Criteria for the Use of Digital Technology in Moving Image Restoration

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Digital techniques for moving image restoration have developed considerably in recent years and have become an alternative to traditional methods of analog duplication. However, enthusiasm about new possibilities suddenly available has been mixed with skepticism among restorers and archivists. Looking at some of the results achieved by digital technologies, this skepticism is understandable, especially when viewing those products that are mistakenly called "restorations." But, taking a closer look at this issue, could it be possible that we are dealing less with a criticism of new tools than with the conventional use of them? This article does not aim to favor digital over analog methods. Rather, it addresses the question of whether the new technology can be applied without violating conventional criteria in moving image restoration.

What are conventional criteria in moving image restoration? Classical restoration theory defines authenticity, reversibility, and transparency as the most important ethical requirements. Furthermore, when considering this question, we have to bear in mind certain aesthetic aspects, such as the concept of the aesthetic value and the characteristic look of a work, both of which become relevant when dealing with moving images.[1] In this article I will discuss to what extent these ethical and aesthetic concepts can be adopted for the use of digital technologies in moving image restoration (as defined in the next section). In some parts, especially those dealing with ethical and aesthetic issues, the principles will apply for both analog and digital restoration methods, since restoration will be discussed as a theoretical concept rather than as a technical process. Theoretically, any technique or system that supports this concept has to be regarded as appropriate for restoration purposes. For most parts, the reader will notice the absence of practical examples. The objective of this article is to propose theoretical guidelines that can help restorers and archivists use available technological possibilities in an ethically sound manner. In this discussion, digital techniques will be regarded as merely additional tools for moving image restoration in general. Nevertheless, their role within my discussion is crucial, since the wide range of new possibilities they offer brings ethical considerations back to the attention of restorers and archivists. Furthermore, the fact that this discussion applies to both analog and digital techniques underlines the requirement that ethical principles for traditional restoration methods must not lose their validity with the advance of digital tools. The fields of reconstruction and sound restoration will not be discussed, since I am focusing on the restoration of the image alone.

Moving images consist of two components: a material component, which is the image carrier as an object, and an immaterial component, which is the image content. The latter is represented by the image, being the readable and visible part of the work. The image has two functions: an aesthetic one, referring to its aesthetic value, and a narrative one, as it tells a story. "Story," or content, is not restricted to so-called narrative films; it can also be of documentary or abstract character. This article deals with the aesthetic function of the image. Thus it will discuss theoretical principles for the restoration of the image on a visual level.

To prevent confusion that could arise from the lack of a definitive terminology in the field, I commence by defining some relevant

terms. Naturally, they are based on interpretations and personal opinions of several authors. Although many differing interpretations of these relevant terms can be found in literature, to me the following provide the most logical explanations.

TERMINOLOGY

Before proposing a definition of *restoration* it is necessary first to clarify some terms that relate to the condition of moving images. Using texts by Michele Canosa and Gian Luca Farinelli and Nicola Mazzanti, we can differentiate between *damage*, *errors*, and *defects* when describing the physical condition of moving image material.[2]

Damage (Italian: *guasto;* French: *dommage;* Spanish: *daño;* Portuguese: *dano;* German: *Schaden*) concerns the physical and chemical condition of a moving image.[3] Its origin lies in the history of the work. Damage includes traces of age, decay, and use or misuse of the material, such as scratches, tears, fingerprints, stains, shrinkage, and loss of color. Additionally, Canosa suggests a distinction between *damage* (physical condition) and *change* (Italian: *alterazioni*), the latter describing the chemical condition of the material. *Change* could be any appearance that results from material decay, often due to inadequate storage conditions.[4]

Error (Italian: *errore;* French: *erreur;* Spanish: *error;* Portuguese: *erro;* German: *Fehler*) refers to a modification of the moving image that does not belong to its original content but rather to a treatment to which the work has been subjected. These often unintended alterations can be errors made during copying processes, such as visible framelines, flickering, unsteadiness, as well as editing errors such as inverted shots, or cuts made by censors.

A *defect* (Italian: *difetto;* French: *défaut;* Spanish: *defecto;* Portuguese: *defeito;* German: *Mangel*) can be *damage* or an *error* causing a visually (and/or acoustically) perceptible effect in the moving image that can be dated back to the original production of the work and is therefore part of its original characteristics. Furthermore, a *defect* can be any imperfection deriving from the original production of the moving image, such as that which resulted from technical limitations during the time of production. Because they derive from the original production, *defects* have to be regarded as an integral part of the original work.

Having defined terms relevant for the condition of moving images, I will now continue with interpretations of the terms *conservation, duplication, restoration, reconstruction,* and *preservation* in relation to moving images.

