polishing can be an effective way of removing multiple, relatively shallow base scratches, environmental concerns around the use of acetone remain (like the chemicals used in ultrasonic cleaning, it is also an organic solvent). It is also unsuitable for use with polyester film base, which is so thin that the polishing process would cause deformation of the film itself, and can only be done once on nitrate and acetate elements for the same reason.

These are the only mainstream methods of scratch diminution that attempt to reduce or reverse the damage itself to the film's surface. The other techniques used to remove evidence of scratching from the restored image take a different approach, that of duplicating the film in a way that leaves the physical damage in place, but does not copy the visible evidence of it. These will be discussed below in the section on duplication. It is also important to note that scratch diminution treatments involving direct physical intervention can only be used if the element that is actually scratched is available to be worked on. A duplicate of a scratched element that has retained an image of the scratch from its source does not itself have any of the damage that these treatments are designed to mitigate (these will be visible as transparent artefacts when reproduced in a negative-positive process), and therefore will not be affected by them. The only way duplicated scratches can be addressed is in the digital domain, through software-based approaches after scanning.

Master element assembly

Like the technical selection process, this stage in the restoration can be insignificant, extensive or anywhere in between. The technical object of a restoration is either or both of two processes: to restore the order or sequence of shots and images that were known to exist once but do not in any extant element in the form that it is currently preserved, or to enhance the aesthetic characteristics of the image itself. If the main reason for doing a restoration project in the first place is the former (e.g. to reverse cuts made to a film as the result of censorship) and the source footage is in relatively good condition, then this stage can form the bulk of the work on the overall project.

In a photochemical workflow, master element assembly consists of physically joining sections of different film elements together, from which the restoration master element will be created by printing after assembly. As has been stated above, an important principle in film archival practice is to do nothing that is known to be or risks being irreversible if it can possibly be avoided.[52] Therefore (and to put it somewhat crudely), cannibalising different elements of a film to produce one 'good' one is a potentially controversial practice, not least because the act of physically cutting a piece of film, which may be necessary (or at least desirable, if the alternative is printing a section and thereby incurring another generation of analogue image loss) in the assembly of a restoration master, is itself an irreversible act. For this reason, the cutting of preservation master source elements is considered undesirable, and current archival best practice mandates that in most situations where cutting is necessary for the creation of sections, these should be duplicated first and the copy edited.

If a photochemical workflow is to be used throughout, it is necessary to ensure that all the footage components within the assembled master element are of common polarity, i.e. either a positive or a negative image. Three stages of duplication are typically used in the traditional, photochemical post-production process. When editing is complete and the camera negative has been 'conformed' (i.e. cut to match the editor's workprint), a fine grain positive is printed from it, often incorporating analogue special and optical effects into the process. From that interpositive, one or more duplicating negatives are printed, and it is from those that the high contrast positive release prints for projection and low contrast prints for broadcast and video mastering are typically printed.[53]

In some cases, restorations can draw on sections of footage from different generations. In order to integrate sections of, for example, an interpositive and dupe negative into a single reel of restoration master, it will be necessary to duplicate one or the other first in order to reverse its polarity to conform to that of the rest of the reel. Of course, doing so introduces yet another generation of image degradation into the footage involved, and therefore the decision as to whether or not to use it has to take this factor into account. Further duplication might be needed to avoid having to cut sections of original (or the closest surviving to original) element, with the duplicate then being cut to incorporate sections into the new master reel. Intermediate duplication stages are also necessary if footage from different gauges or formats is to be combined, for example, when newly rediscovered footage from *Metropolis* that existed only on 16 mm was cut into the 35 mm version that had already been preserved.

Generally accepted ethical best practice is for the restorer to take extensive notes and create a full record of all decisions taken during the master element assembly, in order to record all the information necessary for the individual source elements to be returned to the state in which they existed before the project began, should this prove necessary or desirable.[54] For example, if an assembled reel in otherwise good condition contains a few sections of triacetate base footage that are known to be in a relatively advanced stage of deacetylation, it makes sense to remove these sections from the assembled master element immediately after duplication and to store them separately, to prevent the offgases from the decomposing sections from damaging the other, good footage in the reel.

An alternative scenario might be if, following a restoration project, subsequent research established that decisions made as to the original order of the shots in a film were incorrect or are in some way other than definitive, original or in accordance with the aims of the restoration, thereby necessitating a new one. In order for the new project to take place, it is necessary to know precisely what was done on the earlier one, and why.

Arguably the most famous and widely discussed example of this issue can be found in *The Life of an American Fireman* (USA, 1903, dir. Edwin S. Porter). A version of unknown provenance was acquired by MoMA in New York in 1944, [55] which for several decades afterwards was hailed by academics as evidence that the film's director was a pioneer in the development of editing technique, and years ahead of his time in terms of the evolution of film language.[56] In particular, the use of cross-cutting to create parallel narratives was widely compared to another, better known Porter film from the same year, *The Great Train Robbery*, in this respect. As Charles Musser concludes, 'much film history was written' using this analysis,[57] until, in the mid-1960s, the discovery of another, very different version at the Library of Congress. This lacked most of the cross-cutting evident in the MoMA version, with the shots arranged in a linear sequence that was more typical of the embryonic form of narrative cinema widespread at the time. No definitive empirical evidence is known to survive as to how and why the final edit of either version was created, leading to a situation, as Musser puts it, in which 'leading film historians could not establish which version was the correct one.'[58] To this day, the conclusions reached by those historians as to what the sequence of shots was that Porter himself edited and in what form(s) the

film was widely distributed are essentially the result of informed (albeit scholarly and meticulously researched) speculation, for the simple reason that this is all that is available to base them on. It is to avoid a repeat of situations like this that the utmost importance is now placed on record keeping by film archivists carrying out restoration projects.

In a digital workflow, the assembly of a master element for printing, conforming for polarity and the intermediate duplication of elements of differing gauges and formats are all unnecessary. The discrete source elements that would need to be physically assembled for photochemical printing can be scanned individually, without any cutting or splicing needed, and the assembly of shots and sequences carried out as a software function afterwards. Likewise, the polarity of a scanned element can be reversed without loss of image information (calculating the subtractive or additive inverse of a given combination of luminance and chrominance characteristics can be achieved as a mathematical, lossless function), and scans from varying frame sizes upscaled or downscaled as required.

The duplication process – Photochemical

As was noted in the introduction, the restoration of films differs fundamentally from that of almost all other cultural artefacts, in that its end result, which the viewing public will experience, is a copy or reproduction of the source materials that are worked on. The duplication process itself, therefore, is of crucial technical and ethical importance in determining the characteristics of that result. It is also the primary focus of the 'analogue versus digital' debate, schism, transition or sea change in archival practice, because of all the constituent stages in the restoration process, this is the one that has the greatest effect on the aesthetic characteristics of the photographic image which the audience will eventually see.

In a wholly or primarily photochemical restoration project, the main duplication stage begins when technical selection, cleaning and scratch diminution treatments and master element assembly have been completed, and the assembled reels exist with the order of shots as they are to appear in the restored film. The duplication is carried out using a printer, which creates a copy of the assembled master element, in some circumstances changing its visual characteristics in the process.

A printer is a device that re-photographs the image on an existing, processed film element onto unexposed, new film stock. As with most other technology used in archival film restoration, no model of printer

in mass-production was designed from the ground up for this purpose. Most were designed for use in the post-production and release printing of newly made films, and subsequently modified by archivists for the specific requirements of restoration printing.[59] The optical and mechanical actions of a motion picture film printer both fall into two subcategories.

Optical action

In a *contact printer*, the source and destination film elements are placed into physical contact with each other and exposed to an artificial light source of a controlled power output, colour temperature and duration. This creates a higher quality duplicate than optical printing, as there are no glass elements to distort the image. But contact printing cannot be used to copy between different film formats, or if the source element is significantly shrunk (Fig 3.5).

In an *optical printer*, an image of the source element is projected through a lens onto the emulsion of the destination stock, without any physical contact between the two. The focal distance and aperture (and thus the depth of field) of the lens can be varied, just like it can on any other camera or projector, which enables duplication between formats (for example, enlarging from a 16 mm source to a 35 mm dupe) and the copying of shrunken film. The trade-off is a significant loss in contrast, definition and (if applicable) colour saturation in the duplicated image.

Mechanical action

In a *continuous motion printer*, both the source and destination film elements move continuously past the illuminated aperture through which the exposure is made. This enables faster duplication, but often at the expense of image stability, and in the case of a continuous contact printer, without the ability to mitigate even slight shrinkage. Continuous contact printing is used primarily for the creation of release prints, and many such printers are able to print both picture and optical sound negatives onto a combined print stock element in a single pass (see Fig 3.6).

In a *step printer*, the source and destination film elements move intermittently past the aperture, with each frame being duplicated as a discrete exposure. The printing process takes longer, but step printing enables the luminance output, the colour temperature of the light source (in some printers) and the duration of the exposure to be varied between shots, or even individual frames.

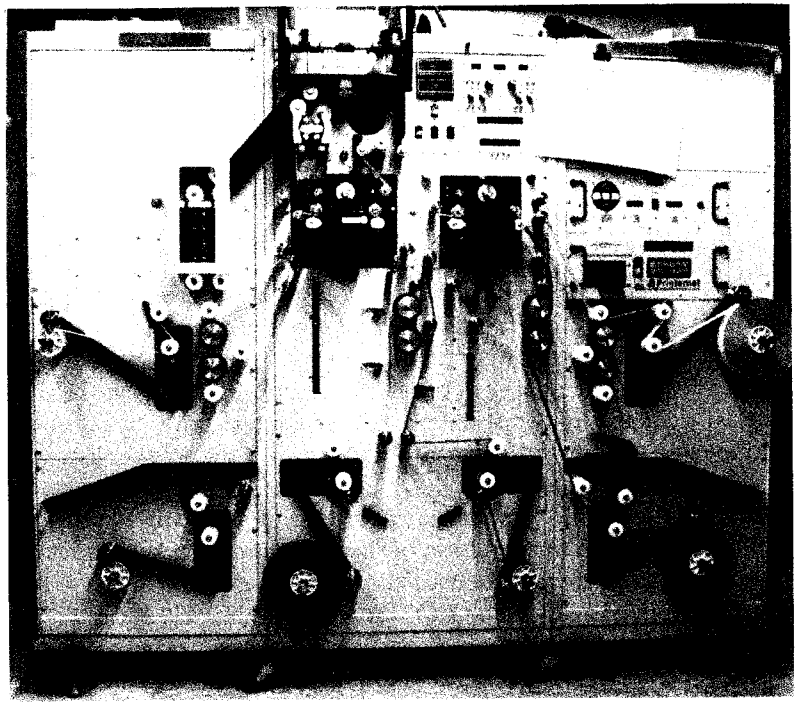

Figure 3.5 A BHP 7700 HD continuous motion contact printer, designed primarily for high-speed release printing. The source film carrying an optical soundtrack is threaded bottom right, and the picture negative bottom left. The raw stock onto which the image and sound will be printed is fed from the centre right spindle, threaded through both printing heads.

Printers can use different combinations of these two sets of actions. For example, continuous contact printers are generally used for the mass duplication of theatrical release prints, because the ability to print a large quantity of footage quickly is important, and no adjustment of the exposure characteristics will be necessary during the print run (this will have been done in the printing of the source internegative). An optical step printer would be used to duplicate a shrunken original camera negative to a restoration master interpositive, as the difference in frame dimensions between the source and destination stocks make contact printing impossible, and the ability to manipulate the exposure characteristics is essential when duplicating ungraded camera originals. Contact step printers are used when the ability to manipulate the exposure characteristics is needed, but the ability to copy between differing frame

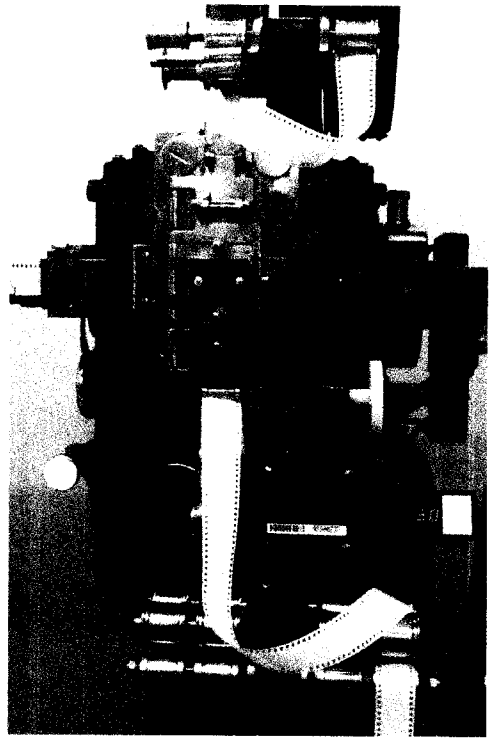

Figure 3.6 The Debrie Matipo contact step printer. It is the only printer ever produced that can duplicate seriously shrunk source elements without either optical printing or the risk of perforation damage, and is therefore a mainstay of film archives and commercial laboratories that specialise in restoration work worldwide.

dimensions is not. Continuous optical printers were used primarily to copy optical soundtracks between formats, a function that has now been almost entirely superseded by digital processes.

In film restoration, the printing process is almost never a 'straight' or non-interventional one. It can incorporate a number of techniques intended to change the aesthetic properties of the image on the destination film stock relative to those on the source. These are applied in order to reverse the perceived effects of physical damage or chemical decomposition to the source element which cannot be removed or mitigated by working directly on the film itself, e.g. by ultrasonic cleaning, rewashing or polishing. The principal forms of defect that can be mitigated or corrected in printing are as follows.

Shrinkage of the film base. As has been mentioned in passing above, nitrate and acetate film base will shrink over time, as the result of the gradual moisture loss that occurs when the stock is in long-term storage. The rate of shrinkage can be retarded almost to the point of being arrested in atmospherically controlled archival storage, but very few source elements used for restoration printing are likely to have been stored that way for even the majority of their shelf life prior to a restoration project taking place. This has been a known problem for over half a century,[60] and in the case of elements that are processed quickly in high temperature chemistry, shrinkage of up to half a per cent can occur even during initial processing.[61] This has two effects: the dimensions of each individual photographic image, or frame, can change, and the dimensions of, and distance between each perforation will also reduce. Given that the sprocket teeth in a film transport mechanism are of a fixed size and pitch, damage to the perforations in the source element and instability in the duplicated frames when they are reproduced as a motion picture will result if a source element that has shrunk beyond a certain point is copied using a printer that has not been modified to cope with a shrunken source. Restorers therefore use printers that are designed in such a way as to be easily modifiable to print shrunken source elements without causing perforation damage, and to minimise instability in the duplicate. These modifications consist essentially of minimising the number of sprocket teeth in the film path, replacing sprocketed film transport components with ones in which the size and pitch of the sprocket teeth are reduced to accommodate shrinkage, and the use of gate assemblies that flatten laterally deformed film base. The Debrie Matipo step contact printer, manufactured in France between 1922 and the late 1960s,[62] remains a highly sought after machine by archives and labs specialising in restoration work, over half a century after it went out of production. It has two functions that make it ideally suited to printing shrunken elements: the ability to remove its registration pins entirely, thereby preventing perforation damage, and a design of gate that flattens lateral deformation very effectively (Fig 3.7).[63]

Severe scratching. As has been covered above, base and emulsion scratching can be mitigated to a certain extent by remedial treatment of the source element before printing. These processes (ultrasonic cleaning, rewashing and polishing) can go so far but no further, beyond which an alternative approach has to be taken: that of duplicating the element in such a way that an image of the scratch is not present in the copy. The technique that is used to achieve this in photochemical duplication is known as wet gate printing. This involves exposing the image of the

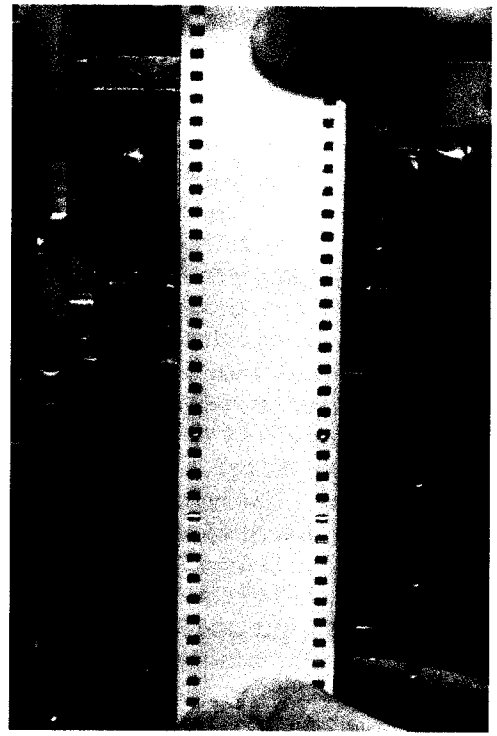

Figure 3.7 Detail of the Matipo's gate. The registration pins are of a specially reduced pitch in order to duplicate shrunken stock without damaging its perforations. As the pins are used purely for registration and not for film transport, they can be removed altogether if necessary, to duplicate severely shrunken source elements.

source element while it is immersed in a liquid that has an almost identical refractive index (the way in which it changes the light that passes through it) to the film base itself, thereby 'filling in' the scratch temporarily and making it invisible in the copy. The liquid used is usually perchlorethylene – the same as is used in ultrasonic cleaning. In contact printing this is achieved by immersing the entire printer head (the mechanism in which the source and destination film elements are held in contact) in a reservoir of liquid. In optical step printing, the wet gate consists of a liquid-filled glass container through which the source element passes, with the glass also helping to filter out the image of the scratches. The destination stock remains dry throughout the film path.[64] Although wet gates are used primarily in photochemical printing, they

were also used on a significant scale in pre-digital telecine technology, and are used on a limited scale as an alternative to software-based image cleaning in digital scanning.

Grading, sensitometry and densitometry. As part of a film's initial post-production process, the contrast, brightness and gamma characteristics are altered and manipulated during the duplication stages that take place between the exposure of the camera original and the striking of the release print or broadcast master. The most fundamental technique to achieve this is grading. If either the cinematographer has made minor errors in the exposure of the camera original, or if it has deliberately been exposed in a different way to that which is desired in the finished film (e.g. in the case of so-called 'day for night' shots, in which a scene is shot in daylight and then printed to look as if it takes place at night), the image characteristics of the duplicate can be changed by varying either the intensity of the light source used to make the exposure in a continuous printer, or the duration of each frame's exposure in a step printer (hence the alternative term 'timing', used more commonly in the USA, for this procedure). This presents two significant problems in film restoration. Firstly, whether or not these changes have been effected in the source element used for the restoration will depend on which generation of element is in use. A camera negative will not be graded, but a dupe negative used for making release prints will be. If sections from both are spliced into an assembled master reel, this has to be taken into account when grading the complete reel for printing. In some cases, evidence of grading decisions made during the original production process survives, and can used by the restorer to recreate the brightness, contrast and (if applicable) colour characteristics embodied in prints from the film's initial release. This evidence usually takes the form of punched paper tapes used to automate the adjustment of a printer's light source between shots, which were simply left in the cans of cut negative on completion of the production.[65] But in many projects no such evidence exists, and the restorer is essentially faced with repeating the grading process that took place during the film's original post-production, making similarly subjective value judgments along the way.

Objective methods of quality control are a fundamental and integral part of modern photochemical laboratory practice, and are used to ensure consistency in the technical characteristics of the duplicated and/or manipulated image. There are two main ways of doing this. Sensitometry takes place primarily in the manufacture of film stock, and involves the measurement of the time taken for the emulsion to

record the exposure from a light source of a given intensity, duration and colour temperature. It is important that this remains consistent between different batches of the same stock type. If it isn't, then a printer operator cannot rely on a given exposure achieving the same image characteristics with the same stock type every time. Each stock type has a published set of densitometric data, or 'curve', which is taken into account by restorers and laboratory technicians in determining printing exposures. Densitometry measures the opacity (how much light a given surface transmits) of processed film, and is done in order to ensure that the light source in a printer is working properly and that the action of the processing chemistry is calibrated accurately.

In the modern laboratory, sensitometric and densitometric quality control is fundamentally objective and carried out to a high level of accuracy. For restoration printing these techniques can be used to take account of different types of source element and printing methods – for example, as Brian Pritchard puts it, 'the density seen by an optical printer will be different from the density seen by a contact printer.'[66] But as with the survival or otherwise of grading data, this was not always the case. Although the principles of densitometry were understood by the late 19th century,[67] the first mass-produced densitometers were not sold until 'around 1920',[68] systematic quality control only became the norm in most motion picture laboratories after the conversion to sound necessitated it. This was due to the need to ensure the consistent density of optical soundtracks to much lower tolerance levels than had been the case with silent picture footage, because of fluctuations in the reproduced volume level that would result from even minute inconsistencies. Gradual developments in laboratory technology, especially in the high speed, mass-duplication of release prints, enabled a consistency of output by the turn of the 21st century that would have been science fiction a few decades earlier.[69] For example, a survey account of British film production practices in the early part of the 20th century reveals that objective quality control methods of any description were virtually non-existent, recalling that 'the [printer] operator watched the illumination of the gate of the printer as the negative passed through it and adjusted the light intensity according to his "snap judgment" of the density'.[70] This creates a real problem for the restorer, if he or she is dealing with a film, the original post-production of which involved rudimentary quality control at best. In cases where multiple release prints from the initial distribution of a film survive in archives, the visual characteristics of each shot often differ enormously between them. Which 'look', therefore, is authentic?

Colour dye fading. As has been noted in Chapter 1, the dyes used in a number of mainstream colour film emulsions produced between the late 1940s and early 1980s are notoriously prone to fading in long-term storage.[71] In a substantive, three-colour coupler emulsion such as Eastmancolor, three dye layers will be present on the film after processing. On a colour positive they will represent the three primary colours – red, green and blue – and on a negative, their subtractive opposites, yellow, cyan and magenta. Put very crudely, these dyes fade at different rates over time, such that an affected positive will typically have a visible reddish pink hue in projection, and lose density in the greens and blues. There are two ways in which the colour balance can be restored in photochemical restoration. The first is to expose three separate strips of black-and-white film with the primary colour record from the source element, by exposing it through filtered light in the printer, in an adaptation of the technique used in the original Technicolor process. Black-and-white emulsion is known to be chemically stable and not prone to fading, and therefore these records were previously considered a reliable way of safeguarding the integrity of the restored image. By taking densitometric measurements from each of the separations after processing, they can be graded such that when printed in multiple passes onto a single element of colour stock afterwards, something approximating the original colour balance can be restored.

The director Martin Scorsese was notably enthusiastic about the use of separation elements, and called for their routine creation during initial-post production as an insurance policy against fading.[72] But it was later discovered that differential shrinkage – an acknowledged problem even in Technicolor production in the early 20th century[73] – caused significant fringing artefacts when the image was recombined. For this reason, the fact that colour stocks produced since the early 1980s have proven a lot more resistant to dye fading and the fact that for restoration purposes, a digital workflow can now produce much better results at far lower cost, the printing of colour separations is now rarely done. If a photochemical approach is still desired, the most common technique is the use of so-called 'light valves' within the lamphouses of printers, in order to vary the colour temperature of the light source used in printing to compensate for the shift in the colour balance of the dye combination in the source element.[74] In 2011, a system was launched that enabled all three separation images to be recorded on a single strip of black-and-white film stock along with digital metadata encoded optically to enable their accurate recombination, though at the time of writing it has not achieved widespread sales.[75]

The duplication process – Digital

In a photochemical workflow, the fundamental technique of duplication is a one-time act of copying, during which the visual characteristics in the source element can be selectively preserved or manipulated in the duplicate to varying degrees of effect and accuracy, depending on the condition of the source element, the efficacy of the technology in use, the skill of the operator and the budget available. A digital workflow consists, in essence, of capturing a digital representation of the source image, manipulating it using software within a computer, and when these functions have been completed to the restorer's satisfaction, outputting the result onto whatever media formats are desired for access to the restored film.