Conservation includes any activity that prevents or minimizes the decay of archived moving image material, such as optimizing the storage environment in order to slow chemical decay *(passive conservation)*. Farinelli and Mazzanti describe the primary goal of *conservation* to be the preservation of the two components of a work, the original object together with the original content.[5]

Duplication should produce a facsimile of the film, made for preservation or access purposes. Paolo Cherchi Usai interprets the most accurate *duplication* to be that procedure which subtracts the traces of time and use from the material under treatment to bring back the copied picture to its original condition.[6] Duplication may, or may not, be part of a larger goal of restoration.

For moving images, *restoration* can be understood as an intervention in the visual or material part of a film. *Restoration* should reduce or remove *damage* and *errors*, while preserving *defects* inherent in the work at the time of production as part of its individual characteristics.[7] When evidence exists that documents have lost original characteristics, those original qualities should be regained where possible. During *restoration*, the restorer must not introduce new *damage* or *errors* or change or distort the work's original nature.[8] Theoretically, any technique supporting this concept should be regarded as appropriate for application within a *restoration* project.

Though not required, image *restoration* can be combined with *reconstruction*, the latter of which refers to the restoration of the narrative element of a film, using editing as an instrument. *Reconstruction* can be described as "editorial restoration" that aims to rebuild a specific version of the work.[9]

Finally, *preservation* is the totality of activities that guarantee the survival and the permanent accessibility of our moving image heritage. It includes the processes of *conservation*,

duplication, restoration, and *reconstruction* of moving images, as well as the "recreation or emulation of obsolete technical processes, equipment, and presentation environments," and all research supporting these activities, as described by Ray Edmondson.[10]

THE CONCEPT OF AUTHENTICITY

According to classical (fine arts) restoration theory, the authenticity of a work refers to its material, structure, the traces of its production, and its individual history, function, and context, as well as its historical, art-historical, aesthetic, and artistic meaning.[11] Thus, authenticity is a value that amalgamates original characteristics as well as new characteristics, such as the traces of the individual history of a work, including signs of age and use. During its passage through history an object loses some of its original characteristics while continuously acquiring new ones, but always maintains complete authenticity.[12] Applying the concept of authenticity to moving image restoration as defined above, which permits, at least partly, the removal of damage and errors (signs of the individual history of a work), their contradiction becomes obvious. In respect to the traditional concept of authenticity, restoration must not be carried out, which is rather counterproductive for our discussion. To mediate between these mutually exclusive positions, I propose to set the term *authentic* in relation to two aspects of moving image restoration: the material aspect, i.e. the restored object *(authentic work),* and the immaterial aspect, i.e. the restored image *(authentic restoration).*[13]

The term *authentic work* could be a subject for a general discussion about the meaning of *authenticity* for moving images, starting from Walter Benjamin's hypothesis that the whole sphere of authenticity is outside reproducibility.[14] This supposition seems obvious, since the term *authentic* refers to the credibility of a work as an original, not to its copy. On the other hand, reproducibility is part of a moving image's nature and arises from its original function (being made for distribution to a broad audience) and production mode: moving images are not works of art that are being reproduced; they are "designed for reproducibility."[15] In other words, being reproduced is part of a moving image's authenticity. However, the discussion about what is decisive for the authenticity of moving images is beyond the range of this article. Whether the authentic value of a work is put only in relation to its original characteristics or in addition to characteristics that derive from its individual history, here I will focus on its meaning for restoration.

How can we preserve the authenticity of a moving image when executing a restoration (and I am not yet talking about what I termed *authentic restoration*? Again, looking at classical art history, the theory of works of art as possessors of various "values" developed by the Austrian art historian Alois Riegl can help in finding an answer to this question (although focusing on buildings, Riegl's theory of different values of monuments may be applied to other works of art).[16] According to the concept of *historic value,* being one of Riegl's *commemorative values* of monuments, symptoms of decay must by all means be removed.[17] Pointing to the importance of the credibility of a monument as a witness of time, however, his concept of *historic value* also claims that this removal of time's wear on the object must not happen with the monument itself but only with a copy or merely in thoughts or words.[18] Thus, Riegl calls for the treatment of a copy instead of the modification of an original. Applying this concept to moving image restoration, the authenticity of a work, i.e., the *authentic work,* can be respected by leaving it unaltered and intervening on a copy, which is hopefully today's practice. The original, however, must be conserved adequately to be available for future generations (this also refers to the concept of reversibility that will be explored below).

From a material point of view one can be fully satisfied. But what about the immaterial part of the work, the image itself? Isn't it the image that is handed down as the "work" through restoration to be presented to the audience? The fact that we are working on copies rather than on the original object should not seduce us to adopt an "anything is allowed" strategy. This concern leads us to the *authentic restoration,* which, in terms of the concept of restoration, means maintaining the characteristic look of a moving image work (to be described further on in this article) and its presumed original characteristics. This goal can

be achieved by following the concept of restoration as defined above; in other words, by removing or reducing only damage and errors while respecting the limits of a restoration by preserving the work's defects.[19] What do we know about the original condition of a work, however? Many different opinions exist concerning the term *original* in the field of moving images. Paolo Cherchi Usai, for instance, insists that the original state is a hypothetical condition, since the restorer cannot know exactly what an *original* looked like.[20] The definition of *original* is another issue that I will have to neglect in this article, because I believe that the term *original* must be evaluated anew for each and every case.