The first stage in the process is the creation of the initial representation, which is done using a motion picture film scanner. This is a machine similar to an optical printer, except that the imaging device is not a reel of unexposed, new film stock, but instead an electronic imaging device. The most commonly used is the charge-coupled device (CCD),[76] which generates an electrical signal that varies in power according to its exposure to light. The CCDs used in film scanning are essentially the same technology that is used in consumer and professional digital cameras. The intensity of the signal output from the CCD can be measured and represented as digital data, from which the image is constructed. Some higher end scanners will contain three discrete CCDs, one for each of the primary colours, and thus record a digital equivalent of the colour separation elements described above. An alternative is to use two: one for the luminance (light and dark) and the other with a Bayer mask (a mosaic of colour filters placed between the CCD sensor and the light source) for chrominance (colour) information. An advantage to this approach is that black-and-white film can be scanned using the luminance sensor only, thus avoiding the need to remove colour 'noise' as a software function after scanning. Single, Bayer-masked CCD machines, are also produced.

A significant drawback to the use of early scanners was their speed of operation. In the late 1990s, machines that cost in the region of half a million dollars each to buy would typically scan at a rate of between one and four frames per second.[77] For a routine feature film restoration project, up to a month with a scanner running 24/7 could be required simply to scan the source elements. At the time of writing, models are available for a similar price that will scan up to 4K resolution in real time. The bottleneck in scanning speed is the computer processing

power needed to convert the electrical signals produced by the CCD into image data of the required format and then store it for future use, one that is being constantly alleviated by developments in computer technology more generally. The determining factor at work is what has become known in the information technology industry as Moore's Law, named after an article written by an American computer scientist in 1965, in which he predicted that the amount of computing power available for a given price would double, approximately every two years.[78] Moore's prediction has proven remarkably accurate over the decades that followed, hence its colloquial status as a law, and has clearly applied in the case of technology related to the digital scanning of photographic image and their subsequent manipulation by computer. At the time of writing, scanners are available that will process film at lower resolutions than are needed for restoration at speeds of up to 33 times real time,[79] and it is likely that the technology to create the scans needed for restoration at many multiples of real time will be available for mainstream use within a few years (Figs 3.8 and 3.9).

The modern motion picture film scanner has a vastly simplified film transport mechanism compared to that of its equivalent photochemical printer, and many will enable the scanning of film elements with physical defects that in most cases would require time-consuming repairs (e.g. the reconstruction of damaged perforations) and in some cases would make photochemical duplication impossible without noticeable defects in the copy (e.g. shrinkage beyond approximately 2 per cent). Some scanners that are designed specifically for archival use, e.g. those made by Kinetta and MWA-Nova, feature continuous motion and have no sprocket teeth in the film path whatsoever: the film is simply pulled through the mechanism by the take-up motor. Individual shots do not have to be scanned in the order that they are to appear in the finished restoration, as non-linear editing can be done on a software timeline after scanning and post-processing, just as it would be in an initial digital production workflow. Therefore, most physical film repair and master element assembly that is undertaken in preparation for photochemical duplication is simply unnecessary in a digital workflow. The source elements from which the restored film will be constructed can be scanned separately.

Film cleaning is a more complex issue. The removal of visible artefacts caused by dirt and scratching on the film surface can also be accomplished as a software function after scanning. However, as with wet gate printing, the quality of the result which can be achieved is variable, and depends on a range of factors including the type of damage, its

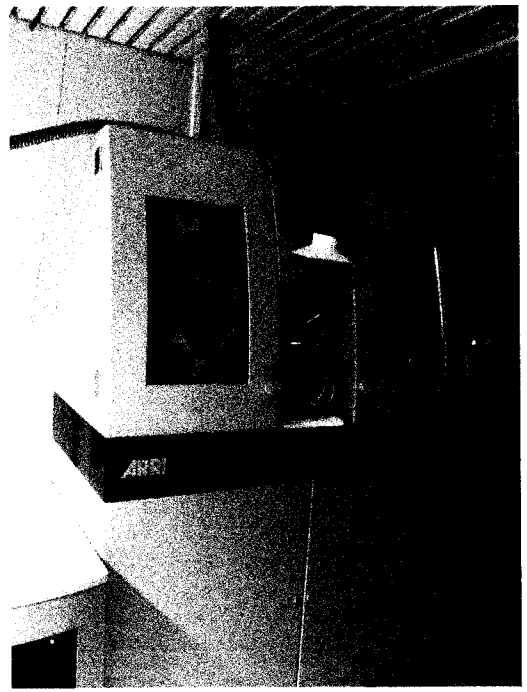

Figure 3.8 An Arriscan 4K film scanner with wet gate in use.

severity and how effective the software available to the restorer is at mitigating it. As is the widely established practice in audio restoration, the removal of artefacts before scanning is generally considered preferable to having to deal with them in the digital domain afterwards, on both pragmatic grounds (it's usually cheaper and achieves a better result) and ethical ones (keeping the amount of digital image manipulation needed to a minimum). Therefore, ultrasonic cleaning, rewashing and polishing are still often done as part of the preparation of source elements for scanning. The difference is that software-based cleaning of the scanned image is now usually able to achieve more, subjectively speaking, than optical and/or wet gate printing in photochemical duplication.

The variables within the scanning process itself are essentially twofold: the resolution and colour depth at which the frames (individual images) will be scanned, and whether any grading or colour correction will be undertaken during the actual scanning or as a software function afterwards. The decisions made will depend largely on the

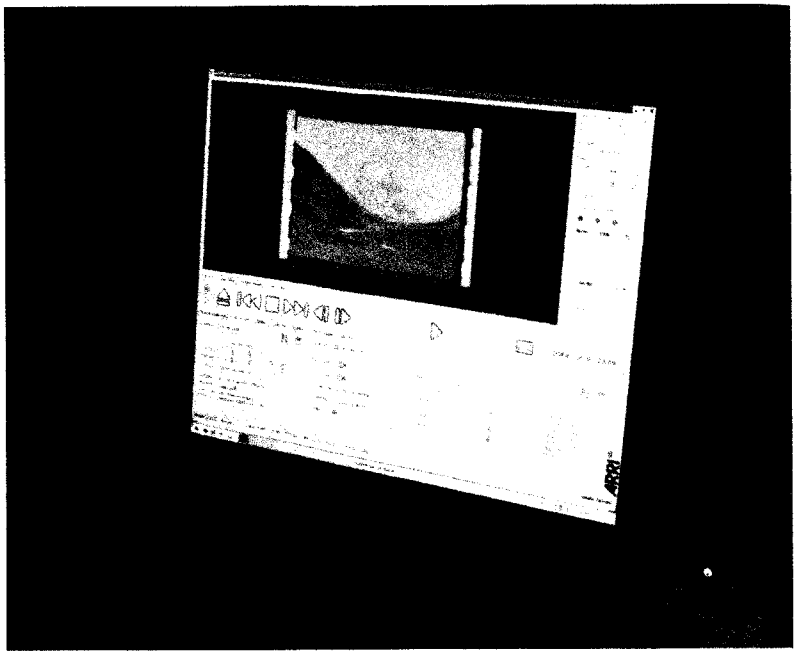

Figure 3.9 The graphical user interface of the Arriscan capture software, seen here during the scanning of a reel of source element from *The Epic of Everest* (UK, 1924, dir. J.B.L. Noel). The contrast, brightness, gamma and colour balance attributes can be manipulated before the capture of each frame, equivalent to the grading process in photochemical duplication.

relative capabilities of the scanner, the restoration software being used to work on the files it produces afterwards, and the speed of the hardware it is running on. The scanning resolution is a trade-off between the detail of image information captured (and thus the perceived quality of the end result) and the volume of data that will need to be stored, and the computing power needed to process it, and thus the overall cost of the project. At the time of writing, two resolution standards are widely used in mainstream digital cinema: '2K', with a width of 2,048 pixels, and '4K', with a width of 4,096.[80] As a general rule of thumb, 2K is generally considered sufficient for scanning film frame sizes up to 16 mm and for digital cinema projection on smaller screens, whereas 4K is regarded as the norm for 35 mm film and projection on larger screens. 6K and 8K resolution standards also exist, but at the time of writing their use is limited to scanning large format (e.g. 65/70 mm and special

venue film formats such as Imax) source elements. The equivalence of film emulsions when expressed as digital resolutions has provoked significant debate in archival circles, with some arguing that scanning at a higher resolution than the visible emulsion granularity is pointless (Read and Meyer, for example, state that 4K is the approximate equivalent to the maximum resolution of modern 35 mm colour negative film at the time their book was written[81]), while others believe that encoding multiple pixels per grain of visible emulsion enables more accurate software image manipulation. In the short term, it seems likely that Moore's Law will bring scanning at resolutions in excess of 4K within affordable reach within a generation or two of technology.

While incandescent filament bulbs are still used in some film scanners, more recent models are increasingly using an array of light-emitting diodes (LEDs), a light source that has two major advantages for archival applications: a LED generates almost no heat, making it relatively safe for use with nitrate stock, and an array can be adjusted to produce almost any colour temperature within the visible spectrum, thereby enabling dye-faded source elements to be scanned with inbuilt colour correction. In some models, software control of the scanner itself enables a reel of film to be graded, with the intensity and colour temperature of the light source changed between shots during the actual scanning pass, comparable to the use of punch tapes to make light adjustment in a printer. But if the sensitivity of the imaging device is sufficiently wide, a 'one light' scan followed by software grading can save time without sacrificing image quality.

The software stage in digital film restoration is conceptually the same thing as a digital intermediate (DI) post-production workflow in the making of new films. In the case of original production, it consists of scanning the rolls of processed negative as they were shot in the camera and without having been cut, editing the images using a timeline-type interface similar to the ones found in consumer and broadcast video editing packages such as Avid, Premiere or Final Cut Pro (FCP, which with some bespoke plugins can be used as the principal software package in a restoration project), grading the image and applying visual effects and incorporating CGI digitally, and then rendering the final output to whatever media formats are required for distribution. *Pleasantville* (USA, 1998, dir. Gary Ross) is often cited as the earliest Hollywood feature film in which DI technology was used to achieve a consistent aesthetic over the majority of the footage, and *Oh, Brother, Where Art Thou?* (USA, 2000, dir. Joel and Ethan Coen) as the first in which an entire film that did not involve the extensive use of special visual effects was post-produced

digitally.[82] Both were shot on film, scanned and then post-produced in 2K, and significantly, both were historical melodramas.

In the case of a restoration, exactly the same stages are undertaken, except that the film elements being scanned are those resulting from the technical selection to form the sources for the overall restoration project (and thus are not necessarily all reels of camera negative), and the visual effects applied are ones that are designed specifically to correct defects in the source element that were not and/or could not be corrected by cleaning or light corrections in the scan.

At the time of writing, most software used in digital film restoration is available on versions that will run on one or more of the operating systems used in consumer personal computers (PCs) – Microsoft Windows, Apple Mac OS or Linux. The processor and memory capacity found in the higher end PCs on sale in 2012 is sufficient for 4K image manipulation processes in a realistic timescale, although additional hard disc storage capacity, which dedicated facilities will often provide through server infrastructure of some description, is generally needed to cope with the volume of data files generated during a digital restoration project. For a 4K restoration of a full-length feature working on uncompressed images, this can easily amount to dozens of terabytes. A number of off-the-shelf digital restoration packages have established themselves in the marketplace during the 2000s, notably the Austrian HS-Art Diamant package, the British PFClean and the American DaVinci Revival system. In addition, some archives, laboratories and post-production companies have developed their own proprietary software for image and audio restoration functions (either in the form of standalone applications or plug-ins for other packages), which are used as part of a bespoke workflow for niche applications and thus are not sold or licensed to third parties. It is also worth noting that some video editing software sold in the consumer, semi-professional and broadcast markets includes image manipulation functions that could be considered to enable rudimentary digital film restoration. For example, the current versions of Avid, Lightworks, FCP and Adobe Premiere all enable manipulation of the colour balance in the captured or imported footage, such that colour correction from a dye-faded source is possible. Whether the use of such a package could be considered restoration, especially if the source being worked on is only standard definition, is really an ethical question as distinct from a technical one. But as with the effect of Moore's Law on scanning resolutions, it seems likely that many of the functions that at the time of writing can only be found in dedicated and relatively expensive restoration packages will eventually be offered as commonplace features in mainstream editing software, especially once the patents on the current generation of restoration algorithms begin to expire.[83]

A decision that the restorer will need to make at the scanning stage is the choice of file format in which the scanned frames will be saved and subsequently worked on. In conjunction with the resolution chosen (typically 2K or 4K at the time of writing), this is, once again, a trade-off between the image quality desired, the capabilities of the scanner in use, capabilities of the restoration software in use, the capabilities of the computer hardware in use and the budget available. The format most commonly used in professional restoration applications at the time of writing is Digital Picture Exchange (DPX), a specification that began life as the proprietary format for the Kodak Cineon system and was then later adopted and developed further by other scanner and software manufacturers. It has several features that were designed specifically with restoration in mind, notably the ability to encode the specific sensitometric characteristics of the film emulsion being scanned (gamma), and the incorporation of a 'lookup table' – calibration data that is used to ensure that the colour space in the scanned film looks consistent in all the display devices used in the workflow, including the monitors used in the restoration workstations, film prints that are burnt out at the end of the process, digital cinema, broadcast and consumer digital outputs. The DPX format also enables the creation and storage of information about the file (e.g. the name of the film, an archive's record number of the film reel it derives from and the name of the scanner operator), known as metadata, within the file itself, for project management purposes.[84]

Another decision that will need to be made by the restorer is whether to use automated software tools, manual ones or a combination of the two. It will have become apparent by now that film restoration is a labour-intensive business. The examination and technical selection of source elements, physical cleaning and repair and the creation of duplicates, either through photochemical printing and digital scanning, requires a lot of relatively highly skilled personnel to accomplish. The highest component of a typical film archive's operating cost is that of its workforce. Furthermore, the weight and bulk of motion picture film, the added safety-related costs of shipping nitrate and the risk of damage to irreplaceable film elements in transit all mitigate against specialised restoration work being undertaken away from the premises of a collecting institution.

The use of automated restoration tools is, therefore, an economically attractive one. These tools will look for similar defects in multiple frames

of scanned film frames and, as their name applies, apply a fix automatically when they find them. This approach has the advantage that the software can be left to get on with it, without human supervision. The drawback is that the sequence of rules, or algorithm, applied by the software to identify defects is not infallible. The difference between a black vertical line in the photographed image and a 'tramline' scratch, for example, can be detected with almost 100 per cent accuracy by the trained human eye. But programmers have yet to find a way of representing that intuition within the coding of an algorithm with anything close to the accuracy of human intuition. If that tramline is against the image of a clear blue sky, the viewer will identify it instantly. But if it is against the background of a city street at night, the viewer will have to look more carefully, comparing the image of the line with the photographic information on either side of it. Automated restoration tools do the same thing, but at the time of writing are significantly less accurate in determining what forms part of the photographic image and what is a defect. In other words, there is only so much care with which they can look. Automated restoration software works by comparing the suspect artefact being analysed with information about known types of defect and the photographic information surrounding it. One analogy would be with the spelling check function available in most wordprocessing software. A student whose essay on Nazi propaganda cinema I once marked made the memorable claim that filmmakers in the Third Reich 'had to have their projects vetoed by Gobbles in advance'. As the cognitive function of the software is limited to comparing the words typed with the ones saved in its dictionary – it can't analyse context – there was no way for the program to realise that 'vetoed' should have been 'vetted', and that the name of Hitler's propaganda minister had been misspelt. Both of the mistyped words were in the dictionary, and therefore their use was not identified as erroneous. And as any regular user of wordprocessing software will know, most proper nouns, the odd phrase in a foreign language and terminology specific to a body of professional knowledge (e.g. the names of obscure chemicals) will all be identified incorrectly as spelling errors.

Likewise, the so-called automated 'dustbusting' function in most digital restoration software in use at the time of writing will fail to spot defects in a sequence of frames with high speed motion and/or where the contrast between the defect and the legitimate photographic information surrounding it is very low, and generate a certain number of false positives. Possibly the most celebrated example of the latter in recent years occurred in the digital restoration of *Beyond the Rocks* (USA, 1922, dir. Sam Wood) by Giovanna Fossati in 2005. In one scene, a dog running out of a house and into the street outside was partially erased from the shot by Diamant's dustbusting filter, and required manual intervention to correct.[85] While the accuracy of automated restoration tools increases with every new generation of software and hardware and their use is an attractive from an economic standpoint (restoration projects are done more quickly and cheaply), the use of digital tools individually and interactively by the restorer generally achieves a higher quality of result, due to the combination this offers of human intuition in identifying what visible artefacts are defects and what are not, the ability to preview digital repairs and then reverse them if they are judged to be unsatisfactory and the ability to experiment with different types of correction. The drawback is that the restorer has to look at up to a quarter of a million scanned frames individually.

Software-based image restoration tools fall into seven broad functions.

Polarity correction is the simplest digital repair. If the source elements identified through technical selection contain a mix of negatives and positives, they must all be changed to a common polarity for editing, restoration and the final output. If a colour mask is used in the base of negative stock being scanned, this is also removed at this stage, as a 'one-click' software function.

Mitigation of dirt is the removal of artefacts that are caused by foreign objects adhering to either or both surfaces of the film as it is being scanned, which either could not be or were not removed by cleaning of the film element before the scanning took place. The definition of dirt includes dust, contaminants introduced during previous use of the film element (e.g. stains from projector oil) and biological contaminants such as mould. This is one of the easier and more accurate types of identification and repair for automated restoration software, as most dirt contamination takes the form of so-called 'one-frame defects', i.e. the precise pattern of contamination is not repeated identically through successive frames. Therefore, a one-frame defect can be identified to a high degree of accuracy by comparing the content of a frame to its proceeding and succeeding one, especially if they are during a continuous shot with little movement of the camera or subject.[86] The repair is accomplished by 'filling in' the artefact by, in crude terms, making a guess at what photographic information lies underneath the contaminant if it was not present, by analysing the photographic information that surrounds it.

Mitigation of scratching is the removal of artefacts that are caused by mechanical abrasion which has scraped or gouged away part of the film base and/or emulsion. The identification of these artefacts is more

difficult to encode as a software algorithm, because the damage is more likely to be consistent, and in the same place, in successive frames. Probably the most widely encountered type of scratch is the one caused by a sharp object making contact with the film surface while it is in motion (for example, an abrasive piece of debris lodged in the gate trap of a projector), which will result in a continuous vertical line, known as a 'tramline' in projectionists' slang, visible in the reproduced moving image over a significant duration of time. Identifying it digitally requires two functions: determining its presence in the first place, and then tracking what happens to it across multiple frames. The former is substantively the same process as with dirt, and the latter consists of 'tracking' the image of the scratch across successive scanned frames. Getting rid of it is once again achieved by filling in the affected area using the image information surrounding it.[87]

Adjustment for consistency of stability and illumination. It will be remembered from the section on photochemical duplication that nitrate and acetate film that has shrunk with age and/or storage in hostile atmospheric conditions can be copied, but that in the case of severely shrunken elements, the use of optical printing will be needed, with a consequent impact on image quality. Even on the most inherently tolerant and heavily modified printers, shrinkage will be visible in the duplicate to a certain extent, in the form of vertical and horizontal instability ('wobble' or 'jitter') in the reproduced moving image. Digital restoration enables this defect to be corrected to a far higher degree of accuracy, especially if the source element has been scanned on a sprocketless machine that is able to detect individual frame boundaries in determining the area to be scanned. Each frame can then be conformed to identical dimensions after scanning. Another consistency issue is that during the silent period when cameras and projectors were hand-cranked, the exposure of each frame was often inconsistent, as the duration of each exposure was determined by the speed of cranking. Inconsistency in projection speed also caused variable heat damage to the frames in release prints.[88] Light leakage in wooden cameras and laboratory processing equipment could cause fogging in part of the frame area, most of which can now be corrected digitally. These 'intensity instabilities' could not be addressed by photochemical printing, which only enables exposure adjustments over an entire frame.[89]

Brightness, contrast and colour correction. This is simply the process of doing as a software function what grading, the creation of separation negatives and/or printing through coloured light is designed to achieve in photochemical duplication: grading the image to recreate its 'original' (however that is defined) brightness, contrast and colour balance, and if necessary reversing the effects of colour dye fading. The digital tools used to do this are to all intents and purposes the same ones used by colourists in grading new films in post-production, in some cases customised to address the specific problems encountered in a restoration project, Eastmancolor-type dye fading being the main one. Indeed, the use of digital image manipulation software to correct dye fading in scanned still images from film has been available at least since the first version of Adobe Photoshop was marketed in 1990.[90]

Recreation of original post-production effects. The source elements scanned in a restoration may not incorporate dissolves, fades, process shots, opticals, titles or special effects in the form that they are seen in the finished film. If this is the case, then they will need to be recreated digitally (as they would need to be recreated photochemically, if an analogue workflow were used), in more or less the same way as they were during the film's initial post-production phase. If the amount of work required is significant, e.g. if a cut camera negative is being used as the principal source element, this is potentially another argument in favour of digital, as at the time of writing, the software tools available have reached the point at which their use will usually be cheaper and achieve better results than their photochemical predecessors. Where possible, reference will be made to evidence from the initial production (e.g. a surviving release print) to ensure authenticity.

Achieving consistency in the overall aesthetic. If a range of elements from multiple generations has been scanned following technical selection, perhaps encompassing everything from sections of camera negative to release print, the grain and definition characteristics will differ between them. In order to give the viewer the impression that they are seeing a unified film, and not an edited montage of sections from disparate sources, digital restoration software can apply image sharpening and grain reduction filters where necessary to achieve a consistency in the overall, subjectively perceived aesthetic. This can be an especially important issue where the object of a restoration is primarily reconstruction as distinct from image enhancement. Once again, arguably the most celebrated case from recent years is *Metropolis*, and in particular the recent rediscovery of missing (from the version as premiered in Berlin) footage in the form of a very poor quality 16 mm dupe (from a release print, and thus very high contrast) negative. The restorer in this case was faced with the decision as to whether or not to attempt digital enhancement of this footage in order to make it look consistent with the rest of the film. He eventually decided not to, both for pragmatic

and ethical reasons: pragmatic, because the damage (most of which had been photochemically reproduced from the source element and thus could not be mitigated by any physical intervention) was so severe, and the image information so thin, that even today's digital enhancement software could not achieve a satisfactory result; and ethical, because the provenance of the missing footage was considered to be a part of the film's history and thus should not be hidden from the viewer.[91] Even though that is an extreme example, a frequently raised objection to digital restoration is that the software tools used, and in particular film grain reduction, change the overall subjective aesthetic of the viewing experience from that of an analogue image to that of a digital one.

Audio restoration

The discussion thus far has only covered the image component of a film. Almost all films made since the late 1920s also include a synchronised audio recording, the restoration of which will usually form a major part of an overall project. As with the picture, what this involves will depend primarily on the source elements available and the goals of the project.

In the initial production process, the picture and audio will almost always be recorded and post-produced on physically separate media, with the two components being combined only on the final release prints.[92] There are some exceptions to this general rule, notably newsreel footage recorded using 'single system' equipment (in which both the image and an optical sound negative are exposed in the same camera and onto the same strip of film) and distribution systems in which separate media are played back in synchronisation in the theatre, e.g. Vitaphone and Imax. But as a general rule it holds, and consequently the image and audio components of a film are usually restored as separate operations. Partly as a result of this, the restoration of film soundtracks is a distinct area of expertise in itself, with archivists such as Robert Gitt and Bob Heiber developing specialisms in the area, and companies such as Chace Audio in Hollywood and Martin Sawyer Sound Services in London taking audio work on an outsourced basis from studios and archives undertaking the restoration of high profile titles.

The history of audio technology used in conjunction with moving image technology in the developed world falls roughly into three periods: before sound-on-film (before the late 1920s), analogue sound-on-film (the late 1920s to the early 1990s) and digital (since then). The sound-on-film period can be further subdivided into the periods in which original recording was mainly on optical (photographic)

soundtracks (the late 1920s to the early 1950s) and magnetic (the early 1950s until the early 1990s). This framework obviously refers to the periods in which these technologies were in mainstream use. For the purpose of this discussion it ignores the exceptions, most notably the use of experimental technologies ahead of their time and the use of obsolete ones for artistic or cultural reasons.

Sound films made before and during the mainstream conversion in the late 1920s, i.e. before sound-on-film, consist of mute picture footage and an analogue audio recording, usually on a phonograph (UK English – gramophone) disc or cylinder. With this type of recording reconstruction isn't an issue, because no editing of the sound recording in post-production was possible and therefore no incomplete audio elements were ever created. Its restoration, therefore, is purely a case of copying the audio content, enhancing the quality of the signal if necessary or desirable, and then re-recording it in a way that enables its reproduction in sync with the restored image. This involves playing the recording on a turntable or cylinder player designed specifically for archival use. The use of original equipment, even in as-new condition, is not considered desirable, because the stylus pitch and tracking force used would cause significant damage to the source element being played. For example, the Warner Brothers Vitaphone system used a softer shellac compound than was typically used to press records for sale to consumers, in order to reduce surface noise. The drawback was that the records quickly wore out: as a contemporary technical article put it, they 'were injured after just a few playings' on the system's original turntables and pickups.[93] Whereas at the time of a Vitaphone film's initial release, replacement discs were readily available from the distributor, the copy of a disc being used as the source element in a restoration project today will possibly be the only survivor, and therefore the use of lightweight pickups and less abrasive styli (diamond or sapphire, as distinct from the steel needles used in original equipment) to prevent damage is essential.

Although the reconstruction of a soundtrack from multiple disc elements will not be needed, the synchronisation of the re-recorded soundtrack to the restored picture can be a significant challenge. When sound-on-disc systems were in mainstream use, most (including the most widely used, Vitaphone) used some form of mechanical interlocking of the projector and turntable. If any footage in the film print was damaged in handling or projection, it had to be cut out and replaced with the precise same length of opaque spacing, or else synchronisation would be lost because the corresponding section cannot be cut from the

grooves of a phonograph disc. Likewise, if the surviving image footage of a sound-on-disc film is incomplete, the track either has to be edited after re-recording to conform to the image, or an equivalent section of black image inserted if it is desired to retain the audio.

Optical sound-on-film was the standard recording medium used in film production and post-production from the early 1930s until the early to mid-1950s, and for reproduction in theatres to the present day (and probably until film projection in theatres is completely obsolete and the conversion to digital complete). This technology works by converting the electrical signal produced by a microphone into a light source, which is then exposed onto raw film stock, thereby creating a permanent record. In reproduction, a light source is shone through the processed film and onto a photoelectric (i.e. converts light into an electrical signal) surface, the signal from which is then amplified and reproduced through loudspeakers. There are two methods of optical sound recording: variable area, which is produced by shining a light source of constant intensity through an aperture that adjusts in size according to the characteristics of the input signal as the unexposed film passes in front of it; and variable density, in which the aperture is of a fixed size, but the intensity of the light source is varied.[94]

The sound record, therefore, is a photographic image on film, just as the picture is. It can thus be degraded by exactly the same problems as the picture footage can: film base decomposition, shrinkage, scratching, dirt and dye fading. These artefacts will all be audible as defects in reproduction, and many can also be mitigated using the same physical repair and cleaning techniques as are used in the preparation of image elements for printing or scanning. In determining how much of the damage to repair physically before duplication and how much to repair by modifying the audio information during or after the copying process, the criteria a restorer will apply are the same ones as with the image: what is more effective, what is cheaper and what is more in line with the ethical goals of the project?

As was the case with Technicolor separation elements in the 1930s, differential shrinkage of the image and optical sound elements caused by laboratory processing was a known problem even in the initial post-production stage. As early as 1938, Bell and Howell marketed a sprocketless, continuous contact printer designed to magnify the image of a track negative very slightly, by wrapping both the source and destination stock around a convex aperture during exposure. [95] From a restoration perspective, this is the equivalent problem to that of missing footage in a sound-on-disc image element. If, for example, over several

decades in storage, a reel of original camera negative has shrunk from 1,000 feet to 990, but its corresponding final mix optical track negative has shrunk to 970, then any attempt to create a combined print from the two using conventional methods will result in the gradual loss of synchronisation during reproduction. Likewise, if the track negative is re-recorded at the standard speed of 1½ feet per second in continuous motion, the resulting copy will have a shorter overall running time than its corresponding picture footage reproduced intermittently at the equivalent speed of 24 frames per second, because the intermittent action of the reproducing mechanism will measure the film in units of the distance between each perforation, not absolute length.

The duplication of optical sound elements can be accomplished in one of three ways: photographic printing, the conversion of a digital image of the soundtrack into a digital audio signal as a software function and re-recording. Once the playback is complete, re-recording and the signal processing incorporated into that process involves doing more or less the same thing regardless of the source element, and therefore will be discussed in a separate section below. Photographic printing is the oldest method of duplicating optical soundtracks. In the absence of defects in the source element that cannot be removed physically, it is still considered the preferable technique in restoration under some circumstances, because the signal degradation resulting from analogue photochemical duplication is not as severe as that caused by 'reading' the signal electronically and then outputting it again to another analogue carrier. In other words, you are only adding one generation of audio 'noise' rather than two. There are, however, drawbacks. As photochemical duplication becomes more expensive and eventually the specialist film stocks for creating optical sound negative masters drop off the market, it is likely to become a more expensive option than digital re-recording, justifiable only for high-budget projects on ethical grounds. More significantly, the chances of defects in the source element that cannot be mitigated in photochemical duplication are high – as Martin Sawyer points out, almost all the possible audio problems in a source element can be identified and addressed in re-recording.[96]

What might be termed the digital photographic approach to reproducing optical film soundtracks for restoration is, at the time of writing, rapidly gaining acceptance within archival practice.[97] This consists of creating a digital, pictorial image of the optical soundtrack in scanning, and then using software to analyse it and turn it into a digital audio recording. In other words, the restoration software is not working on a digital representation of the audio created by analogue to digital

conversion of an electrical signal created by conventional reproduction of the soundtrack, but rather on a visual image of the optical track itself, thus potentially preventing the creation of unwanted artefacts in the conventional reproduction process. Arguably the leading implementation of this technique for restoration purposes is the Swedish GoldenEye scanner, advertising material for which points out another advantage, namely that it permits the capture of optical soundtracks at speeds much higher than real time, thereby potentially reducing the costs of restoration.[98] After scanning, software algorithms can be used to identify and correct defects in optical tracks applying very similar techniques to the ones used to restore photographic images digitally.[99]

Magnetic sound-on-film entered mainstream use in the early 1950s, largely because it was more flexible than optical. It involved coating raw film base with a magnetic oxide and recording on it using what was to all intents and purposes the same technology that is found in analogue tape recorders. Its crucial advantage over optical was that a magnetic track did not need to be processed and printed after recording, and thus was cheaper and could be played back instantly. Film elements could also be 'striped', or coated with magnetic oxide to record a combined track after the image had been exposed and processed.[100] Magnetic tracks also can and do suffer from the same base decomposition-related defects as optical ones, to which can be added mould growth, oxide shedding (loss of the coating that carries the magnetic signal from the film base) and damage to the recorded signal from electro-magnetic interference.

Sound-on-film, both optical and magnetic, won out over phonograph-based systems for a number of reasons, an important one of which was the ease of mixing and editing. Because the film stock used was of the same physical dimensions and ran at the same linear speed as the image footage, it could be edited in the same way, by cutting and joining sections of the audio track while being run on a playback machine in synchronisation with the image. Re-recording during the post-production process was also possible, with the result that the restorer will often have a choice of elements from which to duplicate. Typically, dialogue recorded on a studio set or location synchronously in the picture will be integrated into a final mix together with sound effects and music in post-production. Depending on what audio elements survive and in what condition, the restorer may have to recreate the film's final mix using the original components, in the same way that it will be necessary to recreate fades and dissolves if the image is being duplicated from the original camera negative. If only the final mix (e.g. a release

print) is being used as the restoration source, this will obviously not be an issue.

As with the restoration of the image, a decision needs to be taken as to whether the duplication of the audio signal will be to analogue or digital media. In this case and by the time of writing, however, it is usually a far less contentious one. An analogue workflow would typically involve re-recording the signal from the playback of the original element onto magnetic tape, and, as with the photochemical duplication of the image, doing so in such a way as to enhance its audible characteristics. The resulting tape would then serve as the new master soundtrack element from which the required media would be made for synchronisation with the image, e.g. a new optical sound negative or the audio channels on a broadcast master videotape. However, the use of analogue magnetic tape recording is now completely obsolete for professional audio applications, and no major company backed by significant capital manufactures it anymore. At the time of writing, small, cottage industry type operations attempt to restart production from time to time, but there is no longer any source that can be relied upon to sustain an ongoing operation. The use of digital audio recording in the music and radio industries dates from the early 1980s – about a decade earlier than the widespread use of digital moving images in broadcast television and film industry post-production. By the late 1990s, the three major remaining manufacturers of analogue audiotape for professional applications on any significant scale, Europe's EMTEC (spun off from the German chemical giant BASF in 1997), the American 3M and the Japanese Maxell companies, were scaling back their operations in the face of falling demand, and had pulled out of the market by the mid-2000s. In December 2005, the final remaining manufacturer, Quantegy, filed for bankruptcy protection.[101] Worldwide production has been small-scale and intermittent since then.

Except on a small scale, using remaining tape stock and principally for cultural or ethical reasons, therefore, audio remastering for film restoration is now almost exclusively digital. As with film scanning, the output of the playback and capture process will be a digital file that can both be edited and worked on to change the characteristics of the signal itself.

And again, as with the image, the restorer will have to decide if and how far to attempt to enhance the subjectively perceived quality of the audio signal during and/or after the capture playback. The factors informing this decision will be a combination of practical (the capabilities and limitations of the hardware and software available) and ethical

(what the objective of the restoration project is and, if applicable, the working definition of original in use). There are two essential technical factors – the amount of audio information being captured and processed, and the nature and extent of any signal enhancement and/or noise reduction applied.

In analogue sound processing, engineers use a concept known as the 'power-bandwidth product' to determine how much audio information is present in a given recording – specifically, what range within the audio frequency spectrum is captured and how strong the signal is within that range.[102] Similar techniques can be used on a digitised recording to establish how much of a signal is present. A very useful source in establishing the characteristics and specifications of obsolete sound systems used in film production can be found in the slew of technical manuals published in the early 1930s, often with a focus on training projectionists, which describe the technology used to make the recordings the restorer is now faced with remastering in significant detail.[103] The major variable which determines the subjective quality of a sound recording is its bandwidth (how much of the audible frequency range is in use), which for digital audio in turn determines the sampling rate. Audio bandwidth is measured in Hertz (Hz) and kilohertz (KHz). The human ear is typically capable of hearing bass sounds as low as 10 Hz, and high frequencies up to the region of 20 KHz. The early sound systems in use at the time of the conversion had a far more limited range: 50 Hz to 8 KHz in the case of Vitaphone, for example.[104] The frequency range available gradually improved in systems developed throughout the second half of the 20th century, to the point at which the final analogue optical sound system used for release prints on a significant scale, Dolby SR (Spectral Recording), had a frequency response of 20Hz to 20KHz.[105] Knowledge of the original recording system is therefore useful to a restorer in determining the frequency range, and thus the sampling rate, to work with.

A digital signal, unlike an analogue one, cannot in itself change over time: numbers are discrete units, not an infinitely modulating representation. In digital audio, therefore, a way is needed of encoding what to the human ear is a continuous experience as a sequence of numbers. This is done by sampling, which involves taking a snapshot of the sound being produced at any given moment in time, and recording its frequency. The number of samples in a given time period corresponds to the frequency range it is possible to encode. If the sampling rate is 8 KHz, this means that 8,000 individual recordings for each second of running time are recorded. The higher the sampling rate, the higher

the quality of the encoded sound, but the more computer power and data storage capacity is needed. A lower sampling rate reduces the audio quality, but also saves on processing power and storage space. By the time of writing, Moore's Law had advanced computing capacity, even on the consumer market, to the point at which it imposes no effective limit on the sampling rate available, and therefore the restorer can base his or her workflow strategy purely on the needs of the recording being worked on.

Noise reduction is the other major technique in audio restoration, analogous to dirt and scratch removal in the duplication of the image. All analogue recording and reproduction techniques add 'noise' to a signal – in other words, unwanted audio information such as phonograph surface noise or magnetic tape hiss, which is perceived by the listener to be a distraction. Various methods exist of minimising both the creation of noise in the first place and its duplication when a sound recording is copied. At any given point in the audio frequency spectrum, a recording will consist partly of the signal (the part you want to hear, e.g. speech or music) and noise (the part you don't, e.g. surface noise or tape hiss). The comparative loudness of the two is known as the signal-to-noise (S/N) ratio. This will vary between recording systems and the area of the audible spectrum – it is not uniform across the entire frequency range that is capable of being reproduced by the system. As a general rule, the higher the frequency, the worse the S/N ratio gets. The most basic form of noise reduction involves reducing the volume level of those areas of the audible range that have a low S/N ratio, and boosting the level of those where the system's performance is better.

The problem with this is that by reducing the loudness at any given point in the frequency range, you are reducing the level of the signal along with that of the noise. Overly aggressive noise reduction, therefore, will degrade the quality of the overall signal. This is a major ethical issue for restorers. Market research has shown consistently that many consumers who are not experts on audio technology regard the presence of noise as a major defect, and are far more tolerant of a poor quality signal than they are of the presence of noise. The Vitaphone expert Robert Gitt commented that 'I've heard some commercial releases of on CD of old jazz recordings which have been excessively altered. The noise is all gone, but the musicians sound very mechanical and dry and robotic. They sound like mechanical men playing.'[106] It is possible to avoid the 'mechanical and dry and robotic' impression by using less noise reduction, an option that more technologically literate listeners tend to prefer, and furthermore a closer listening experience to the one

that audiences to an initial release of a Vitaphone film in the late 1920s using the system's original playback equipment and auditoria would have had. But within the overall customer base for a DVD (for example), these technologically literate consumers tend to be in the minority, and therefore restorers frequently find themselves under commercial pressure to apply more noise reduction than they would like. This dilemma also highlights the importance of using good quality source elements and playback equipment for the initial capture, as it has long been understood among audio restorers that audio noise and artefacts can be removed far more effectively by minimising their creation in the first place than through digital cleanup in post-production.

As with image restoration, dedicated digital audio restoration software is available on the open market, e.g. Sonic Solutions NoNoise and the software produced by CEDAR (Computer Enhanced Digital Audio Restoration) Audio, the system developed by the British scientist Saeed Vaseghi in the late 1980s and later developed by the British Library. As with image restoration software, audio restoration software offers both manual and automated tools. The latter are more effective at detecting randomly occurring defects in a recording, for example the audible 'pop' caused as a splice in an optical sound element is reproduced, than at noise reduction. Again, the same health warnings apply as with images, namely the detection of false positives and the risk of 'missing' noise artefacts.

The final issue that restorers have to address in the case of audio is that of multi-channel soundtracks. From the early 1950s, the final mix in many feature films started to consist of more than one individual soundtrack (channel). Experiments going back to the 1930s, notably by the British audio engineer Alan Blumlein, established that by making two audio recordings simultaneously with microphones positioned in different places in the space being recorded, and then playing them back in synchronisation with the loudspeakers positioned to the left and right of the listener, it was possible to create a spatial impression for the listener. Put simply, if a speaker was positioned toward the left of a room when being recorded, they would also seem to be speaking in the left of the room when the two-channel recording was played back with appropriately positioned loudspeakers. By the mid-1950s the film industry had taken up this technology, with many of the widescreen systems launched during this decade also incorporating multi-channel sound systems to enhance the viewing experience of the new screen dimensions. Although it was only used on a very limited scale until the 1980s, when cheap and reliable methods became available for multi-channel

playback in the theatre (principally the Dolby stereo variable area release print), playback systems consisting of five or seven main channels are now commonplace in theatres, and increasingly so in consumer audio hardware in the home.[107]

This creates two issues for restorers. The first is the technical challenge inherent in recovering multi-channel soundtracks from elements created using now-obsolete systems and processing and/or re-mixing them in such to enable their reproduction on today's equipment in a way that approximates the listening experience of the film's initial release using authentic equipment.[108] The second is, as with film grain and audio noise reduction, the ethical dimension. Multi-channel sound is now so commonplace in the theatre and home that mainstream audiences have come to expect it, and in response to this commercial pressure digital processing systems have been used to re-mix dialogue, music and effects masters in order to create a new, multi-channel final mix. As Ricci notes, this practice is especially widespread in the case of commercial restorations and re-releases.[109]

It is interesting to note that this practice has not attracted the widespread criticism that some other ethically contentious practices have, most notably the 'colourisation' of originally black-and-white films, which has become almost wholly discredited among the critical establishment and which was never really accepted by mainstream audiences. The ethical dimension of this debate will be deferred to Chapter 5; in the meantime, it will suffice to note that the restorer of a feature film destined for some sort of mainstream release (especially consumer media) may have to decide whether or not a multi-channel soundtrack should be created for a film that was only released with a mono final mix in the initial distribution; or, if it was released with a multi-channel track, only to roadshow screenings that reached a very limited audience.

The final output

The end result of this entire process – technical selection, master element assembly (if photochemical), cleaning, printing (if photochemical), scanning and software post-production (if digital), and audio restoration – will be a new master film element or digital asset, one that is intended to serve two purposes. The first is to maintain its integrity in long-term storage. For this purpose, an analogue final output is considered preferable, as almost half a century of research has now established with as much certainty as will ever be possible that, stored in appropriate atmospheric conditions (i.e. cool and dry), a new polyester base

film element has a useful lifetime measured in centuries. In the case of an analogue restoration workflow for the image, the final result will be either a new negative or fine-grain positive element, depending on the polarity of the assembled source element being printed. A 'film out' can also be created from a digital restoration. This is created using a film recorder, a device which exposes the digital image of each restored frame onto new negative film stock, which is then processed in the normal way and serves as the preservation master for the restoration project. An optical sound master can also be created in the same way if desired. Although some early film recorders used a cathode ray tube as the imaging device, laser film recorders, which expose the precisely desired colour temperature pixel by pixel, are now more common, and are produced and supported by a number of major manufacturers for both 2K and 4K mastering. Eastman Kodak also markets a number of film stocks that are formulated specifically for laser film recording (Fig 3.10).[110]

In the case of a digital restoration, it is likely that an attempt will be made to preserve the digital assets created during the project for

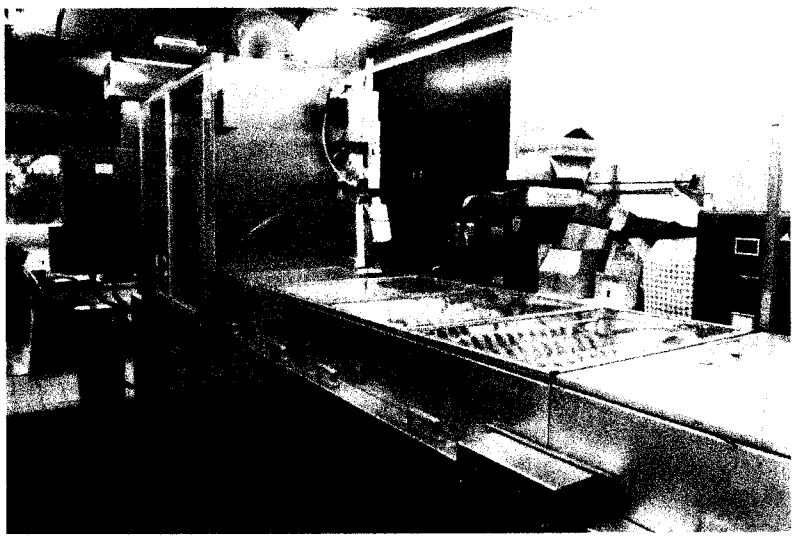

Figure 3.10 An automated film processing machine. A reel of processed black-and-white print has just emerged from the lightproof fixing bath (right) into the final washing bath (with transparent lids). From there it will proceed to the drying chamber at the far end.

the long term. These assets will include the raw scans (i.e. the digital image created by the scanner before any image restoration took place) and the post-restoration frames. While a number of technologies exist for doing this, notably a hard disc server array such as a RAID and the LTO high capacity magnetic data tape, the bottom line is that at the time of writing, there is no widely accepted 'store and ignore' technology in existence for archiving digital data. The options currently on the market all either take an 'always on' approach (i.e. online storage such as a server), and thus have high running and maintenance costs, or have a reliable storage lifespan limited to a few years, after which the data has to be copied to a newer offline storage medium in order to ensure its survival. Both chemical decomposition and format obsolescence are contributory factors to the current state of the art, whereby long-term storage of moving images on film is cheaper and more reliable than their digital equivalents. The volume of data involved in digital audio is so much smaller than with film-equivalent digital images that digital audio master files are typically regarded as preservation masters, though even then a new final mix optical sound negative of the restoration will often be made as a safeguard.

The second function of the final output is to serve as the source element from which all subsequent access copies are made. As will be seen in the next chapter, the needs are diverse – potentially, everything from Imax to YouTube! If the image restoration was photochemical, the final negative or fine grain positive will itself be scanned, and the resulting digital version will be used as the source from which to transcode the versions required for distribution. If the image restoration was digital this step will not be needed, as the final output will itself be in digital form. Software available today enables downconversion (reducing the resolution or other quality characteristics in the act of copying a digital file), and therefore it makes sense to plan a digital restoration project such that the final output file will be of the highest quality needed for access, or higher. Upconversion is also possible, but this cannot add quality, only compatibility. A 2K master upconverted to a 4K copy will not appear subjectively to the viewer to be of comparable quality to a film that was scanned in 4K to start with.

The behind-the-scenes work of the restorers is now complete.

4

The Presentation of Film Restoration

Introduction

As Henri Langlois would have been the first to argue, there is no point in restoring a film if you're not going to show it. Indeed, as has been discussed in the previous chapter, many if not most restoration projects are initiated, at least in part, by the prospect of a high profile access output at the end of the process. That is one of the principal distinctions between film preservation and film restoration. Preservation is essentially a passive process. In the case of an archive institution that uses a passive conservation model, this can consist of little more than the rudimentary technical examination of a film element (to determine if there is any imminent risk of content loss, primarily through decomposition), and then putting it in a vault with the temperature and humidity optimised for the long-term storage of that particular film base and emulsion combination. It is not necessarily anticipated that there will be any immediate demand for access to that content. In fact, many of the world's larger film archives have a waiting list of many years between the initial accession of an element, intended purely to safeguard its preservation, and carrying out the further, more resource-intensive work that is needed before its content can be considered fully accessible. This work includes extended technical preservation and/or restoration, the creation of copies needed for access, the research needed to obtain the necessary copyright permissions for full access and the curatorial work needed to interpret the significance of a preserved film to the archive's audience, especially in the case of relatively obscure material that mainstream viewers are unlikely to have heard of.

Restoration, in contrast, either represents the latter stage of that two-stage process (initial acquisition followed by full-scale work), or its

conflation following a discovery of major topicality or cultural significance. Most film restoration projects are undertaken either by non-profit institutions anxious to justify their existence to the taxpayers who fund them, or by commercial entities anxious to monetise their intellectual property assets. As was noted in the previous chapter, a restoration project is usually initiated in one of three ways: 'back from the dead' rediscoveries of lost or incomplete films, film search initiatives and the decision to restore material that is already held in archival preservation. Reasons for the latter can vary – they can be curator-led, prompted by access requests (e.g. a broadcaster wants footage for use in a documentary and is willing to pay whatever it takes to get the work done now), prompted by technical factors (e.g. routine periodic vault checking reveals that nitrate decomposition has advanced) or simply because a film reaches the front of the queue for attention by an archive's technical staff. But the fact is that as a general rule, films are not restored and then put straight back on a shelf without some sort of initiative to bring them to the attention of a significant audience.

Who sees a restored film, in what cultural context and in what media forms and technical circumstances will vary enormously from project to project. Some will only ever be shown in a small circuit of festivals attended mainly by film archivists and historians. Others will have a theatrical release, be distributed on consumer media (DVD, BD and Internet streamed), and/or broadcast. At this point, it is worth making one general observation. This is that the market and potential audience for what might loosely be termed 'old' films has grown exponentially from the mid-1950s to the present day. Until the emergence of television, there was no possibility of any commercial exploitation on any significant scale for films after their initial theatrical release had been completed. This, David Pierce argues, is a major reason why so many films were lost in the first place: before there were any non-profit archives to look after them (which also emerged on a significant scale from the 1950s onwards), their custodians were for-profit businesses faced with the ongoing cost of storing large quantities of a highly hazardous substance, and no prospect of earning any significant revenue from them.[1] The 1930s and 1940s saw the beginning of the film society movement, what would now be termed 'arthouse' theatres (i.e. ones which programme content outside the commercial mainstream) and the development of non-theatrical exhibition, which began to include the screening of older titles, often from private collections – what a writer in a magazine associated with Britain's 'highbrow' or 'intellectual' film culture in 1946 called 'specialised audiences outside the cinema'.[2]

But the scale of this activity was tiny compared to the market for archival films that was created by television. By the mid-1950s, the newly emerging broadcasters (many of which had institutional links to the Hollywood film studios) were raiding what remained of the studios' back catalogues to fill the hours outside prime time. Two decades later, consumer video emerged as the 'unexpected saviour' for many collections, as the author of a book on lost films somewhat dramatically put it,[3] while cable channels dedicated to archival content emerged in the following decade. This process was accompanied both by what Barbara Klinger terms 'remembrance of films past' – in other words, increasing cultural knowledge of cinema history and a desire to engage with it on the part of the public[4] – and the broader cultural impact of two decades of formal media education in universities, which began in the late 1960s. The technical quality of consumer media took a quantum leap with the launch of the Digital Versatile Disc (DVD) in 1997, and the development of the Internet and the personal computing devices connected to it to the point at which it is now commercially viable to stream digitised film content online with a technical quality comparable to that of offline consumer media has created yet another market for archival content.

Today's restored films, therefore, have a wide range of avenues through which to reach the viewing public.

Theatrical projection – Film

Cinema release prints can be and routinely are made as one of the final outputs from a restoration project, usually continuous contact printed from a graded internegative. In the case of a photochemical restoration, that print will either be continuous contact printed directly from the assembled restoration master element, or, if necessary, duplicated through a subsequent generation first. In the case of a digital restoration, the print will usually be made photochemically from a laser-recorded dupe negative. At the time of writing, laser film recorders run too slowly for the direct film-out of release prints to be economically viable in most circumstances. Unless the film is silent, an optical soundtrack will also be needed, the source negative for which will either be produced by a conventional variable area sound camera (variable density sound is not generally used for re-recording or release printing in restoration work, because of the inherently limited frequency range of the process, the higher densitometric quality control requirements and compatibility issues with the reproduction equipment typically found in a modern theatre) or, once again, a laser film recorder.

The major technical challenge in screening restorations on film is that very few theatres are equipped to screen so-called 'legacy' picture and sound formats in accordance with their original specifications. In fact, by the time of writing, a rapidly diminishing number of theatres are equipped to screen film at all, with the conversion to digital projection estimated at 45 per cent of theatres in Europe by the third quarter of 2011,[5] and, as has been noted in Chapter 1, two of the major Hollywood studios having announced plans to discontinue distribution on film altogether by the end of 2013. The vast majority of theatres that still can show film will only be equipped to screen the image and sound formats in current mainstream use, both in terms of the hardware and specialist expertise available.

The aspect ratio (the proportion of width to height in the projected image) created by a full-width image and a 'pulldown' of four perforations on 35 mm film is approximately a third wider than it is tall. This is typically referred to as 'full frame', 'the Academy Ratio', 1:33:1, 1:37:1 and 4:3. These terms have technically precise meanings (please refer to the relevant entries in the technical glossary at the back of this book for the full distinctions), but they all describe what is essentially the screen shape that most readers born before around 1990 will be very familiar with from the television sets and computer monitors that were ubiquitous until the 16:9 widescreen shape of display superseded it in Europe and North America over about a five-year period from the late 1990s. This was also the standard for theatrical feature film projection until a similar process of conversion to a variety of wider formats took place over about a five year-period from the early 1950s.[6] Some of these formats used anamorphic technologies, while others were created using conventional, spherical lenses and reducing the height of the frame and leaving a larger proportion of the film's surface area unused. Three components in the theatre are needed to project a given aspect ratio correctly. A lens of the appropriate focal length is required, that length being determined by the dimensions of the frame being projected, the surface area of the screen and the distance ('throw') from the projector to the screen. An aperture plate is used in the projector, positioned between the light source and the gate through which the film passes, to mask the area of the film surface that is not to be projected. Finally, a masking system is fitted in front of the screen itself, consisting of curtains made from an opaque and non-reflective fabric, which are usually operated by electric motor. The area of the screen surface that is not required to display a given ratio is covered by the masking curtains when that ratio is in use.

Two aspect ratios are commonly used in modern theatres: spherical 1.85:1 and anamorphic 2:35:1. A typical, first run neighbourhood

theatre will only have the lenses and aperture plates needed to show these ratios, and in the case of purpose-built mainstream theatre auditoria from the 1960s onwards (i.e. most multiplexes), the architectural design of the screening room will also be optimised for widescreen. The problem for theatres screening restoration prints (or any other archival film print, for that matter) is that lenses are relatively expensive items (as are aperture plates, given the amount of skilled labour required to cut them), and therefore only those theatres that screen archival and repertory titles regularly are likely to be equipped with the lenses and plates needed to do so without cropping the image, and with masking systems that are fully configurable for the entire range of aspect ratios likely to be encountered when screening archival films. A repertory theatre screening a typical range of restored films from the origins of cinema to the 1980s could require up to ten sets of lenses and plates per projector, due primarily to the proliferation of ratios that were in use during a brief widescreen format war in the 1950s and 1960s.[7] On the rare occasions that newly released mainstream films are produced in the Academy Ratio (or electronic equivalent) or a well-known classic is re-released in mainstream theatres, distributors will sometimes produce so-called 'windowboxed' 35 mm prints, in which the 4:3 shape image is maintained within a 1.85:1 film frame, by placing an opaque vertical matte on either side. Recent examples of titles distributed in this way include *The Blair Witch Project* (USA, 1999, dir. Daniel Myrick and Antonio Sánchez) and films made by the Danish 'Dogma 95' movement, the rules of which mandate the use of the Academy Ratio on artistic grounds. This enables the correct ratio to be screened using a 1.85:1 lens and plate without cropping, but at the expense of image quality, because only a small proportion of the overall 35 mm frame is being used. For this reason and because of the costs of making an extra optically printed (or laser-recorded) internegative, windowboxed 35 mm prints are not considered a desirable method for screening most archivally restored films.

During the silent period there was no universally accepted standard projection speed (frame rate). A substantive body of research and scholarship exists on the shooting and projection practices in use in the world's film industries during cinema's first three decades,[8] which has established that a theatre wishing to screen the restoration of any silent feature at the projection speed intended by the filmmakers and/or that a typical audience would have seen in the initial release (the two were not always the same) needs to have projectors capable of any speed from approximately 10 to 30 frames per second. Modifying the 35 mm

projectors that were sold on a large scale for first-run and multiplex use since the 1960s, which will usually be shipped from the factory capable of running at the standard sound speed of 24fps only, to add this facility is once again a procedure that requires expensive parts and skilled labour, necessitating the replacement of the projector's power supply, motor and shutter components in most cases.

Other areas of a projection booth's equipment that could require modification are the optical sound reproducers (which, if optimised for modern cyan dye soundtracks, will be unsuitable for use with the older silver redeveloped type that are still produced by many archives' photochemical printing operations) and the addition and maintenance of projection equipment for gauges other than 35 mm, of which 16 mm and 70 mm are most likely to be encountered (Fig 4.1).[9]

The final hurdle that repertory theatres screening restored films on film will have to overcome is that archival institutions undertaking

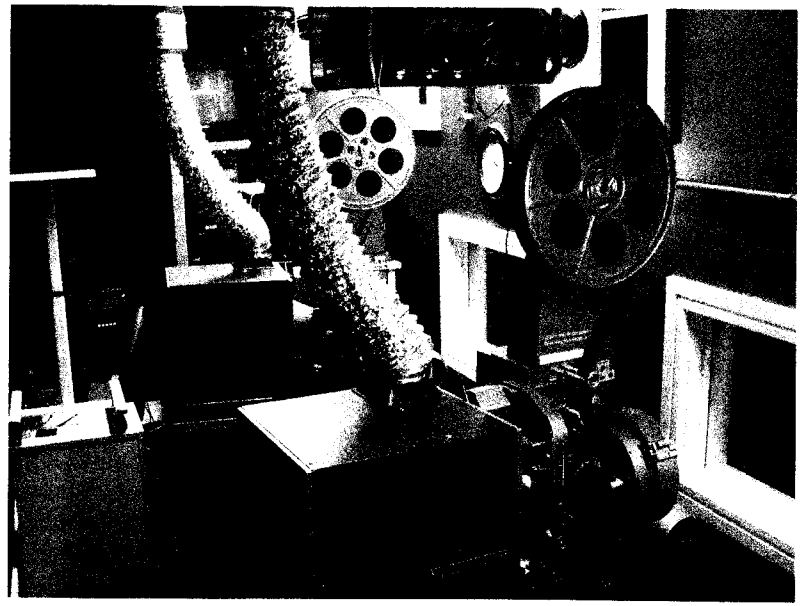

Figure 4.1 A projection booth equipped for dual projector operation, to enable the projection of a complete feature film without having to cut and splice any footage. This facility is often insisted on by archives as a precondition for screening their prints, and is only usually found in well-equipped repertory theatres and cinematheques. A digital e-cinema projector can be seen at the top in the foreground.

restorations will often demand far higher technical standards of print handling, preparation, equipment provision and equipment maintenance than can typically be achieved in a mainstream venue. Most archives require that screening venues comply with an extensive list of technical requirements, and some even go as far as to carry out inspections of venues before allowing them to screen material from their collections.[10] One widely imposed condition is that the use of automated projection systems and labour-saving devices found in most multiplexes, notably the non-rewind or 'platter' film transport device, is prohibited by many archives in the belief their use inevitably inflicts damage on film prints that are projected using them. In the professional opinion of this author (who earned his living as a projectionist in repertory theatres for over a decade, and also holds a postgraduate degree in film archiving) this is an oversimplification of a complex problem. Film transport systems, including, but not limited to, the non-rewind platter, will damage film if they are not operated and maintained as their designers intended. The safety or otherwise of an archival film print in the care of a theatre is determined principally by the skill and experience of the projectionist handling it: the choice of booth equipment is a secondary issue.

Looking to the medium-term future, the skills base of projectionists and maintenance technicians is likely to become a significant problem. There are now hardly any projectionists left in the workforce with professional experience of using most of the obsolete film gauges, aspect ratios and audio formats involved in contemporary film restorations when they were still in mainstream commercial use. Most projectionists working in the repertory theatres that screen archival restoration titles at the time of writing, therefore, will have started their careers and received their basic training in mainstream houses, and then have developed their skills and knowledge in film handling and equipment maintenance after graduating to the repertory venues that present a more technically challenging environment. At the present rate of conversion, it is likely that film will have disappeared totally from the mainstream sector by the middle of the decade, meaning that new projectionists will no longer be entering the profession and receiving that basic training. And although at present, an infrastructure exists for the supply, maintenance and repair of the equipment and consumables needed to run the projection booths of repertory theatres, with companies such as Boston Light and Sound in the USA and Future Projections in the UK specialising in this market, equipment manufacturers are likely to wind down production (both of complete projector mechanisms and

the replacement spare parts needed to keep them operational) as the mainstream industry completes the conversion to digital. This process is already underway: on 4 January 2012, the last remaining manufacturer of 35 mm film projector mechanisms in the USA announced that it was ending production.[11]

The theatrical screening of restored films on film is considered by many to be the gold standard, primarily on ethical grounds. But as the mainstream industry goes increasingly digital, the practical difficulties involved in doing this will increase to the point at which it is likely that only a small number of prestigious cinematheques, most of which will be operated by archive institutions themselves, will be in a position to be able to continue to do so.

Theatrical projection – Digital

For about a decade before equipment started to be installed in theatres on any significant scale, debates and negotiations took place between the Hollywood studios and the multinational electronics and IT manufacturers with the objective of determining a comprehensive software standard for the distribution and exhibition of theatrical feature 'films' in digital form. In March 2002, a consortium of studios formed a non-profit organization, Digital Cinema Initiatives (DCI), LLC, to publish, maintain and promote the use of this standard. The first version, DCI 1.0, was published on 20 July 2005. It should be borne in mind that the DCI specification was conceived and designed with contemporary mainstream releases in mind, not archival titles and restorations. Most of the text covers encryption and other anti-piracy measures. Despite intensive lobbying by archive representatives, principally members of FIAF's Technical Commission,[12] for the incorporation of a full set of compatibility features that would enable the projection of archival digital content with the ability to represent almost any obsolete aspect ratio and audio format with reasonable accuracy, these were largely absent from the specification as implemented.

Following the creation of the final output files from a digital restoration project, the files needed for digital cinema projection are produced, by transcoding, in more or less the same way as they would be for a newly produced feature film. The first stage is the creation of a Digital Cinema Distribution Master (DCDM), a digital asset in which each frame is encoded as an uncompressed, individual file. In the act of transcoding from there to the Digital Cinema Package (DCP), the set of files covered by the DCI standard, compression is applied, multiple soundtracks or

subtitles can be added (for example, an archive screening a restoration at an overseas film festival could add subtitles at this stage to a DCP that is produced specially for that screening) and, if desired, anti-piracy encryption and other software-based security devices. The DCP itself is a series of files that, at the time of writing, is usually delivered physically to the screening venue on a portable hard disc drive.

The current DCI standard (version 1.2) allows for 2K or 4K resolution, and frame rates of 24 and 48. Almost any desired projection speed can be simulated as divisors of those. DCI only supports two aspect ratios natively: 'scope' (2.39:1, or 4,096 × 1,176 pixels in 4K) and 'flat' (1.85:1, or 3,996 × 2,160 pixels in 4K). The scope ratio is achieved by using an anamorphic lens in projection, just as it is with film.[13] The only way to achieve taller aspect ratios than 1.85:1 is to windowbox the imaging device, thus decreasing the resolution of the overall projected image. For this reason, 4K is considered by most restorers to be essential in the archival digital projection of restored films that were shot in the full-frame or Academy ratios.

Two pieces of equipment are used to project the DCP in the theatre. The DCP server decodes, and if necessary decrypts, the individual image frames and audio, and passes them to a digital cinema projector and the theatre's audio processor. The projector itself receives the image data from the processor and represents it using a digital imaging device. As it began to become clear in the early 2000s that digital theatre projection was on the verge of becoming a commercial reality, a frequently expressed concern was the limited colour space available from the LCD imaging chips used in the video and computer display projectors in use at the time when compared to film, especially in the high contrast ranges. A common complaint was that what should be black typically appeared as dark grey. A major step forward was the use of the Digital Light Processing (DLP) imaging device, originally invented in 1987 and used on a limited scale in scientific imaging applications over the following decade. The core of the DLP system is the so-called 'micromirror array', in which the angle of a hinged mirror (one for every pixel projected) is adjusted in order to refract a light source at the precise angle needed to project a given colour shade. As with the CCDs in film scanners, cheaper projectors will usually feature a single DLP chip with a Bayer-type device to reproduce colour images, whereas the higher end ones, including almost all the models used in commercial theatre projection, will include three separate chips (one for each of the primary colours). Since then alternative display technologies have also been developed, notably liquid crystal on silicon (LCoS), which

have also been used in digital cinema projectors. This generation of electronic imaging devices has been a major part of the reason for the widespread commercial acceptance of digital cinema: for the first time, a subjective viewing experience became possible that for many viewers was comparable to that of film projection.

It should be noted that the digital projection of consumer media of archival titles, principally DVDs, in theatres takes place occasionally,[14] and that the practice is widespread in non-theatrical venues, especially universities and film societies. It is considered fundamentally unethical by most archivists and curators, on for the principal reason that the image quality specifications of these media were designed only with the dimensions of domestic television sets in mind, not big-screen projection. The reason why this happens is primarily economic. Even for a commercial, mainstream theatre, the cost of meeting the technical standards demanded by many archives is prohibitive, especially for a high risk title that might only attract a small audience. Even the cost of shipping a 35 mm print can represent a significant deterrent. When large-screen video projection based on cathode ray tube (CRT) technology emerged as an affordable and reliable option in the 1980s, it was quickly adopted for use in university lecture theatres and other educational screening venues, where it rapidly superseded (mainly 16 mm) film projection. As a position statement issued by the Society of Cinema and Media Studies (SCMS) noted in 1991, 'Over the past ten years, teachers of film courses have come under increasing pressure from budget-conscious school administrations to use video rather than film in the classroom.'[15] In comparative terms, the cost of video projection has steadily decreased and the cost of film projection has steadily increased ever since. At the time of writing, a typical DVD player and a digital projector designed for classroom or lecture theatre use sold for in the region of £10,000, whereas a typical DCP server and 4K d-cinema projector cost between £150,000 and £200,000, depending on options. Most non-theatrical venues, therefore, are no longer equipped for any form of film projection at all, and significant economic and technical barriers remain even for those that are.

Broadcasting

As was noted in the introduction to this chapter, broadcast television followed by videotapes rented or sold outright to consumers emerged as the first significant market for archivally preserved and restored feature films. As with theatrical presentation, two major technical issues

affecting their representation in standard definition broadcast video were the aspect ratio and the frame rate for silent films, added to which is the dramatically lower image resolution of a televisual image compared to a projected film.

Until the 16:9 standard superseded it in broadcast television, almost all consumer TV sets had as their display device a CRT in the 4:3 ratio, which was close enough to the proportions of Academy Ratio film frame to enable its broadcast with no significant image loss. With the emergence of widescreen, therefore, a way needed to be found of reformatting the wider image to fit the 4:3 frame. Two methods were devised, one of which is considered ethically preferable by archivists but was largely rejected by viewers, while the other was largely accepted as uncontroversial by most viewers (and was therefore preferred by broadcasters) but was condemned and vociferously opposed as unethical by filmmakers, archivists and what one might for want of a better word call educated viewers.

Panning and scanning is probably second only to colourisation in the extent of the controversy provoked by the practice. The height of the film frame is adjusted to match that of the video frame, and then within each shot, the video aperture is panned horizontally so as to retain the essential action from the film image, while cropping away what are judged by the operator to be unused, or lesser used, areas of the film frame.[16] This enables the entire surface area of the televisual image to be used, but with the loss of a proportion of the original filmic image. The ethical opposition to panning and scanning rests on the contention that, quite simply, the process destroys the cultural integrity of a widescreen film that is screened in this way. Further objection are that it depends to a large extent on the skill and judgment of the operator, especially when panning and scanning a technically complex shot in the original film (e.g. one containing fast movement of the action within the frame, or where the camera itself pans or tracks); and in some cases is done against the wishes of the filmmakers. In a classic 'industry versus artistry' showdown of the sort that go right back to Erich von Stroheim's battles with the Hollywood moguls in the 1920s, the director Sydney Pollack (who was also a high profile opponent of colourisation[17]) took a Danish broadcaster to court in 1997, claiming that its panning and scanning of *Three Days of the Condor* (1975) violated his copyright. The resulting case precipitated a full-scale debate as to the moral rights of a filmmaker when his or her work is materially changed in post-production against his or her wishes, much of which is potentially relevant to the practice of restoration in general. Pollack lost

his case, because he had directed the film as the paid employee of his producer, who, under widely accepted international principles of copyright, was the actual owner of the intellectual property embodied in the film, and was therefore legally entitled to licence it to a broadcaster for panning and scanning.[18]

A complicating factor with panning and scanning is that throughout the second half of the 20th century, mainstream filmmakers understood that their work would be distributed both theatrically and for broadcast (and from the late 1970s, home video) in panned and scanned form. In many cases, directors and directors of photography actually took part in the panning and scanning process, by planning the composition of shots on the set such that they could be panned and scanned without the loss of essential action (e.g. by avoiding rapid movement within the frame), and by supervising the scanning operator's work in post-production.[19] In some cases filmmakers are even on record as preferring the panned and scanned 4:3 version over the theatrical widescreen release, one notable example being *Sorcerer* (USA, 1978, dir. William Friedkin).[20] Even if the criteria applied are restricted to artistic intent, therefore, it is often an oversimplification to just condemn panning and scanning out of hand.

The alternative method of converting the aspect ratio widescreen films to fit a 4:3 video monitor is known as letterboxing. This involves masking a horizontal area of the frame above and below the action with a black matte in order to preserve the ratio of the original film image. As one commentator wryly put it, letterboxing was the method of televising widescreen movies preferred by 'foreign film and Woody Allen buffs'[21] – in other words, the highbrow or educated viewer, who is concerned more with preserving the filmmaker's artistic intent than maximising the size of the displayed image. Before 16:9 replaced 4:3 as the de facto consumer television standard, letterboxing was only used on a very limited scale, and then usually for deluxe VHS and laserdisc publications of titles marketed principally to middle class and highly educated customers.

As with their theatrical presentation, the broadcasting of restorations of silent films was for a long time hampered by speed (frame rate) inflexibilities in analogue television technology. The device used to capture film frames electronically and encode them as an analogue television signal is known as a telecine. These machines are frequently confused with the scanners used in digital film restoration, a situation that is not helped by the fact that during the early 2000s, machines that combined both functions were produced. The essential difference is that a telecine

does not capture the film images as discrete (individual, separate) frames in the way that a scanner does: rather, it converts their representation as a moving image into that of one of the two major methods of broadcasting an analogue television picture, Phase Alternating Line (PAL, used in most of Europe and miscellaneous countries scattered around the world, mainly Commonwealth ones) and the US National Television Standards Committee (NTSC, used mainly in North and South America, Japan and parts of Asia) system. These work in essence by dividing the picture into a series of horizontal lines, which are periodically refreshed, or scanned. Because of the nature of the electronics in use, the scanning rate, and thus the number of frames per second displayed, is determined by the alternating current mains electricity supply in a given country. PAL runs at 50Hz, or 25 frames per second (two scanning sequences per frame), and NTSC at 60Hz or 30 frames per second. These are fixed and cannot be changed. Methods were developed for enabling the standardised sound film speed of 24fps to be converted into these two standards. In the case of PAL, the film is typically transferred at 25 and the speed difference accepted, because it is too small for most viewers to notice (this is why a typical feature film will be 3–5 minutes shorter on PAL television than in the theatre). The so-called '3:2 pulldown' – in essence, a method of repeating the broadcast of some frames and scanning fields in order to pad out the difference between 24 and 30 frames per second – was devised for NTSC.[22] Material shot on film but intended either primarily or exclusively for television broadcast was often shot either at 25fps (PAL) or 30fps (NTSC) in the first place, to avoid speed compatibility issues.

However, no such systems for converting slower film speeds were initially devised for frame rates below 24fps, with the result that until the emergence of digital consumer technologies, it was very difficult and very expensive to undertake telecine transfers of silent films at their correct speed. There were a small number of telecine machines on the professional market from the 1970s to the 1990s that could do this, usually after significant modification and/or the purchase of aftermarket options. This and the cost of commissioning music scores acted a significant impediment to the televising and consumer video publication of restored silent films during this period. There were, however, exceptions. In collaboration with the restorer and historian Kevin Brownlow, the London broadcaster and production company Thames Television launched the 'Thames Silents' programme, which broadcast a series of Brownlow's film restorations and documentaries inspired by them between 1979 and 1993, many of which were also published on

VHS, and later DVD. Brownlow recalls that Thames's investment in what was for its time advanced telecine and video post-production technology, which could reproduce electronically both the full range of silent frame rates and the impression of tinting and toning, was crucial to the success of the project.[23] In particular, the Channel Four (UK) broadcast of an early version of Brownlow's restoration of *Napoléon* on 5 and 6 November 1983 attracted significant media attention, and is credited with stimulating a revival of popular interest in silent cinema.

However, Thames Silents and a few isolated broadcasting projects like it are notable exceptions that proved a rule. The point of this technical narrative is that until the early 2000s, restrictions inherent in the technology by which archival films reached the consumer for domestic viewing prevented the object of most technical film restoration (as distinct from reconstruction) from being communicated to them. In other words, the recreation of an obsolete widescreen format (as in *The Big Trail*, for example) or multi-channel audio system was impossible, given the broadcast systems in use and the playback technology found in most homes: the end result would still be a mono soundtrack, silent films shown at the wrong speed and in all probability a panned-and-scanned picture if the original film was widescreen. This situation began to improve gradually from the early 1990s. The rollout of digital stereo audio television broadcasting took place in most of the developed world during the 1990s. Before then, the occasional simultaneous broadcast of the video on television and the audio on VHF stereo radio was the only way a film with multi-channel sound could be broadcast, an event which happened very rarely. One notable example was the broadcast of *Blue* (UK, 1993, dir. Derek Jarman) on Channel Four and BBC Radio Three on 19 September 1993. In 1991, the NICAM (near instantaneously compacted and expanded audio multiplex) digital audio system was launched. By the middle of the decade, receivers were commonplace in consumer TV sets and videocassette recorders, thereby enabling stereo audio with TV and consumer video in the home. Some of the later Thames Silents broadcasts took advantage of this to showcase newly commissioned orchestral scores.

In the late 1990s, television worldwide began to shift to the 16:9 widescreen standard (lobbying for this change goes back to an SMPTE working group that was convened in the late 1970s). Equivalent to a cinema aspect ratio of 1.77:1, it permits the screening of the most widely used cinema ratio worldwide, 1.85:1, with only minimal letterboxing or cropping. The 16:9 standard quickly gained widespread acceptance, largely due to support both from consumer electronics manufacturers

and government agencies. The European Union passed a directive in July 1993 'to ensure the accelerated development of the market for advanced television services in the 16:9 format, using 625 or 1,250 lines, to contribute to the market penetration of television receivers in the 16:9 format', and provided substantial funding for broadcasting pilot programmes towards the end of the decade.[24] Similar initiatives took place elsewhere in the world, with the result that by the middle of the 2000s, almost all the consumer television receivers being sold in the developed world had a native aspect ratio of 16:9. The introduction of digital (picture) broadcasting and consumer video media from 1997 also enabled the native support for widescreen television.[25]

This of course invoked the law of unintended consequences as far as letterboxing is concerned. The conversion to 16:9 television was stimulated by the demands of contemporary production, not archival re-releases and restorations. Just as pre-widescreen television could not broadcast widescreen films without either horizontal panning and scanning or letterboxing, so widescreen television cannot show the Academy Ratio without either vertical panning and scanning or what has been nicknamed 'windowboxing' – screening the 4:3 frame in the centre of the 16:9 frame with a horizontal black matte on either side. At the time of writing it appears that vertical panning and scanning has not become such a widespread practice as horizontal panning and scanning in the 4:3 TV era, possibly because many consumer TV receivers and DVD players include the facility to crop a native 4:3 picture (i.e. one that is broadcast or encoded on a DVD as 4:3) to fit the 16:9 display, meaning that the content provider can give the end user the choice as to how they wish to view it. But there have been occasional high-profile restorations in which vertical panning and scanning has been 'hard coded' into consumer releases, a notable recent example being the publication on BD of a restoration of a widely celebrated television documentary series from 1973–1974, *The World at War*. The decision to reformat the picture for 16:9 attracted significant criticism, especially given that most of the footage consisted of archival actuality film from the 1940s.[26] The vertical panning and scanning of archive material for incorporation into recent television productions with original footage shot natively in widescreen is commonplace: in fact, the windowboxing of such footage is very unusual.

Developments in consumer video playback technology from the early 2000s onwards have provided further opportunities for the restoration of films which were made using technologies that are fundamentally incompatible with 20th century television to be screened in the home

without the need for invasive reformatting. From the late 1990s onwards and essentially in parallel with the shift from 4:3 to 16:9, the LCD began to supersede the CRT as the display device used in most consumer television receivers and personal computer monitors. These do away with the scanning restrictions of CRT-based television (an LCD display is limited only by the broadcast signal or video playback format as to what frame rates it can reproduce), thereby removing another barrier to presenting silent films at their correct speed. In comparison to a consumer market CRT-based display at a similar price point, an LCD screen also offers a significantly larger colour space and a faster response time (i.e. the time taken for each pixel to change colour compared to the photosensitive phosphors in a consumer-grade CRT).[27] Sales of LCD televisions worldwide exceeded those of CRT-based receivers for the first time in the fourth quarter of 2007,[28] and by the time of writing, the manufacture of CRTs for consumer market displays had ceased in the developed world almost entirely.

Consumer distribution media

Consumer video recording media systems matured significantly over a three-decade period from the late 1970s to the late 2000s. From its launch in 1976 until its obsolescence in the early 2000s, the format through which off-air and pre-recorded video was seen in a non-theatrical setting was the vertical helical scan (VHS) magnetic tape. Before the launch of VHS (and a shorter-lived rival consumer video format with which it competed, Betamax), the only method of home viewing available was on small-gauge film prints. Projectors and prints (both on a mail-order rental and outright sale basis) were marketed on a limited scale to wealthy consumers from the launch, once again, of two competing systems in the early 1920s (the American Kodascope 16 mm system and the European Pathéscope 9.5 mm format) until the mid to late 1980s.[29] A notable landmark came in May 1926, when Eastman Kodak signed an agreement with Warner Brothers to distribute 16 mm prints of its feature films non-theatrically.[30] Due to the cost of film stock and shipping, many titles were abridged into what were in effect highlights reels. 16 mm, and later Super 8 mm film, was also used to screen feature films to non-theatrical gathered audiences such as film societies, schools and on airliners during this period.[31] Although film-based consumer systems were never used as release channels for archival restoration projects on any significant scale, there have been occasional instances of non-theatrical and consumer small-gauge prints

providing source footage for a restoration in cases where no better elements are known to survive. Once again, the 2009 *Metropolis* restoration is an example of this, as is the inclusion of 9.5 mm material in Kevin Brownlow's *Napoléon* reconstruction.[32]

VHS was a technically flawed medium as far as the publication of restored films was concerned. It was tied to the PAL or NTSC broadcast standards (plus a variant of PAL, Séquentiel couleur à mémoire, or SeCAM, used primarily in France and the former Soviet Union), and thus limited to native frame rates of 25 or 30 and a native 4:3 aspect ratio. Its resolution was 625 (PAL) or 525 (NTSC) horizontal lines, widely considered to be a tiny fraction of the image information captured by even the fastest and grainiest 35 mm film stocks, and the contrast and gamma ranges, which were also limited by the CRTs on which most tapes were played, were also highly restricted. It was possible to record (analogue) stereo sound on VHS, but these tracks could only be played by the more expensive VCRs that, as a general rule, were bought by well-heeled hi-fi enthusiasts – a similar demographic to small-gauge film users a generation earlier. The technical limitations of VHS, which was designed for screening on a 20–30″ display, were one of the major reasons why, when large screen CRT video projectors began to supersede 16 mm in university lecture theatres, museum displays, corporate training events and other non-theatrical venues in the early 1990s, a familiar refrain heard from film purists was that video projection was ethically undesirable because it would never match the subjective image quality of even 16 mm film projection. This was a largely uncontroversial position at the time, hence the assertion by the curator of a major European archive that 'If a film scholar relies on VHS video for serious study, there is little reason to discuss style in great detail.'[33]

Nevertheless, VHS was an important first step in bringing the results of archival film restoration to a broader public. Unlike repertory theatre screenings, the audience was not restricted to the larger cities and cultural centres (e.g. university towns) where the cinemas that are technically and curatorially equipped to screen these titles tend to be located, and unlike national broadcasts, it was possible to publish a niche interest title that might only achieve a few hundred sales, e.g. a letterboxed edition of a title that was distributed more widely in panned and scanned form. The physical format itself enabled the inclusion of supporting curatorial material such as scholarly essays or booklets packaged with the tape cassettes. Furthermore, the relatively low size and weight of the media permitted its distribution through a wide network of retail and rental outlets, and by mail order. Publishers specialising

in archival titles, notably Kino Video of New York from 1987 and the British Film Institute's Connoisseur label from 1990, released a number of restorations that had been undertaken by the world's major public sector archives in the preceding two decades. These started to build the foundations for the proliferation of titles available on consumer digital media at the time of writing.

VHS was a widespread format: as Brian Winston notes, 'no [consumer electronics] device has been adopted more quickly', with the number of machines in use in the USA growing from 1.8 million to 86 million in the USA between 1980 and 1995.[34] In parallel with it, an alternative consumer format, the laserdisc (also marketed under the trademarks LaserVision, DiscoVision and CD-Video at various times and by various manufacturers during the 1980s and 1990s), was also on the market. Though these 12″ optical discs also encoded the video using the PAL and NTSC broadcast standards, laserdiscs offered a significantly higher definition of picture (425 or 440 lines of horizontal resolution, compared to 240 for VHS), meaning that a letterboxed frame could be shown on a larger television monitor with less subjective loss of quality. The format also supported stereo and from the early 1990s surround sound audio as standard, and in addition to the sale of pre-recorded media to consumers, was used extensively in interactive media applications, notably museum displays.[35]

The principal drawback was that laserdisc was a 'read only' format: as with the phonograph record, no home recording was possible and therefore the owners of players were limited to purchasing pre-recorded media. Unlike on VHS, they could not record broadcast television off the air for later 'time shift' viewing or long-term collection. This attribute is generally credited with having restricted the laserdisc's market appeal to audio-visual technology and arthouse cinema enthusiasts, who bought deluxe editions of mainstream titles and high-quality transfers of foreign and re-release films (including archival restorations) respectively. Throughout the format's commercial lifetime (for mainstream titles published by Hollywood labels, this was from *Jaws* in 1978 to *Bringing Out the Dead* in 2000), the discs retailed for up to five times the price of their VHS equivalents and were only ever distributed through a small range of specialist retailers, many of them mail order.[36]

But the laserdisc did develop the curatorial precedent established by VHS, in that it entrenched the niche market for sales of archival film restoration projects on consumer media, to which was added the desire to increase the technical quality of the image and audio and the range of formats and aspect ratios that could be reproduced in a domestic setting.

The American Criterion label was one of the first laserdisc publishers to concentrate on archival titles, beginning its projects (*King Kong* and *Citizen Kane*) in 1983 and emphasising the use of high quality source elements and telecine transfers, together with many of the curatorial extras that have since become standard features of the consumer media that followed it: alternative commentary tracks, the 'making-of documentary', trailers and other promotional material dating from a film's initial distribution.[37]

Arguably the watershed that transformed home viewing from a flawed distribution channel, through which the technical objectives of most film restorations could not be communicated objectively, to what is arguably the primary conduit through which the work of archival film preservationists reaches the bulk of its audience came with the launch of the DVD in 1997. Like the laserdisc, it is a read-only (in its initial form) optical disc.[38] However, a number of factors combined that, taken together, enabled the DVD to succeed VHS as the de facto medium for the distribution of pre-recorded video content to consumers. In order to understand how the DVD became such an important medium in the dissemination of archival restorations, it is worth considering these.

- The DVD being essentially a read-only medium was less of a disadvantage than was the case with laserdisc, as VHS continued to be used by consumers for time-shifting applications in parallel with the DVD for pre-recorded material.
- The manufacturing and distribution costs of the discs themselves were considerably lower than with laserdiscs, not least because they are a lot smaller and lighter.
- The DVD has a common form factor with the audio Compact Disc (CD), meaning that the same machine could play both types of media.
- Early consumer acceptance on a significant scale enabled economies of scale that drove down the cost of players, thereby enabling further market saturation.
- 'Home Cinema' equipment began to be marketed on a significant scale in the early 2000s. This consisted essentially of large screen televisions and multi-channel surround sound systems that were in effect scaled down versions of the ones used in cinemas. The primary motivation for buying these systems for many consumers was the ability to view digital television broadcasts, listen to CD audio recordings and other sources. The DVD player was thus an essential component in this infrastructure, and one which integrated easily with other audiovisual equipment in the home. This was not the case during the period in which attempts were being made to market the laserdisc as a mainstream consumer format, when the additional equipment needed to take advantage of the higher (relative to VHS) picture and sound quality was a lot more expensive in real terms, and required significant technical skill to install and operate (and in some cases, as Barbara Klinger points out, architectural modifications to your home[39]).
- Although still based on a digital representation of NTSC and PAL (i.e. standard definition), the DVD enables a widescreen aspect ratio (16:9) to be supported natively, by varying the pixel aspect ratio, thereby enabling a more satisfactory reproduction on large-screen televisions of films that were shot in wide ratios. During the early 2000s, 16:9 television sets superseded 4:3 ones in most developed world markets.
- The relatively sophisticated (compared to VHS) anti-piracy technologies incorporated into the DVD video standard made the medium attractive to publishers.
- The ability to integrate extra content (similar to the functionality of the laserdisc, but with a more flexible and user friendly front end) opened up curatorial possibilities that restorers, archivists and publishers found attractive.

The DVD replaced VHS completely for sales and rental of pre-recorded video content within a decade of the format's initial marketing: for example, the *Los Angeles Times* reported that the final pre-recorded VHS tapes produced by an American manufacturer were shipped to retailers in October 2008.[40] Meanwhile, in June 2006, a format intended to succeed the DVD, the BluRay Disc (BD) was launched by a consortium of Japanese electronics manufactuers, which was followed a two-year format war with another high-definition optical disc format backed by a single rival (Toshiba), the HD-DVD. Toshiba discontinued the HD-DVD in February 2008. The BD was the first (and so far the only) widespread consumer video medium that is not based on a standard definition television system, offering a native resolution (1,920 × 1,080) that is almost equivalent to 2K digital cinema and, like the DVD before it, multi-channel, multi-soundtrack digital audio. Like the DCP, the BD enables the accurate reproduction of most of the frame rates used in silent cinema – the first home viewing medium to do so.

In little over two decades, therefore, consumer video technologies with significant market saturation had matured from the rare occasion on which a prominent restoration received a network television

broadcast to a high definition offline medium (BD) that, with all other factors being equal, many would regard as being the subjective equivalent of a typical 35 mm film print. This is in some ways a crude generalisation, and one that does not take into account some of the nuances of the technologies involved. For example, the DVD and BD both make use of a technique known as lossy compression, which reduces the volume of data used to represent a frame (or sequence of frames) of a given resolution by 'losing' visual and aural information, especially that generated by conflating the transition between individual frames into 'groups of pictures' (GOPs), to which the human senses are less receptive.[41] Within the technical constraints imposed by the DVD and BD standards themselves (e.g. a maximum bandwidth of approximately 36 mbps for BD and 10 for DVD), the quality of the encoded media can vary enormously, the most important factor being the level of investment a publisher is willing to commit to a given title. The crucial point is that each successive generation of consumer video technology has enabled the reproduction of archival films to a greater degree of what their restorers would regard as greater objective technical accuracy, and therefore greater subjective ethical acceptability.

At the time of writing it appears likely that the BD will be the last significant physical, offline medium through which pre-recorded video content is delivered for home viewing, and that the streaming of material via the Internet, currently in its commercial infancy but already in widespread illegal use, is likely to supersede physical media. This has already largely happened in the recorded music industry, and the last remaining barrier is essentially to wait for Moore's Law to achieve the necessary increase in speed and capacity needed to be able to transport the required volume of data, quickly and reliably enough, from the supplier to the customer. In the case of the equivalent to the quality of a BD, this means up to 50 gigabytes within the running time of a typical feature film, an infrastructural prerequisite which is only currently possible for the residents of a relatively small number of conurbations in developed countries, and even then only at premium prices. And as one author notes, there is likely to be a cultural dimension to this transition as well as a technological and an economic one. As with the archival institutions that carry out restoration work, much of their audiences have spent many years building a collection of physical objects, and there may well turn out to be significant consumer resistance to a new distribution model that no longer permits this. But the quid pro quo is that, as he argues, 'retail release acted as a gatekeeper that afforded certain films a prominence among the thousands of titles in a studio's library',[42] and that with many of the costs incurred by a physical media release no longer an issue, a far broader range of archives' restoration activity can be made available to researchers and the public.

Conclusion

It will have been noted that, as with the chapter on the restoration process itself, this narrative has documented an industry that is in a process of inexorable and largely commercially driven transition from three technologies that, at the time of writing, are entering obsolescence (film projection, analogue television and magnetic tape-based recording media) to a state of the art, science and economy in which moving images represented and manipulated by computers dominate – 'From Grain to Pixel', as the title of Giovanna Fossati's book succinctly puts it. I have argued that in purely pragmatic terms, these changes have enabled and encouraged the end result of more archival film restoration to reach a greater viewing public – a claim that would surely be borne out by a visit to any large video store in comparison to one made a decade ago. This of course brings with it an ethical debate related to the desirability or even acceptability of rendering and viewing moving images that were initially created on analogue media by means of a digital surrogate. This was addressed in the introductory chapter and will be developed further in the concluding one.

It will suffice to note for the purpose of this discussion that as time goes on, the ethical dimension will increasingly be eclipsed by the pragmatic one. As has been noted above, the manufacture of 35 mm film projectors ceased in the USA in January 2012. At the time of writing, only one manufacturer in the world confirmed to the author in a brief telephone survey that they still maintained a production line for 16 mm projection equipment (Kinoton of Germany). In the aftermath of Tacita Dean's campaign against the decline of 16 mm release printing (see Chapter 2), one of the BFI's archivists observed that the discontinuation of film stock manufacture and laboratory processes 'could have consequences for archival work'.[43] While there have been prominent calls among some leading archivists and curators to the effect that the 'film experience' should continue to be a crucial objective of any restoration activity – if it was shot on film, it should be shown on film – it is likely that, even disregarding the ethical complications of this position, within a couple of generations, this will be quite simply impossible in all but a handful of venues. The cessation of film stock manufacture, and especially dye coupler colour emulsions, will be the biggest

hurdle. As Robert Shanebrook's account of the manufacturing process at Eastman Kodak dramatically illustrates, this is an enterprise that requires literally, billions of dollars of plant and infrastructure, and a concentration of scientific expertise that is, by the time of writing, only to be found in one company left in the world: Shanebrook observes that 'it was very unusual for experienced film technical experts to leave Kodak to work elsewhere in the industry.'[44]

One ominous straw in the wind was the discontinuation of Kodachrome manufacture and processing, culminating in the last remaining lab ceasing operations in January 2011. Various rumours have circulated around the Internet ever since about various individuals and groups of enthusiasts who are trying to restart production either of the stock itself or a processing facility. None of these projects has thus far succeeded, because the manufacture of dye coupler colour film emulsion requires infrastructure, the economies of scale of which simply do not enable its operation or maintenance as a cottage industry with a customer base, the size of which is represented by archival film preservation and restoration activity worldwide. On 13 September 2012, further evidence of this trend emerged when Kodak's only commercial rival in the manufacture of colour film on any significant scale, Fuji of Japan, announced the discontinuation of all motion picture film manufacture apart from a black-and-white stock designed for printing separation negatives for preservation.[45]

The challenge for archivists and their audiences, therefore, will be to understand the reception contexts of restored films in a technological form that predates their restoration. De facto ethical objections to the post-restoration form are rapidly becoming irrelevant.

5
Conclusion: The Ethics and Study of Film Restoration

Multiple editions destabilise texts[1]

Introduction

In August 2012, a new word entered the English language: 'wreckstoration'. It was inspired by the work of Cecilia Giménez, an 81-year-old volunteer churchwarden at the Sanctuario de Misericordia in the village of Borja, north-east Spain. Giménez, an amateur, was concerned that a fresco on one of the church's interior walls had suffered significant humidity damage over the century or so since it was painted. This had caused, among other visible artefacts, pigment fading and the loss of paint fragments. So she decided, quite simply, to restore *Ecce Homo* herself. After Giménez was through with it, the original image, a portrait of Jesus Christ wearing a crown of thorns (inspired by John 19:2) and painted by the local artist and teacher Elías García Martínez, had to all intents and purposes been destroyed. In the words of one of the army of journalists who reported the event, what was once an image of Christ 'now resembles a hairy gorilla'.[2]

With hindsight, it is obvious why this incident grew into an international media event. Giménez's failed restoration was portrayed as the work of an unknown country bumpkin, in a village in the middle of nowhere, damaging an obscure and (monetarily) almost worthless painting, but at the same time attracting the sneering attention of some of the world's journalists and art critics, who gleefully spun the story as the archetypal cautionary tale of a little knowledge being a dangerous thing. The 'before and after' photographs printed alongside the articles ensured that their readers did not have to be any sort of an art expert to understand what had happened, and thus enjoy a joke at Giménez's

expense. One joker even created an online web application in which visitors can attempt their own restoration of *Ecce Homo*, starting with the 'before' illustration and using Photoshop-style paintbrush tools.[3] Furthermore, the interpretation and criticism of arts and culture in general tends to emphasise and celebrate the role of individual creative genius (hence the prominence given to authorship theories and the role of the director in the study of cinema). Therefore, figures who acquire a reputation for attempting to punch above their weight and living to regret it inevitably become the object of public amusement, hence the infamous careers of William McGonagall, Florence Foster Jenkins and Ed Wood, to name but three.

But after the giggling had died down, the question then arose, as *Time*'s journalist succinctly put it, of 'what the heck do they do with the thing now?'[4] As more reflective commentators began to point out, professional art restorers have a centuries-long track record of going to work on paintings, sculptures and other works of fine art using methods that, objectively speaking, are not that dissimilar from the approach taken by Giménez. In 1985, Sarah Walden's seminal book *The Ravished Image* was published. In it the author, widely acknowledged as one of the world's foremost art conservators, attacked what she called the 'mechanical activism'[5] of restorers, who she argued were trying systematically to 'impose an inappropriate 1980s conformity to the masterworks of former centuries'[6] with little regard to the empirical context of their creation or exhibition over their lifetime as a whole. Walden's essential point was that what might be perceived subjectively as visible imperfections by today's audience in fact embody important evidence as to an artwork's history and cultural impact, and therefore that eliminating them using interventional chemical or physical techniques is not necessarily an act of restoration at all. If we accept that, then what Cecilia Giménez was trying to achieve could be perceived as coming uncomfortably close to the motivation of Helmut Ruhemann, the controversial former art restorer at London's National Gallery, who his detractors accuse of having cleaned the paintings in his care so enthusiastically that he washed away a lot of the original paint along with the dirt he was trying to get rid of.[7]

Ruhemann's work, like Giménez's, was motivated by his personal beliefs as to what the paintings he restored *ought* to look like. The only difference between the two of them is that Ruhemann's beliefs were shaped by a formal art education followed by years of professional development, whereas Giménez's were not. Both the old masters that

Ruhemann worked on and *Ecce Homo* as restored by Giménez thus reflect certain cultural attitudes about art in the time and place that the work was done. Art historians such as Walden would argue that this evidence is in itself a crucial part of the artwork's overall history, and at the very least should not be undone without serious thought. It would be destroyed if, as at the time of writing is being proposed, state-of-the-art and very expensive techniques are used to undo Giménez's handiwork and return *Ecce Homo* to the state it was in before she started. The question of what the heck to do with the thing, therefore, has suddenly become a lot more complicated.

If one had to think of equivalents in cinema, the nearest candidates are probably Ted Turner's abortive attempt to colourise *Citizen Kane* in the mid-1980s[8] and, of course, the Giorgio Moroder *Metropolis*. The latter makes for an interesting comparison. As with Giménez's work on *Ecce Homo*, the initial critical response to the film's release was one of horrified, emotionally charged objection.[9] Admittedly, there are some subtle differences: the former was an act of deliberate sacrilege (so its critics would argue), the latter accidental.

But a second wave of critical response to the Moroder *Metropolis* later emerged. Writing in 2000, Giorgio Bertellini argued that the Moroder *Metropolis* demonstrates that 'there is no stable heritage to preserve',[10] and argued that, in effect, it should be regarded as a creative reinterpretation of the film (comparable, say, to the staging of a Shakespeare play set in the 20th century) rather than the Giménez-style wreckstoration that film critics and historians spent almost two decades queuing up to condemn it as. When it was re-released on DVD and BD in 2011 after over two decades of being almost completely out of distribution, the publisher stated that 'Rather than substitute digitally enhanced footage from one of the restorations that have occurred in the 27 years since the release of Moroder's *Metropolis*, Kino Classics has chosen to present the film exactly as it appeared in 1984, mastered from an archival 35 mm print.'[11] In other words, whether or not this version was in accordance with the original filmmaker's personal vision or tells us anything significant about how *Metropolis* was received in 1920s Germany is irrelevant. The point of returning Moroder's version to circulation was, as the sleeve of the BD states, to enable an audience in the present decade to understand how in 1984 in America, Moroder 'introduced Fritz Lang's classic vision of the future to a new generation'. It is a part of the film's history, whether the critics and historians who objected to its creation in the first place like it or not.

Archival ethics and the object of restoration

Flowing from that is the question as to why critics and historians did object to the creation of the Moroder *Metropolis* in the first place, and what those objections tell us about what those who set out to restore films are trying to achieve. There has been significant debate within the film archiving profession over what does and does not constitute ethically acceptable practice in film preservation and restoration. Both of its major professional bodies, FIAF and AMIA, have codes of ethics to which their members are expected to adhere. While there has been substantive debate over the nuances and details, two cornerstone principles tend to be articulated and embedded deeply within professional practice, neither of which has been subjected to significant, systematic scrutiny. The first is that the technical integrity of the physical medium used to originate the moving image should be respected ('new preservation copies shall be an accurate replica of the source material'[12]), and the second privileges the role of the filmmaker (usually the director) in determining the content to be preserved or restored: in the AMIA code, for example, members are required 'to make decisions consistent with the intentions of the creators',[13] even if doing so (it is implied) produces a restoration that is not in accordance with what audiences actually saw when a film was initially distributed, or which ignores a form in which a film circulated to a significant audience, and with significant cultural effect (e.g. the Moroder *Metropolis*) since.

These imperatives are expanded in the only monograph-length work published at the time of writing that is devoted to the ethics of moving image archiving, which emphasises the importance of preserving obsolescent physical media and the technologies needed to reproduce it,[14] and 'the work' as a self-contained unit of cultural production, essentially in isolation from its reception context or changes over time.[15] The importance placed on them is a reflection, in turn, of the two formative influences that have largely shaped the film archiving profession.

The first is that the profession did not grow out of mainstream archival practice. With the notable exception of Eileen Bowser, who entered the profession with a degree in art history,[16] the pioneers of the movement – Lindgren, Langlois, Barry, Hensel, Card and Brown, for example – did not receive their initial education in legal deposit libraries, preserving illuminated manuscripts or palimpsests or in any established branch of document archiving or museology. They were first and foremost experts and/or enthusiasts in cinema, and thus were motivated primarily by their desire to preserve the technology and culture that

went with it, and informed by their knowledge of that technology and culture, not by formal methods of historical enquiry, librarianship or archival science. Their immediate priority was thus to preserve the physical medium of cinema (i.e. film), especially once the process of nitrate decomposition began to be understood in the late 1940s. Preservation of the physical artefact related as closely as possible to the initial creation of a film (the camera negative, in most cases), together with restoration practices intended to replicate the experience of viewing that film in the form approved and endorsed by its principal creative force thus became the guiding principle of orthodox archival practice.

The second is that the study and criticism of cinema itself enshrined and prioritised the concept of creative authorship. It dates back to 1920s Europe (the formative milieu of Lindgren, Langlois and Barry), when, in an attempt to distinguish themselves from the perceived cultural hegemony of the rapidly globalising Hollywood, the French and German film industries in particular promoted and celebrated the idea of the director as creative force. Although we tend to think of '*auteur* theory' as being essentially a concept that was invented in the 1950s, it is worth noting that the use of the noun *auteur* in its original French to denote a film director of significant artistic talent goes back a lot further. In 1930, for example, an article in the French mainstream press condemned the practice of 'putting the name of a famous *auteur* on some miserable "ersatz" by a third-rate director'.[17] As the editors of an introductory undergraduate reader in film studies note, the privileging of this idea is specific to that discipline, observing that 'it emerged from cinephilia, a particularly intense relation to film which has always been the property of the few (critics/cinephiles) rather than the many (audiences)'.[18]

Therefore, these two imperatives have shaped the objectives of film restoration that are now enshrined in the film archiving profession's 'holy writ', so to speak, namely the FIAF and AMIA codes of ethics, and Edmondson's monograph. It is not for nothing that academic research and teaching related to the moving image is usually under the banner of a discipline known as film studies – film as distinct from cinema, thereby privileging the creation and interpretation of the film 'text', as the metaphor invented by 1960s theorists calls it, over the empirical circumstances of its reception and understanding, or how this has changed over time. The accepted wisdom, therefore, is that what should be restored is the 'original' film, original being defined in terms of the material characteristics of the production when it was initially made and shown, and the artistic intent of its principal creative force. Hence, therefore, John Belton's warning that 'the most important concern about the

digitization of the cinema is its implications for film preservation',[19] and the complaint of a correspondent to *Sight and Sound* that DCP projection 'makes it quite difficult to understand what the film was originally shot on... leaving the sterile flatness that is so characteristic of digital filmmaking'.[20]

Once again, there is no 'original'

As Andreas Busche reminds us, comparisons of film restoration with art restoration will take us so far and no further, and for one crucial reason (one that has been discussed extensively in previous chapters). In the consumption of a work of fine art, the viewer looks directly at the artefact that was created by the artist (the creator almost always being a single individual), whereas with a film, the viewer does not.[21] Copying is an integral part of the production process. Cinema depends for its economic viability on the ability to make unlimited copies from a single recording, with little loss of quality and at little extra cost. It also depends for its creative potential on the ability to manipulate images aesthetically, combine multiple images and affect other material changes during the copying process itself, processes that range from comparatively simple ones such as creating a dissolve between two shots, to complex and expensive ones such as integrating CGI with live action. The definition of 'original' used as a default by the majority of restorers – on the medium it was made, and what the filmmaker wanted – is in reality just one of a vast array of potential definitions.

The obsolescence of the physical medium on which almost the entire 20th century's cinematic output was initially recorded, photographic film, is having the effect of dragging the question of what constitutes originality out of the realm of ethics and into that of pragmatics. The 'within the technical possibilities available' qualifier Edmondson places on his diktat to archivists to use original media forms for preservation and restoration copying turned out to be a prophetic one.[22] As I noted in the conclusion to the previous chapter, the manufacture of film and the infrastructure needed to use it (e.g. processing chemistry) is rapidly winding down at the time of writing, and it is becoming increasingly clear that within a generation at most, restorers will probably not have the option to carry out restoration work based on photochemical duplication (and in the case of colour film, almost certainly not).

The combination of film archiving's twin obsessions – the preservation of physical media forms and the emphasis on creative authorship – and the approaching obsolescence of the media form that has

dominated moving images for a century and a quarter, has inspired a spate of prophecies of doom in recent years. One of the more widely discussed within the profession has been Paolo Cherchi Usai's 'digital dark age' thesis, a position articulated through numerous books, articles and lectures, in which he warns that what he sees as the fundamental loss of materiality associated with digital images (i.e. they are not embodied within a physical carrier in the way that filmic images are – an identical file can be duplicated without limit and stored on multiple physical carriers) represents a direct threat to our ability to understand the provenance and significance of a given film.[23] As Usai put it in a 2010 lecture, 'the real problem with digital restoration is its false message that moving images have no history, its delusion of eternity.'[24]

But why did no-one raise comparable objections to the restoration of film by duplicating it on to other film? After all, the representation of colour information using the organic dyes of a Technicolor imbibitions print involves totally separate chemistry from that of chromomeric dye-coupler stock. And enthusiasts who have significant experience of seeing nitrate prints projected frequently and consistently insist that it has a distinct aesthetic – 'a certain visual quality to it that is really unique, because of the silver content. It really has a lot to do with it; it really looks luminous.'[25] Yet despite the fact that this certain visual quality, if it objectively exists (a question that is debated endlessly by archivists and enthusiasts), is lost in the photochemical duplication process from nitrate to triacetate or polyester base stock, no-one has tried to argue seriously that film restoration based on such duplication is fundamentally unethical, and/or that it threatens to rob the film of its history, or has advocated the restoration of pre-1950s films by duplicating them on to new nitrate stock.

The reason why does not require a doctorate in philosophy or theoretical ethics. It is, quite simply, that *no nitrate stock is made anymore*, and therefore the option does not exist to do this. At the time triacetate superseded nitrate, the film archiving profession was in its infancy and the conversion process happened so quickly that there was neither time for nor point in ethical hand-wringing, even among the minority who might have been inclined to do so. By the late 1940s, nitrate was known principally for rotting and blowing up, the industry was glad to see the back of it and preservation represented such a tiny sector of that industry that it had no choice but to comply with the mainstream. The only difference with the conversion to digital imaging is that it is taking place over a significantly longer timescale: the first mainstream features to incorporate a significant CGI component (*Terminator 2* and *Jurassic*

Park) were released in 1992, and at the time of writing, two decades later in 2012, film is just about still with us. But in other ways and from the perspective of restoration, the two transitions are directly comparable. The subjective visual properties of a 1940s nitrate camera negative and 1980s triacetate fine grain positive stock onto which an archivist would typically have duplicated it are significantly different. Unless it is duplicated by contact printing, evidence as to the provenance of the source elements (e.g. edge markings and camera apertures) will be lost in the duplication process, just as they will in the digital scanning process. And, most crucially, it seems that the mainstream commercial sector has decided which way it wants to go, leaving taxpayer-funded and other non-profit preservationists in their wake to squabble over the ethics.

As the post-house colourist who worked on the recent restoration of *Wake in Fright* declared, emphatically, 'traditional restoration gives you a five out of ten... this is clearly ten. It's a lot better.'[26] To borrow Tony Blair's infamous declaration in respect of the question as to whether or not global warming is caused principally by human activity, the debate is over. Furthermore, it is not just the commercial sector that is acknowledging and planning for this. In October 2012, the British Film Institute convened an informal 'Future of Film Archiving' group, consisting of senior technical experts from a number of the world's leading public sector archives, to identify and address the likely challenges resulting from the impending commercial obsolescence of photographic film. Their findings (which have not yet been published at the time of writing), are that the availability of film stock, consumables, laboratory services and professional expertise related to photochemical distribution are all in danger of disappearing in the medium term, and that the response of archives should effectively be to manage this process with the aim of preserving objective knowledge and evidence of photochemical processes as completely as possible, even after it becomes impossible to continue undertaking the processes themselves.[27]

So, is there is an alternative to the fatalistic acceptance of the belief that digital film restoration inevitably destroys evidence of its past, and that it is therefore a bad thing?

In 1929, the pioneer social historian Lucy Maynard Salmon argued that 'the world has shrunk through the application of new motive powers to all forms of transportation; through the invention of new ways of communicating thought... as the material world has contracted, the relation of man to the world in which he lives has correspondingly and proportionately expanded.'[28] She is arguing implicitly that our experience of the present forces a shift in perspective in our understanding of

the past, not least because those new ways of communicating thought include new ways of communicating evidence of human activity in the past. Given that she was writing three quarters of a century ago, it is striking how relevant that passage is to the archiving profession now, at a transition moment when the method of communicating thought that is the primary object of a lot of our work is becoming obsolete, and another is in the process of replacing it. Her essential point is that we rewrite history because we are constantly discovering new ways in which, and new evidence with which, to do so. The rewriting of history does not necessitate its destruction. It *does* necessitate the analysis and evaluation of the source material that we discover and use, and in the case of audio-visual artefacts that includes understanding the provenance of digital surrogates made from analogue sources.

This point was not lost on the movement of academics who founded what might loosely be termed the Film and History movement in the early 1980s. The origins of this movement are usually linked to the launch of the International Association of Media and History (IAMHIST) and its journal *Historical Journal of Film, Radio and Television* in March 1981, its aim being to promote the use of 'evidence provided by the mass media for historians and social scientists, and with the impact of mass communications on the political and social history of the 20th century'.[29] Unlike the discipline of film studies as it had developed to that point, the Film and History Movement did not privilege either auteurism, the internal exclusivity of the 'text' as the body of evidence under analysis or the sanctity of physical media. Their starting point was to gather source material related to the production, distribution and exhibition of films and to use this in order to form arguments as to their evidentiary potential and limitations.

Almost two decades later, a group of historians published a manifesto in which they called for a 'new film history', which they characterised as an expansion of what this movement had accomplished since the 1980s. This, they assert, should be characterised by the 'the critical evaluation of primary sources, both filmic and non-filmic... *expanding the range* of primary sources available for the researcher'.[30] However, I would argue that a more constructive approach to the study and understanding of restored films would be to approach a film's restoration history as one of those sources to be evaluated: and specifically, the decisions and assumptions made by the restorer as to what does and does not constitute authenticity. The ability to do this demands a thorough empirical knowledge of the technologies used, the processes involved and the ability to distinguish between the objective (we know

that certain footage shown in the initial 1933 distribution of *King Kong* was removed from the 1937 re-release) and the subjective (the belief that a digital projection is sterile and flat).

The restorers themselves are laying down this challenge, often carrying out their work using highly subjective and fluid goals and criteria. One recent example can be found in a 2012 BD re-release of *The Devil Rides Out* (UK, 1968, dir. Terence Fisher), an entirely forgettable low-budget horror film that had been given a digital restoration by its current rights owner the previous year. In a restoration featurette on the BD, the daughters of the film's special effects supervisor explained that the original production had run out of money, and that as a result certain optical shots 'weren't quite finished properly'. So the London post house commissioned to undertake the restoration finished them: in the words of the project director, 'enhancing that work, but keeping it true to how it was undertaken'. The colourist who undertook the digital post-production then talked the viewer through the digital restoration steps used on these process shots, noting that his goal was effectively based on an educated guess as to how they would have looked if the filmmakers had not been under budgetary constraints. The end result was in many ways a visually slicker and more polished aesthetic than had characterised many of the Hammer horror films upon their initial distribution, with matte lines and other visual artefacts having been rendered invisible.[31]

A viewing of the restored version of *The Devil Rides Out* would not necessarily mislead a researcher concerned with its economic, political or cultural aspects (in the same way that a viewing of a 1930s feature on VHS would probably be sufficient for a researcher interested in, say, film censorship), but it most certainly would mislead someone researching the history of cinematography or special effects technology. The fact that there are already many film restorations taking place with a primary objective that is not evidential authenticity (the claim of 'enhancing that work, but keeping it true to how it was undertaken' is an oxymoron, because it was undertaken with the visual properties that are now being regarded as defects and thus 'enhanced' out of existence) gives the viewer and scholar a major problem. The 2012 version of *The Devil Rides Out* can no more be considered objectively authentic than Robert Haas's edition of Bruckner's eighth symphony, because in both cases the restorers tried to second-guess what the original authors of the work might have done under different circumstances.

As one leading historiographer notes, 'today, as all archivists will testify, students and even established scholars approach sources without the necessary methodological skills.'[32] As I have demonstrated in the introduction, this statement applies to a significant proportion of the film studies establishment. Only in 2011, a monograph was published on the cultural impact of the DVD, subtitled 'The Attainable Text'. However, the authors give little consideration to how the archival histories of many of the films they discuss contribute to the belief that there is no single, definitive text.[33] In doing this, I suggest that they unintentionally vindicate Leff's point that multiple editions destabilise texts, to the point of calling into question the fundamental validity of the 'film as text' metaphor.

The practice of film restoration, and in particular its transition to the use of digital technologies, has set critics, scholars and even mainstream audiences the challenge of asking some fundamental but vital questions: who did this, when, why, how and for whom? Addressing them will require engagement with issues of technology, potentially way beyond the comfort zone of some humanities scholars, in conjunction with the use of methods and approaches that have traditionally been marginalised by film studies, informed as it primarily is by literary criticism, cultural theory and sociology. It remains to be seen how they rise to that challenge.

Appendix: Technical Glossary

Explanatory note

This glossary is not just intended to be a quick reference guide for readers unfamiliar with specific terminology as they read the main text. Many of the terms used in moving image technology and in preservation and restoration practices and academic research in film studies and history have multiple, imprecise and/or ambiguous meanings, and in many cases have come to mean very different things in common usage relative to that of their usage in professional practice. The glossary, therefore, attempts to identify where these disparities exist and articulate the difference between those meanings as clearly as possible, in order to support their inevitable shorthand use in certain passages of the main text. Given that the arguments and conclusions in this book relate to a number of discrete bodies of applied knowledge and intellectual enquiry, principally technical operations within moving image archiving, history and film studies, the glossary also represents an attempt to assist readers who may be familiar with some, but not all of the fields covered.

UK English spellings are used in the main text. Where alternative words tend to be used in US and UK English to mean the same thing in the same context, I have tried to identify and use the word that is in the widest overall use in the English-speaking world in the main text. Some frequently occurring examples are:

- Grading (UK) instead of timing (US)
- Phonograph (US) instead of gramophone (UK)
- Theatre (US) instead of cinema (UK)

Where alternative words tend to be used in technically correct and everyday colloquial speech within professional practice, I have once again tried to use the word that is most commonly used in practice in the main text, unless this is the colloquialism and its use would risk imprecision and/or ambiguity. Some frequently occurring examples are:

- Vinegar syndrome (colloquial) instead of deacetylation (precise)
- In the context of film duplication, source (precise) instead of original (colloquial)
- In audio, multi-channel (precise) instead of stereo (colloquial)

There appears to be no universally agreed or standardised nomenclature as to whether to use the upper or lower case 'K', 'M', 'T' and 'G' for the prefixes 'kilo-', 'mega-' , 'giga-' and 'tera-'. They are used interchangeably within the technical literature, although the use of lower-case initials in bits-per-second abbreviations (e.g. mbps for megabits per second) appears to be more widely used. In the

main text, therefore, upper-case initials have been used except in bits-per-second abbreviations.

1.0/2.0/3.0/4.0/5.1/7.1

These are shorthand expressions for the number of channels recorded and/or reproduced in a film soundtrack. They refer to the number of channels in the final mix, with the 'point one' indicating whether or not a sub-bass channel (an extra channel with a smaller frequency range than the main ones, used to improve the quality of the bass) is present. For example, the Dolby SR 35 mm SVA release print format would be considered 4.0 – left, centre (dialogue), right and a single channel of surround.

2K/4K/6K/8K

These are shorthand expressions for image resolutions used in digital cinema.

3D

See Stereo or Stereoscopic (moving images).

1080p/1080i/720p/576i/480i

These are shorthand expressions for image resolutions used in broadcast and consumer digital moving images, and whether or not the encoding and/or display device is progressive scan (p) or interlaced (i). The frame rate is sometimes appended to these abbreviations, e.g. 1080p24 indicates an image of 1,080 lines of horizontal resolution, progressive scan and 24 frames per second.

4:1:1/4:2:0/4:2:2/4:4:4

In digital imaging, ratios that specify the amount of luminance (light) and chrominance (colour) information that is encoded within a given picture area. For example, 4:2:2 means that a sample area of four by two pixels contains four separate pieces of chrominance data, plus the luminance samples.

1.33:1/1.37:1/1.66:1/1.85:1/2.1:1/2.35:1/2.55:1 – see also Aspect ratio

With reference to film-based moving image technologies, aspect ratios are typically described as proportions of one.

4:3/16:9 – see also Aspect ratio

With reference to television and digital moving imaging technologies, aspect ratios are typically described as proportions of integers.

1,1,1,Trichloroethane

An organic solvent that was used extensively in ultrasonic film cleaning during the 1970s and 1980s, before it was superseded by perchloroethylene. Its molecular formula is $C_2H_3Cl_3$. While highly effective and safe to the film being treated, 1,1,1 is extremely hazardous to human health and damaging to the Earth's ozone layer, with the result that its use was regulated almost out of existence by the Montreal Protocol of 1989.

Academy ratio

The aspect ratio produced by the 35 mm camera gate aperture dimensions of 0.825 × 0.6 inches, which was proposed by the Academy of Motion Picture Arts and Sciences in 1932 in order to accommodate a combined optical soundtrack on release prints while preserving a the four-perforation pulldown and a similar screen shape to that of the full-gate silent aperture it superseded. This ratio was largely accepted worldwide by the film industry until the emergence of widescreen in the 1950s. The actual ratio is 1.375:1, with the result that it is frequently referred to colloquially as both 'one three seven' and 'one three eight'. The Academy Ratio's closest expression in integers is 11:8, despite being frequently and incorrectly cited as 4:3.

Accession

The procedure carried out by a collecting institution to record the initial acquisition of an object or artefact, acknowledging formally and legally that it is now in the institution's ownership or custodianship. In the case of a moving image archive, this will typically consist of assigning the element a unique identifying number, entering basic filmographic information about its content into a database and performing a basic technical examination to determine its preservation needs.

Acetate – see Cellulose acetate

Algorithm

In digital film restoration, an algorithm is the articulation of a precisely defined procedure for carrying out a processing function, as distinct from its representation within a specific software programming language.

Analogue

Derived from the Greek noun *analogos*, meaning 'proportionate', this adjective can describe: (i) an electronic signal, the amplitude or frequency of which changes over time, and which can be saved on a recording medium, e.g. magnetic tape, or (ii) a photographic image created chemically. The signal or recording is analogue in that it is proportionate to, or an analogy of, the original signal. This is distinct from a digital signal or recording, which is encoded as numerical data using a computer. The term is often used colloquially to mean 'inferior to digital', though in strict technical terms this judgment is subjective at best and misleading at worst.

Aperture plate

A small metal plate (usually made from a heat-resistant alloy) that is placed between the light source and the gate in a film projector. A hole is cut out of the plate, corresponding to the aspect ratio in which the film is to be projected in. Used in conjunction with a lens of an appropriate focal distance for the desired ratio (which is determined by the dimensions of the screen and the distance from projector to screen) and screen masking curtains made from a dark fabric, it ensures that only the area of the film frame that is intended to be visible in projection is shown. The unwanted area of the frame is masked by the plate. All modern projectors are designed such that the aperture plates and lenses are easily interchangeable, thereby enabling any desired aspect ratio to be projected.

Archive

A collecting institution with a remit to preserve original works.

Aspect ratio

The proportion of width to height in the dimensions of a moving image. In film, aspect ratios are usually expressed in multiples of one, whereas in television and digital imaging the convention it is conventional to express the proportion as integers. Thus, the 'Academy ratio' in cinema is approximately 1.37:1 (or 'one three seven' in colloquial speech), meaning that the image is a third wider than it is tall, whereas a pre-widescreen computer monitor would be described as 4:3 ('four by three').

Audiovisual

A term that was in widespread colloquial use before the adjective 'multimedia' was devised to describe a combination of still images, moving images, sound recordings and text mediated by computer technology. It was used to describe any synchronised combination of photographic images (still and moving) and sound recordings, and the equipment used to create and reproduce them. The phrase 'audiovisual archives' is typically used today to refer to any repositories that preserve such content, including silent films, synchronised sound films and standalone audio recordings (e.g. recordings of radio broadcasts or oral history tapes).

Autuerism/politique des auteurs/auteur theory

In academic film studies, a body of argument and scholarship which proposes that the director is the primary creative force that determines cultural significance in a film.

Bandwidth (audio) – see also Hertz

The proportion of the audible frequency spectrum that is captured within a sound recording.

Bandwidth (digital)

The amount of data transmitted or processed within a given time period.

Base

The flexible, transparent support of film, to which the emulsion is applied.

Bayer mask

A series of colour filters that enable the entire visible colour spectrum to be scanned by a single digital sensor or projected using a single imaging device.

Bit rate

The amount of data used to encode the images and/or sounds over time in a digital media asset. In a consumer DVD video recording, for example, the bitrate is typically between 3 and 9 megabits per second (Mbps).

Born digital

An audiovisual work that was originally created on a digital recording medium.

Carbon arc

A form of artificial light used in studio lighting and theatre projection that was in widespread use from the mid-1920s until the late 1960s. Carbon arc lamps produce a significantly lower colour temperature than the incandescent or xenon arc lamps that replaced them, which restorers need to compensate for when working with release prints that have been graded for carbon arc projection.

Cathode ray tube (CRT)

The imaging device used in almost all television and personal computer display devices (the Eidophor being about the only significant exception) until the emergence of liquid crystal technology for this purpose in the 1990s. CRTs were also used in telecine, telerecording and high definition film recording systems.

Cellulose acetate

An organic film base consisting of acetylated cellulose. Early forms of acetate film, e.g. cellulose diacetate and cellulose acetate propionate, were in mainstream use for certain niche applications, principally amateur cinematography, from the early 20th century until the early 1950s. Following the commercial launch of the cellulose triacetate base in 1948, it rapidly superseded nitrocellulose for professional motion picture use. Unlike nitrocellulose, it is not usually inflammable, but like nitrocellulose it is susceptible to chemical decomposition in long-term storage.

Charge coupled device (CCD)

A CCD is a photosensitive surface which creates digital data in response to being struck by light; in other words, a digital representation of that light. It can be considered the digital equivalent of film emulsion, and is the form of imaging device found in most digital cameras (both still and moving image) and motion picture film scanners.

Chromogenic

A colour film system in which chemical couplers are used to transform separate emulsion layers, sensitised to two or all three of the primary colours, into corresponding visible dyes in developing.

Cineon

A fully integrated digital post-production system marketed by Eastman Kodak between 1992 and 1997, Cineon consisted of a 4K film scanner, intermediate hardware and software for digital image manipulation and a laser film recorder to produce the final output. Although it was designed primarily for the creation and incorporation of visual effects in a production environment, what was probably the first full-scale feature film restoration using an entirely digital workflow, that of *Snow White and the Seven Dwarves* (USA, 1937, dir. David Hand) in 1993, was carried out using Cineon.

Codec

A conflation of 'encoder/decoder'. In digital moving images, a codec is the software standard or algorithm that is used to represent to represent the video and audio in digital form. Examples include MPEG-2 and H.264.

Colourist

This term is generally used to describe a technician who manipulates the colour balance in an electronic or digital image, often synonymously with 'telecine/datacine operator'. It is not usually used to describe someone who carries out grading or timing in a photochemical workflow.

Colour space

The way in which the three primary colours (red, green and blue) are combined to produce a potentially limitless number of shades. In the digital representation of photographic images, the term is also used colloquially to refer to the limitations imposed by a given encoding format.

Colour temperature

How biased a given light source is towards one end of the visible colour spectrum or the other. Colour temperature is measured in kelvin. For example, the yellowish flame produced by burning wood will have a colour temperature of approximately 1,500K, the xenon arc lamp used in a typical cinema projector 4,500K and bright sunlight 20,000K. The accurate measurement of colour temperature is important in film restoration, because some imaging devices are more sensitive than others in reproducing certain areas of the visible spectrum. Grading or other colour balancing processes also have to take into account the light source used in reproduction. For example, a release print graded for projection using carbon arc illumination will have a lower colour temperature (i.e. the picture will appear more yellow) than was intended by the filmmakers if it is projected using a xenon arc.

Colourisation

The practice of adding colour information to moving images that were photographed in black-and-white with the intention of making the footage look as if it had been shot in colour (i.e. colour information recorded at the point of initial photography) in the first place. This technology emerged in the 1980s and was initially used extensively by broadcasters trying to make their black-and-white archival holdings more acceptable to mainstream audiences. However, early colourisation technology produced largely unconvincing results, and the practice has since been almost totally discredited by critics and archivists on ethical grounds.

Compression (digital media)

The use of algorithms which reduce the total volume of data needed to encode a given audiovisual media asset. *Lossless* compression (e.g. the JPEG2000 format), used mainly in professional media production and post-production workflows, achieves this by reducing the volume of data using mathematical formulae that preserve the original encoded data intact. The end result is that less storage space or bandwidth is needed to handle the media asset, but that more computer processing power is needed to encode it and to play it back (and thus potentially higher hardware and software costs). *Lossy* compression (e.g. the MPEG-2 format), used mainly in broadcast and consumer digital media, works by discarding video and audio information which it is believed the human eye or ear is less sensitive to, or in some cases cannot discern at all. Although the hardware and software needed to encode lossy compression formats is relatively sophisticated and expensive, most are designed to be decoded and played back using relatively low levels of processing power and simple software, hence their widespread use in consumer media applications.

Computer generated imagery (CGI)

The practice of integrating non-photographic and photographic moving images using computer technology, which has been in mainstream use since the early 1990s. While the main application of CGI is for creating special visual effects, its underlying techniques – primarily the process of manipulating the properties of an image that has been scanned from an original camera negative on film – have been adapted to form the basis of most software used in digital film restoration.

Contact printer

A device used in photochemical film duplication, in which the source and destination film stocks are placed in physical contact with each other as the exposure is made.

Continuous printer

A device used in photochemical film duplication, in which the film transport mechanism is continuous and each frame is duplicated progressively while the source and destination film stocks are in motion.

Copyright

A legal framework for defining and enforcing the ownership of intellectual property in moving images and recorded sound. Copyright law is a major issue in film restoration, not least because the duplication of source elements, which is an essential part of the restoration process, is often an act regulated by the copyright legislation of the country in which the restoration takes place.

Curation/curator

In film archiving, the role of the curator focuses primarily on the selection and interpretation of an institution's holdings, educational and outreach work and determining cultural policies related to its work. Unlike a traditional museum curator, the curators of moving image archives generally do not oversee or carry out hands-on preservation and restoration work, which is usually devolved to technical specialists.

D-cinema

This term is used very specifically to describe the origination, post-production and distribution of digital moving images intended for theatrical projection. For

example, the Red One camera or a DCI-compliant DCP would be considered part of a d-cinema workflow, but a DVD or a data projector intended for classroom use would not. The large-screen projection of moving image digital assets intended for other purposes (e.g. consumer use) is known as e-cinema.

Datacine – see Motion picture film scanner/scanning

Dataset

A related collection of digital assets.

Deacetylation – see Vinegar syndrome

Densitometry

The measurement of the amount of light absorbed by a given surface. In photography and the photochemical duplication of film, densitometric measurements are used to ensure consistency in printing and processing.

Developing

Developing is the first stage in the processing of photographic film after exposure, in which the film is immersed in a chemical that converts the latent image into a dye that is visible to the naked eye. The term is sometimes used colloquially, and incorrectly, as a shorthand to describe the entire processing operation.

Digitisation or Digitalisation

These two words are commonly used interchangeably to describe two different processes. (i) The creation of copies, in digital form, of moving image and/or audio recordings that were originally created on analogue recording media; for example, the dataset that is created by scanning a film original. (ii) The replacement of analogue technologies with computer-based ones within a given workflow, e.g. a cinema that replaces 35 mm film projectors with digital ones.

Digital

Literally 'of numbers'. This widely used adjective refers to the creation and use of moving images and sound represented in the form of numerical data that is processed by computers. The word is increasingly entering colloquial usage as a noun, to mean, in effect, an audiovisual digital asset.

Digital asset

Any substantive work of intellectual property embodied within a digital file, e.g. a written document, still image, moving image, audio recording or software program.

Digital asset management

The practice of creating, cataloguing, preserving, commercially exploiting, providing access to and migrating digital assets; sometimes referred to as *media asset management* within the audiovisual industries.

Digital cinema

The origination, post-production, distribution and/or theatrical exhibition of moving images using computer-based technologies.

Digital Cinema Initiatives (DCI)

DCI is a not-for-profit organisation founded in 2002 to develop and promote a set of technical standards related to digital cinema exhibition. The first version of the DCI standard was published in 2005, and has gone through two revisions since (DCI 1.2 is current at the time of writing). The DCI standard covers the method of image and audio encoding, content encryption and metadata.

Digital Cinema Distribution Master (DCDM)

The precursor files to a Digital Cinema Package (DCP), produced at the end of a digital restoration workflow. A DCDM cannot be played in a digital cinema server itself, but is the source from which the DCP files themselves are transcoded. It can be considered an intermediate stage between the output files from a film restoration project (or the post-production of a new film) and the files that are played in a digital cinema projection.

Digital Cinema Package (DCP)

A collection of files used to project a moving image programme in a theatre. The package consists of separate files holding the image, audio and metadata that comprise the programme. Although the term DCP is increasingly entering common usage to mean 'a film in digital form' in the generic sense, it was first used by an industry standards body, Digital Cinema Initiatives, LLP (DCI), to describe a package of files that is compliant with their own digital cinema standards. In common usage, the term DCP can refer to a package that may or may not be DCI-compliant.

Digital intermediate (DI)

A stage in a film production workflow whereby footage is originated on film, which is then scanned. The resulting digital dataset is then manipulated in the post-production stages using computers (e.g. editing, the addition of special effects or audio mixing), before a final output on film for distribution and exhibition.

Digital light processing (DLP)

An imaging device used in digital cinema projectors since 1999, consisting of a 'micromirror' array, in which the angle of an individual mirror, representing each pixel in the mirror, is adjusted by a microscopic hinge to refract a light source prismatically in order to form any desired colour temperature within the visible spectrum when focused through a lens. DLP chips are able to reproduce a greater contrast range, especially in the darker colours, than the imaging devices that were previously used in electronic projection.

Digital noise – see Noise

Digital picture exchange (DPX)

An uncompressed, bitmap-based digital image file format used to encode and manipulate the scanned frames of source film in a digital restoration workflow.

Digital print

A term that is sometimes used to describe a file or dataset used for digital projection in a theatre; the digital equivalent of a release print on film. In effect it is a synonym for DCP, though perhaps a more accurate description for a digital asset that is not DCP-compliant.

Digital surrogate

A digital copy of an archival media asset that was originally created on an analogue recording medium, used to provide access to its content in order to reduce the use of, and thereby safeguard the preservation of, the original.

Digital Video (DV)

This term is very widely used generically to refer to any technology for originating, post-producing and distributing photographic moving images using computing technology. Specifically, it is a trademarked brand name that refers to a package of hardware and software for recording PAL or NTSC (standard definition) images, developed principally by Sony and launched in 1995. The form factor for DV magnetic cassette tapes has also been used for other image encoding (software) systems launched since, notably High Definition Video (HDV).

Discrete

Literally, 'without continuity'; separate; independent. For example, Eastmancolor could be described as a discrete technology, because the film stock does not depend on any specific camera to function. Technicolor is not, because the proprietary film stock and camera could only be used in combination with each other.

Downconversion/Downconvert/Downrez

The transcoding of a digital moving image to an alternative format in a lower resolution, e.g. a 2K DCDM to DVD video.

Dye transfer or imbibition (IB)

The method of producing release prints used in the three-strip Technicolor system, in which dyes are absorbed, or 'imbibed' by gelatine layers applied to the print stock. As it is not a substantive coupler process and the dyes were inorganic, IB prints are not affected by colour dye fading, and are therefore considered valuable primary evidence by archivists and restorers as to the colour balance and timing intentions of the filmmaker.

Dye coupler

A colour film technology whereby a latent image is converted into a visible colour dye during processing. This can be divided into *substantive* coupler chemistry, in which the dye is present in the emulsion since the film's manufacture and is 'activated', or made visible, by the chemical developer; and *non-substantive*, in which only the couplers are present, which receive the dye in processing. Kodachrome was the only non-substantive dye colour system to be used on any significant scale.

E-cinema

A workflow involving the large-screen projection of a digital asset that does not meet the technical standards necessary to be considered d-cinema. The projection of a DVD in a classroom using an sub-2K LCD projector would be one example.

Empirical

Literally, through experience: in academic research, inquiry based on gathering and analysing information or observations. In historical or historiographical research, in crude terms it means finding out what happened, when and how. An empirical approach is generally considered distinct from a theoretical one, which seeks to identify conceptual models that can be applied to the analysis of cultural artefacts such as novels, plays or films.

Emulsion

Multiple layers of chemicals on the surface of photographic film which carry the image and, in the case of optical recording, sound information. Before exposure the emulsion is photosensitive, or 'raw'; after exposure it carries a *latent image*; and after *processing* it takes the form of visible dyes.

Evidence

In historical research, the result of the analysis of source material.

Film

There are major differences between the common and colloquial uses of this word, both as a noun and a verb, and the specifically defined ones used by technicians and engineers. As a noun, 'film' is typically used to describe a complete, post-produced sequence of moving images, regardless of the original recording medium. The word originally described analogue, photochemical film specifically, and is still used as such by professionals in the audiovisual industries. The same ambiguity and confusion applies to the word's use as a verb: for example, it is commonplace to describe 'filming' an event on a mobile phone camera, even though no actual film is involved.

Film out, film-out or filmout

The process or end output of creating a copy on film from moving image material that was originated and/or manipulated in electronic and/or digital form. An example would be a preservation internegative or fine-grain positive made using a laser film recorder following the digital restoration of a film element that had been scanned at the start of the project.

Film stock

Unexposed motion picture film as it is sold by the manufacturer.

Film history

A sub-discipline of history within academia. Among academics film history is considered distinct from film studies and media studies. Its origins are linked to a specific movement of historians who promoted the analysis of audio-visual artefacts, adapting existing methods of empirical study used to evaluate other forms of source material in history and historiography, from the launch of *Historical Journal of Film, Radio and Television* in 1981.

Film studies

A humanities discipline within academia. Among academics film studies is considered distinct from film history and media studies. Undergraduate courses began on a significant scale in European and American universities in the late 1960s, adapting established methods and approaches in literary criticism, linguistics and cultural theory to the study of films as 'texts'. Film studies rejects the analysis of empirical sources and evidence as practised by historians and historiographers in the belief that the communication of meaning between a film

'text' and its viewer is not necessarily specific to a time or place, and uses social science-based methods less prominently than media studies.

Fixing

Fixing is the final major stage in the processing of photographic film after exposure, in which the film is immersed in a chemical that desensitises the developed dye to further exposure to light, thereby enabling the film to be viewed.

Form factor

The physical characteristics of an offline carrier or medium, which can be common to multiple software systems for encoding images and sounds on them. For example, CinemaScope and VistaVision (35 mm film) and the CD and DVD (8 cm diameter optical disc) share common form factors.

Format

As a noun, the unique combination of technical characteristics of a given storage medium, analogue or digital. In computing, the word is also used as a verb to mean the complete erasure of a rewritable digital storage medium.

Gauge

The width of film, expressed in millimetres, e.g. 9.5 mm or 35 mm.

Grading – see Timing

Grain

The individual units of film emulsion that form a photographic image.

Hertz or Hz – see also Bandwidth (audio)

In strict technical terms, a unit of measurement of frequency in any oscillating signal. In the restoration of film soundtracks, it is used to measure the frequency range (bandwidth) of the recorded signal. Human hearing is typically in the range of 10 to 20,000 Hz.

High Definition Video (HDV)

This term is often used colloquially to refer to a television image (i.e. not intended for theatrical projection), but with a significantly higher resolution than 'standard definition' PAL or NTSC. In strict terms, it is actually the trademarked name of a software specification developed by a consortium of Japanese electronics manufacturers and launched in 2003, for recording high definition images onto media of the existing (since 1995) DV video cassette tape form factor. At the time

of writing HDV is a widespread origination format for low and medium budget high definition television production, including electronic news gathering.

Historiography

Literally, the history of history: the study of methods and approaches used to carry out historical inquiry.

Interlaced scan

In television technology, an interlaced display is one that refreshes alternate lines of resolution, thereby using two scanning passes per frame displayed. The process was developed to address the problem of the rapid luminance decay in a CRT display, in order to achieve even brightness across the picture. Although more recent display technologies such as the liquid crystal display and digital light processing do not suffer from this problem and have thus rendered interlacing obsolete, standard definition broadcast television standards encode the broadcast signal in interlaced form, and therefore it continues to be supported in many digital imaging technologies. A video recording or broadcast signal in which the horizontal lines of the image are not interlaced is known as *progressive*.

Laserdisc (LD)

A standard definition consumer video medium marketed between 1978 and 2001, in which recordings were distributed on optical discs, usually 12 inches in diameter. The format was read-only, meaning that people who owned players could only buy pre-recorded media to play on them: the system did not enable home recording. The system used an analogue, composite video signal, while later versions of the format also allowed for digital audio. Laserdiscs offered a significantly higher image and audio quality than the VHS-tape-based system, and therefore occupied a niche market of middle class arthouse cinema and audiovisual technology enthusiasts in the two decades before it was effectively superseded by the DVD. Specialist labels, notably Criterion and Kino, published a number of archival restoration titles on LD, making it the first consumer format on which a sustained attempt was made to distribute the technical enhancements of film restoration for viewing in the home.

Latent image

The image information on a photographic *emulsion* which has been exposed, but not *processed*. A latent image is invisible to the naked eye.

Letterbox

The display of footage originated in a wider aspect ratio than that of the display device (e.g. a 1:1.85 ratio feature film shown on a 4:3 television monitor), preserving the original aspect ratio using a horizontal matte to mask the unused part of the display.

Library

A collecting institution without a remit to preserve original works.

Light-emitting diode (LED)

A light source used in some modern motion picture film scanners and digital displays. A LED uses very little power compared to an incandescent filament bulb, generates almost no heat and can be configured in an array that enables an infinitely variable colour temperature within the visible spectrum. It is therefore ideally suited to archival film scanning applications. At the time of writing it is not possible to produce LED arrays with sufficient power for use in cinema projectors, though it is speculated that future generations of LED technology may enable this.

Liquid crystal display (LCD)

A moving image display device in which liquid crystals are used to modulate a light source and thus display any colour within the visible spectrum. LCD displays gradually replaced the CRT as the display device used in the manufacture of computer monitors, televisions and some video projectors during the first decade of the 21st century, and at the time of writing the manufacture of CRTs had ceased almost completely.

Lookup table (LUT)

In digital image processing for film restoration, a LUT is a dataset that maps the relative values of the three primary colours as recorded in the source file, in order to enable them to be adjusted so that the colour balance appears consistent on different display devices and output image encoding systems and recording media that have differing inherent colour reproduction characteristics.

Lossless compression and lossy compression – see Compression (digital media)

Lost film

In strict terms, a film that was once known to exist but for which no moving image elements are known to remain. Although this phrase was originally used to describe a film that is missing in its entirety (e.g. *The Mountain Eagle* or *London After Midnight*), it is also sometimes used in reference to films that survive, but only in poor quality copies and/or incomplete form.

Magnetic sound

A method of sound recording and reproduction in which a coating of magnetically sensitised material, or oxide, is applied to the film base. The polarisation of the individual oxide particles form the audio information, either as an analogue or digital signal.

Material exchange format (MXF)

The encoding wrapper used in the audio and video files within a Digital Cinema Package.

Media studies

A social sciences discipline within academia. Among academics media studies is considered distinct from film studies and film history. It uses methods drawn and adapted from areas such as sociology, economics, politics and cultural studies to analyse the role and impact of mass-communications media in society. Within this framework film is not studied in isolation, but considered alongside and in terms of its interaction with broadcast media, the press and new media.

Metadata

Literally, data about data. The term is commonly used to describe information that identifies and describes an audiovisual digital asset that is contained within the asset itself.

Monochrome

Literally 'one colour', this adjective is commonly used as a synonym for 'black and white'. A more technically precise definition would be to describe a photographic emulsion or dye with only one visible shade, to which multiple non-photographic dyes (e.g. hand colouring, stencil colouring, tinting and/or toning) can be applied in separate processes.

Motion picture film scanner/scanning

A device for (noun) or the process of (verb) creating a digital representation of the images on motion picture film as individual, discrete frames. Some scanners, but not all, also capture optical or magnetic audio tracks in the same pass as the picture. The scanning of source film elements is the first major step in a digital film restoration workflow. In strict technical terms, motion picture film scanning is considered distinct from telecine in that in the latter the image is encoded in a way that is compatible with the scanning requirements of interlaced television, whereas in the former each frame is encoded as a discrete image, and usually at a much higher resolution than is required by SD television. But as the conversion

of consumer broadcast television to digital systems in the developed world progressed in the late 1990s and early 2000s, the words 'telecine', 'scan' and 'transfer' entered interchangeable colloquial use without regard for their technical distinctions. The situation is further complicated by the fact that some models of machine made during the transitional period (e.g. the Philips Shadow, launched in 2000) could produce both telecine and individual frame outputs. Even more confusing is the fact that the term 'datacine' was used as a trademark by at least one equipment vendor in an attempt to distinguish scanning from telecine.

National Television Standards (originally System) Committee (NTSC)

Formally, a subcommittee of the US government's Federal Communications Committee. In general usage, NTSC refers to the colour television broadcasting standard the committee authorised for use in December 1953. NTSC was used principally in the USA, Canada, much of South America and Japan from the early 1950s until its replacement by digital terrestrial systems from the early 2000s. It is considered a standard definition system, roughly equivalent to 480i30 in digital nomenclature.

Near instantaneously compacted and expanded audio multiplex (NICAM)

A method of broadcasting two channels of digital audio alongside PAL and SECAM television, used extensively in Europe and on a more limited scale in Asia during the 1990s and early 2000s.

Negative cost

The cost of making a film to the point at which post-production is complete, i.e. an original, cut camera negative exists. In other words, the cost of actual production, excluding distribution and marketing.

New film history

An academic approach to the study of film as evidence of human activity in the past, distinguished by its proponents from what they would term 'old' film history by an emphasis on understanding the use of cinema to reflect and inform the subjects and issues it covers, as distinct from the history and development of the medium itself.

Nitrocellulose or cellulose nitrate or nitrate

An organic film base consisting of cellulose and nitric acid. Almost all 35 mm film manufactured for motion picture use from the medium's invention until the early 1950s was on a nitrate base. Nitrate film is highly inflammable and decomposes

over time, thereby creating significant technical problems for archivists charged with its long-term preservation.

Noise

This term is most frequently used to describe the audible but unwanted component of an analogue sound recording, e.g. phonograph surface noise or magnetic tape hiss. In colloquial use it has been extended to describe unwanted artefacts in an audiovisual recording more generally, including scratches on film, dropouts on a videotape or 'digital noise', consisting of clearly visible pictures in a compressed digital moving image.

Non-theatrical (distribution and exhibition)

The screening of films to an assembled audience, but not in a public theatre to members of the public who have purchased individual admission tickets. Examples of non-theatrical exhibition include screenings by film societies and to university students. Non-theatrical screenings, often on 16 mm prints, was an important means of access to archival films before the emergence of consumer video technologies in the late 1970s.

Optical (effect)

An elementary visual effect added to a film during the duplication process in post-production, e.g. a fade to black or a dissolve between two shots. These will have to be recreated in restoration if the source elements used do not incorporate these effects.

Optical printer

A device used in photochemical film duplication, in which an image of the source element is projected through a lens onto the raw film stock that is receiving the copy.

Optical sound

An audio recording made as a photographic image on film, either as an analogue waveform, digital data or a timecode to synchronise an external playback source.

Original

The physical medium on which an initial recording is made, from which all other elements are copies. In the case of film this is the roll that is exposed in the camera. In archiving, 'original' is often used informally to mean 'best surviving element', 'best' being defined either as the closest generation of duplication to the original, or suffering from the least damage or decomposition of all the known surviving elements.

Orphan film

A phrase that began to be used by film archivists in the late 1980s to describe films which survive and have been preserved, but for which it is impossible to identify the legal copyright owner or if copyright still subsists. Its definition in everyday speech has since broadened to include any film which has been neglected in general, is poorly understood and/or overlooked by archivists, historians, critics and the public.

Panning and scanning

A technique used to facilitate the television broadcast and/or publication of a film on a consumer video with a narrower aspect ratio than the one in which the film was originally produced. It uses the entire surface area of the destination ratio without the need for letterboxing, by cropping the original image selectively from shot to shot in order to retain as much of the action as possible in the transferred image. Panning and scanning was used extensively during the second half of the 20th century, when almost all broadcast television systems used the 4:3 ratio, but most cinema films were shot in something wider. The conversion to widescreen (16:9) television from the late 1990s onwards resulted in a dramatic reduction in the use of panning and scanning, and the extent of the cropping needed in cases where it was still used (usually from anamorphic ratios to 16:9). Panning and scanning was a highly controversial practice and frequently criticised on ethical grounds, but preferred to letterboxing by a majority of the viewing public.

Passive conservation

An approach to preserving films that emphasises the long-term survival of original or best surviving elements over the creation of copies on newer media that are considered more resistant to chemical decomposition or format obsolescence. The most widely used form of passive conservation is storage in temperature and humidity conditions optimised to inhibit the decomposition of film bases and colour dyes as far as possible. The other considerations involved in the long-term storage of archival documents and media also apply, principally fire protection and suppression systems, security, and, ideally, the siting of archival film stores away from areas that are at significant risk of natural disasters (e.g. earthquakes and floods) or man-made ones (e.g. near airports or industrial facilities that use explosives).

Perchlorethylene or Perc

An organic solvent used in the cleaning and duplication of motion picture film, known formally as tetrachloroethylene , its designation by the International Union of Pure and Applied Chemists, and outside film archiving circles colloquially as 'dry cleaning fluid' due to its more widespread use for the dry cleaning of clothes and other consumer fabrics. Its molecular formula is C_2Cl_4. Perchloroethylene replaced 1,1,1,Tricholoroethane as the most widely used solvent in ultrasonic film cleaning during the early 1990s, and is also used in

wet gate printers. While it is considered the most effective chemical currently available for use in these applications (chemicals that have previously been used, principally carbon tetrachloride and 1,1,1-trichloroethane, are generally considered more efficient at cleaning film, but are effectively outlawed under international agreements to protect the environment), it is highly toxic and significant environmental concerns relate to its use.

Phase alternate [or alternating] line (PAL)

A technical standard for colour television broadcasting and videotape recording developed in West Germany. Variants of PAL were used in many countries worldwide between the late 1960s and its replacement by digital terrestrial systems from the late 1990s. It is considered a standard definition system, roughly equivalent to 576i25 in digital nomenclature.

Photochemical

A production, preservation or restoration workflow based on analogue duplication through successive generations of photographic film.

Photogard

A film cleaning treatment sold by the 3M company from 1977 (and renamed Scotchgard in 1993), in which a liquid polymer solution forms a permanent protective coating on the film surface.

Photosensitive

Literally, sensitive to light: a medium which undergoes a physiological or chemical change in response to being struck by light, e.g. photographic film emulsion or a CCD.

Piracy

The commercial exploitation of moving images in contravention of copyright law. The most common forms of piracy today are unauthorised copying and distribution. Before the use of consumer recording media for moving images became widespread in the 1980s, copyright theft also took the form of illegal theatrical exhibition, both by screening stolen prints and falsifying sales figures submitted by exhibitors to distributors.

Polarity

Whether a film element carries a negative or positive photographic image.

Polyester

A commonly used contraction of polyethylene terephthalate. A wholly synthetic film base initially developed in the 1960s and which entered widespread use for the production of release print and some intermediate film stocks in the late 1980s. It has now largely superseded cellulose triacetate for this purpose, and is believed to be immune from decomposition issues of the sort that affect cellulose acetate and nitrocellulose bases.

Post-production

The processes undertaken between the shooting of individual scenes and the distribution of the finished film.

Post house

A business that carries out post-production operations subcontracted by a filmmaker. These can include the creation of special effects, negative cutting, sound mixing, the preparation of titles and telecine transfer. Some post houses also provide services related to film restoration, ranging from the management of complete projects to individual processes, e.g. the examination, cleaning and repair of film elements prior to duplication at a lab.

Print

As a noun, this can refer to any film element that carries a positive image which is a copy of another film element (i.e. any positive film except camera reversal originals). In common usage it is usually synonymous with *release print*, though there are other specific types of print used in the photochemical post-production process, e.g. rush prints and workprints.

Printer

A device that duplicates motion picture film by rephotographing the image on an exposed and processed source element onto new and unexposed destination stock. See also *continuous printer*, *step printer*, *contact printer* and *optical printer*.

Preservation

An archiving activity that is generally understood to be distinct from restoration, although the distinction between the two is often blurred in everyday speech and understood in different terms among professionals (in other words, there is no universally agreed definition of the distinction). In broad terms, preservation refers to the long-term storage of the content of a film in the condition that an archive acquired it, either by conservation of original elements or the creation of copies that embody as little technical change as possible from the characteristics of the source.

Processing

The procedure in which exposed photographic film is immersed in a series of chemical solutions which transform the emulsion from a latent image into a visible dye.

Progressive scan

In television, video and digital imaging technology, a broadcast signal, video recording or digital file in which the moving image content is not *interlaced* (see above).

Provenance

In very crude terms, where something came from. The study of a film's provenance can include establishing the history of multiple versions, the generational sources of elements in an archive's collection, a film's release history and preservation or restoration work carried out in the past. This knowledge can be used to inform decision-making in restoration projects.

Psychoanalysis

In film studies, the application of the ideas and theories of Sigmund Freud to the interpretation of cinematic narratives and aesthetics.

Public sector

In the context of this book, this UK English term is used to describe a film archive or museum that is a state-mandated agency , funded wholly or mainly from direct taxation. It is not a direct synonym for a 'non-profit' or '501(c)' in the USA, which simply means that it does not return a dividend to shareholders: a non-profit can be privately owned and funded. The term 'charity' or 'charitable organisation' is used in the UK to describe an organisation that is not for profit but does not receive a significant proportion of its funding from the taxpayer either.

Pulldown

The number of perforations in a 35 mm, 65 mm or 70 mm film element that are advanced by the intermittent mechanism in a camera, step printer or projector. The most widely used 35 mm formats have a four-perforation pulldown, and five for 65/70.

Private sector

In the context of this book, this UK English term is used to describe a commercial organisation that undertakes film preservation and/or restoration activity. It is roughly synonymous with 'for profit' in the USA.

Real time

Carrying out a technical operation in the same time it would take to view and/or listen to the content being worked on. For example, if a typical 35 mm sound film was being scanned in real time, the scanner would be running at 24 frames (or 1½ feet) per second.

Release print

One of a large number of identical film prints made as the final output of the post-production process, for projection in theatres.

Remaster

This term, though in widespread common usage, is in strict technical terms an oxymoron. It is usually intended to describe the practice of producing a new copy derived from original, or best surviving elements of a given film, incorporating significant technical modifications (e.g. the correction of colour dye fading, or noise reduction on a soundtrack), and from which subsequent mass-production copies are made, on consumer media, theatrical distribution media or both. Of course the verb implies the creation of a new original, which is a technical impossibility – there can only ever be one original element that passes through a camera or recording device at the moment of capture.

Restoration

An archiving activity that is generally understood to be distinct from preservation, although the distinction between the two is often blurred in everyday speech and understood in different terms among professionals (in other words, there is no universally agreed definition of the distinction). In broad terms, restoration refers to one or a combination of processes of technical intervention, intended to create a copy of the content of a film from elements acquired by an archive, which more closely recreates aesthetic characteristics of that content which were known to exist at some point in the past, but which are not present in the surviving elements.

Scanner – see Motion picture film scanner

Scotchgard – see Photogard

Sensitometry

The measurement of how quickly a permanent record is created on a photographic emulsion in response to a given intensity, duration and colour temperature of light exposure. Accurate knowledge of the sensitometry characteristics of a given film stock is essential in order to ensure consistent brightness, contrast and (if applicable) colour balance in photochemical duplication.

Séquentiel couleur à mémoire (SeCAM or SECAM)

A technical standard for colour television broadcasting and videotape recording developed jointly in France and the Soviet Union. It was used in France between 1961 and its replacement by digital terrestrial broadcasting between 2005 and 2011, and in the former Soviet Union and some African countries. It is considered a standard definition system, roughly equivalent to 576i25 in digital nomenclature.

Server

In digital cinema, a server is a computer which holds the DCP on a hard disc, decrypts the image and sound data (if necessary) and passes it to the digital cinema projector and the cinema's sound system. Some servers perform digital-to-analogue conversion on the audio data internally, while in other systems this function takes place in a separate integrated audio processor and pre-amplifier.

Single system

The recording of picture and sound on the same strip of film and in the same camera on location or in the studio. Single system filming was only used extensively in news filming (optical sound in the 1930s, and 16 mm film with combined magnetic sound for television news gathering from the 1960s to the 1980s).

Slow fire

In archival document conservation, this term refers to the chemical decomposition of paper caused by acid used in its manufacture. The process is in many ways comparable to the decomposition of nitrocellulose and cellulose acetate-based film. The term is borrowed from the title of a documentary film made to bring the problem to public attention, *Slow Fires: On the Preservation of Human Record* (USA, 1987, dir. Terry Saunders).

Small gauge

Film formats with a width below 35 mm. The term is most commonly used to refer to 8 mm, 9.5 mm and 16 mm film. The term 'substandard' (based on the idea that 35 mm was the universal standard film gauge) was also used before it acquired negative connotations in everyday speech.

Society of Motion Picture [and Television] Engineers (SMPTE)

A professional body founded in 1916 in Hollywood to represent and promote the role of technical workers in the film industry, and to establish technical standards. The 'and Television' was added to the organisation's name in 1950. SMPTE standards are used in film restoration, notably in relation to media formats and timecodes.

Source (film archiving)

The film element from which a duplicate is made in photochemical printing or digital scanning. The term is frequently, though incorrectly, used interchangeably with 'original', as the source used In a given duplication process is not necessarily the camera original element or even the closest surviving generation to it.

Source (historical study)

Artefacts or data that are analysed in order to understand the historical event or issue they relate to. For example, a propaganda film made during the Second World War could be used as a source for studying the reasons why it was fought.

Standard definition (SD)

A video image of a resolution equivalent to the terrestrial broadcast television systems in mainstream use until the second decade of the 21st century, i.e. NTSC, PAL and SeCAM. In traditional television industry nomenclature these are referred to as 525-60 (NTSC) and 625-50 (PAL), and in digital video terminology, 480i (NTSC) and 576i (PAL and SeCAM).The initials SD also refer to the Secure Digital flash memory card format, but are not used in this context in this book.

Step printer

A device used in photochemical film duplication, in which the film transport mechanism is intermittent and each frame is duplicated as a discrete image while the source and destination film stocks are stationary.

Stereo or stereophonic (audio)

From the Greek, literally meaning 'firm' or 'solid'. In the context of audio technology, this word is used primarily as an adjective to describe a consumer audio (e.g. music) recording that consists of two individual recordings, or 'channels', that are played together in synchronisation through loudspeakers positioned to the left and right of the listener (2.0 in digital nomenclature), thereby creating a sense of space in the reproduced sound. In the film industry it has also been used colloquially to describe soundtracks with three or more channels, so much so that it can no longer be regarded as a reliable synonym for a 2.0 recording.

Stereo or stereoscopic (moving images)

A technique whereby two separate moving images are photographed in synchronisation using two cameras, and then projected or displayed in such a way as to

give the viewer the impression of seeing a three-dimensional picture. The cameras are positioned in order to approximate the difference in the field of vision of the left and right human eyes.

Stereo variable area

A variable area optical film soundtrack containing multiple, synchronised, channels of analogue audio waveforms.

Stripe

A combined magnetic soundtrack that has been applied to the base side of a film element after processing.

Technical selection

The process of evaluating multiple film element copies of the same footage in order to determine which is to be used in a restoration project.

Telecine

A device for (noun) or the process of (verb) creating an electronic representation of the images and audio on motion picture film using an SD broadcast video system (NTSC, PAL or SeCAM). In strict technical terms, telecine is considered distinct from motion picture film scanning, in that in the former the image is encoded in a way that is compatible with the scanning requirements of interlaced television, whereas in the latter each frame is encoded as a discrete image, and usually at a much higher resolution than is required by SD television. But as the conversion of consumer broadcast television to digital systems in the developed world progressed in the late 1990s and early 2000s, the words 'telecine', 'scan' and 'transfer' entered interchangeable colloquial use without regard for their technical distinctions. The situation is further complicated by the fact that some models of machine made during the transitional period (e.g. the Philips Shadow, launched in 2000) could produce both telecine and individual frame outputs. At the time of writing, standalone telecine technology had become almost obsolete in the developed world.

Text

A metaphoric device often used by cultural theorists in the 1960s and 1970s and adopted within film studies, to treat films as works of literature. Methods of film analysis such as semiotics, structuralism, Marxism and psychoanalysis involve the 'close textual analysis' of individual films or scenes within them, in order to identify what the practitioner believes is meaning or significance being communicated between the filmmaker and audience.

Throw

The distance between the projector's gate and the screen in a theatre. This figure is significant in that, along with the surface area of the screen in a given aspect ratio, it determines the focal distance of the projection lens that is needed. Theatre designers tend to avoid a short throw to a large screen if possible, because this requires the use of a lens with a very small aperture in order to achieve even focus across the projected image (equivalent to depth of field in a camera). Conversely, in a film projector, very long throws tend to magnify the slight vertical and horizontal weave that will be present in even the highest quality and best maintained mechanisms. In the architectural design of a theatre auditorium intended to showcase the entire range of aspect ratios, including the legacy ratios used in restorations, the throw needs to be thought through carefully.

Timing

A term used mainly in North America (its UK English equivalent is *grading*) to describe the process of determining the contrast and density of a photochemically copied or digitally captured film. This was originally accomplished (and in some cases, still is) by adjusting the duration of exposure in a step printer, hence the term.

Tinting

The application of a coloured dye that is absorbed by the emulsion of black-and-white film, thereby giving the dark areas of the image a uniform colour hue.

Toning

The application of a coloured dye that is absorbed by the cellulose base of black-and-white film, thereby giving the lighter areas of the image a uniform colour hue.

Tramline

The colloquial term for a mechanically inflicted lateral scratch on the surface of a film element that is visible in reproduction as a vertical line.

Transcoding

Duplicating a digital media file into a different encoding format from that of the source.

Transfer

A colloquial and imprecise (to the point of being almost technically meaningless) term that is often used to describe the process (verb) of making an electronic

representation of a motion picture film and/or audio recording, or the resulting representation itself (noun) – in crude terms, copying between media formats.

Ultrasonic film cleaning

An automated method of cleaning motion picture film in which it is immersed in a chlorinated solvent and agitated by ultrasonic energy in order to separate and remove contaminants from the film's surfaces.

Upconversion/upconvert/uprez

The transcoding of a digital moving image to an alternative format in a higher resolution, e.g. a 2K DCDM to a 4K DCP.

Variable area

A method of optical sound-on-film recording in which an aperture in front of a light source of fixed intensity is modulated by the audio signal as the unexposed film passes it.

Variable density

A method of optical sound-on-film recording in which the intensity of a light source is modulated by the audio signal as the unexposed film passes a fixed-width aperture in front of it.

Video

Literally, Latin for 'I see'. The word has traditionally been associated with television technology, hence terms such as 'video monitor' (a screen that displays electronic moving images, but does not contain a broadcast tuner or playback device), 'videotape', 'videotape recorder' or simply 'video' as a colloquial shorthand to refer to a recording or the hardware and/or software associated with its creation and/or playback. In recent years its use has crept into high definition digital moving images as well, with phrases such as 'the video' being used to distinguish the image from the audio component. As with 'film', the colloquial use of 'video' is now so widespread, in so many contexts that any attempt at a meaningful and specific technical definition is impossible.

Vinegar syndrome

A process, known formally as deacetylation, which causes the decomposition of cellulose acetate-based film stocks. Acetic acid attacks and degrades the cellulose within the film base over time, resulting in the film base shrinking, deforming and becoming brittle, eventually to the point at which affected elements can no longer be projected or copied. Vinegar syndrome, named colloquially (by the pioneer archivist Harold Brown) as such after the acetic smell of affected elements, can be inhibited by storage in a cool and dry atmosphere.

Virtual print fee (VPF)

The business model through which large numbers of mainly independent theatres in the developed world installed d-cinema projection equipment from around 2007–2008. The initial cost of the equipment is borne by a third party and effectively supplied to the exhibitor on a hire-purchase basis, through repayments proportional to box office takings.

Vitaphone

The trademark name of a sound recording and reproduction system for films, developed by Warner Brothers and used commercially between 1926 and 1931 for production, and until the mid-1930s for distribution and exhibition. Vitaphone is generally regarded as the first film sound system to have been marketed on a significant scale.

Wet gate printing

The photochemical duplication of film while immersed in a liquid with a similar refractive index to that of the film base itself, usually perchlorethylene, in order to prevent the image of scratches in the source element from being present in the copy.

Windowbox

The display of footage originated in a narrower aspect ratio than that of the display device (e.g. an Academy ratio feature film shown on a 16:9 television monitor), preserving the original aspect ratio using a vertical matte to mask the unused part of the display.

Wrapper

In digital moving images, a file format within which a number of different codecs (the software used actually to represent the media content in digital form) may be used. Examples include MXF and Apple's QuickTime.

Xenon arc

The artificial light source used in used in most theatre projectors since the late 1960s. Xenon arc lamps produce a significantly higher colour temperature than the carbon arc lamps that preceded them, which restorers need to compensate for when grading release prints of restoration projects of films that were originally made in the carbon arc era.

List of Acronyms and Abbreviations Used in the Text

AMIA	Association of Moving Image Archivists
AMPAS	Academy of Motion Picture Arts and Sciences
BBC	British Broadcasting Corporation
BD	BluRay disc
BFI	British Film Institute
BASF	Badische Anilin- und Soda-Fabrik
BKS[TS]	British Kinematograph [, sound and television] Society
CEDAR	Computer Enhanced Digital Audio Restoration
CCD	Charge coupled device
CDS	Cinema Digital Sound
CGI	Computer generated imagery
CRT	Cathode ray tube
DCDM	Digital Cinema Distribution Master
DCP	Digital Cinema Package
DLP	Digital Light Processing
DPX	Digital Picture Exchange
FCP	Final Cut Pro
FIAF	Fédération Internationale des Archives du Film (International Federation of Film Archives)
FIDO	Film Industry Defence Organisation
DI	Digital intermediate
DV	Digital video
DVD	Digital Versatile Disc
HDV	High definition video
IAMHIST	International Association of Media and History
IB	Imbibition (a release print made using the Technicolor dye-transfer process)
IEEE	Institute of Electrical and Electronic Engineers
EMTEC	European Media Technologies
HD-DVD	High definition – Digital versatile disc
IP	Interpositive *or* intellectual property
IWM	Imperial War Museum
Kbps	Kilobits per second
LoC	Library of Congress
LCD	Liquid crystal display
LD	Laserdisc
LED	Light-emitting diode
LTO	Linear tape-open
LUT	Lookup table
Mbps	Megabits per second
MOD	'Making-of' documentary
MoMA	The Museum of Modern Art
MXF	Material exchange format
NFL	National Film Library (the name of the British Film Institute's film archive from its inception in 1935 until it was renamed the National Film Archive in 1955).
NICAM	Near Instantaneously Compacted and Expanded Audio Multiplex

NTSC	National Television Standards Committee
PAL	Phase alternate [or alternating] line
PVR	Personal video recorder
RAID	Redundant array of independent discs
RCA	Radio Corporation of America
SCMS	Society of Cinema and Media Studies
SD	Standard definition
SeCAM	Séquentiel couleur à mémoire
SMPE	Society of Motion Picture Engineers
SMPTE	Society of Motion Picture and Television Engineers
S/N	Signal-to-noise [ratio]
UCLA	University of California, Los Angeles
UEA	University of East Anglia
UHF	Ultra high frequency
VCR	Videocassette recorder
VHF	Very high frequency
VHS	Vertical helican scan (correct) *or* Video home system (often claimed, incorrectly).
VTR	Videotape recorder
VPF	Virtual print fee

Notes

Introduction – Why Restoration Matters

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34. An example, once again, can be found in the saga of the restoration of *Metropolis*. As recalled by interviewees in the documentary *Die Reise nach Metropolis* (Germany, 2010, dir. Artem Demenok) the almost complete version discovered in Argentina in 2008 was in the form of a 16 mm internegative, optical reduction printed from a nitrate projection print, probably in 1973 or 1974. The print had since been destroyed. It was part of a collection of prints belonging to a prominent film critic which had been 'preserved' in this way, because the extent of the loss of quality in the copying process was not understood and the cost of storing a large nitrate collection long term was considered prohibitive. As a result, extensive physical damage to the 35 mm print used to strike the surviving 16 mm internegative was transferred as a photographic image and thus could not be removed or mitigated using physical treatments, which would have been possible had the earlier generation element survived.
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2 Where are Films Restored, Where Do They Come From and Who Restores Them?

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3 The Technique of Film Restoration

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4 The Presentation of Film Restoration

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5 Conclusion: The Ethics and Study of Film Restoration

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Index of Film Titles

Subject Index