THE CONCEPT OF REVERSIBILITY

History shows that restoration methods that were accepted during a certain period were subsequently criticized and abolished by the following generation. These ever-changing standards concerning the way cultural heritage should be treated have made reversibility of any restoration activity one of the most important principles of restoration theory. It implies the possibility of unrestricted recovery of an object's state before intervention.[21] Generally, restorations of moving images are carried out on a copy of the original material and thus guarantee reversibility, meaning that the starting material is not modified and is thus available for future restorations or other purposes, as long as it is conserved adequately. This tenet is true for analog as well as digital restorations.

In today's discussions, however, reversibility is mostly regarded as an illusion, since certain methods of restoration induce changes in the original material that might not be immediately visible to the naked eye but are absolutely significant on a chemical or physical level. To give an example in moving image restoration, washing film material as a preparatory measure for duplication and wet-gate printing can have a negative effect on the long-term stability of the material by affecting the plasticizer, which leaves the film brittle after several applications.[22] Furthermore, passing any film material in questionable condition through printing or other machinery puts it at risk of being torn, scratched, or otherwise physically damaged. Obviously, in such a case reversibility of restoration is not a given.

In moving image restoration, reversibility is regarded rather as "repeatability," as suggested by Paul Read and Mark-Paul Meyer.[23] It implies that one has at one's disposal the same range of options and conceptual decisions for all future restorations.[24] In this context, digital restoration possibilities can offer an advantage over traditional methods, such as in the case of tinted films that show dye loss after solvent cleaning. The "dilemma" described by Read and Meyer of there being no cleaning method possible that does not irreversibly damage the material could be solved by scanning the film before attempting to clean it and then digitally restore it.[25]

Concerning the reversibility of digital restoration, another issue has gained importance. It can happen—and has many times—that the results of digital restorations are lost. We are all aware of the poor safety offered by hardware and digital storage systems. A slight problem and all data, including the results of perhaps several weeks of work, can be lost. Therefore all data produced during the digital process (scanned material as well as results and metadata of the digital restoration) have to be preserved in order to guarantee the repeatability of the digital restoration process. Please note that I am not talking about digital preservation of film heritage but about fulfilling the claim for reversibility or repeatability of digital restoration. This requirement also supports the third ethical concept mentioned in the introduction, the concept of transparency, which will be discussed below.

The following section will explore aesthetic aspects pertinent to restoring moving images. Again, this will be a general discussion that does not focus on a specific (analog or digital) technique of moving image restoration.

AESTHETIC ASPECTS

Every work has an aesthetic value, which can be understood as its characteristic look. It derives from and refers to the material properties of the work. When speaking of film, the characteristic look can be determined by such qualities as structure of grain, contrast, degree of

sharpness, and image stability. This characteristic look can be affected by traces of the individual history of a work, like signs of age and use or misuse. Significant damage, of course, will be immediately noticeable to the spectator. In bad cases, the viewing experience can be disturbed to such an extent that the viewer will not be able to experience the work's aesthetic value. It might even be impossible to follow a film's narrative. In order to regain the readability of the work's aesthetic value in such a case, restoration must ensure that appearances that do not belong to the original work cease to dominate the image. This approach refers to Cesare Brandi's concept of lacunae, where he points out the "devaluating" effect that the presence of lacunae, being extraneous objects, can have on the image, reducing it to mere background for the lacunae.[26]

Nevertheless, signs of decay and use can also be appreciated for their aesthetic appearance. The classical restoration theory's concept of respecting a work's authenticity, as it was described above, postulates the preservation of all signs of the work's individual history. From an aesthetic point of view we find similar approaches, for instance again from Riegl, who was convinced that *age value* of a work (partly, although more radically, sharing principles with *historic value* manifests itself in imperfection, incompleteness, and decay of form and color. Riegl claims that the modern viewer receives aesthetic satisfaction not from a stasis of preservation (and restoration) but from the degraded state of an object. In this sense, traces of physical use (and abuse) should by all means be preserved, as they can contribute to the work's aesthetic value.[27] Up to a certain point Brandi agrees with this idea, pointing out a work of art's historical significance and claiming its independence from constantly evolving aesthetic values due to changes in taste and fashion.[28] In this sense, restoration that aims to make a work spotless risks the loss of authenticity in favor of modern taste. However, a work—and this is true as well for moving images—cannot be reduced to being a historical document only. Its aesthetic value must be perceptible. If this is not the case, due to conspicuous signs of individual history, restoration must aim at regaining the readability of the aesthetic value of the work.

Whether or not signs of individual history are considered to be part of a work's aesthetic value, within a restoration project aesthetic considerations and the concept of restoration are connected to each other in a way that can be supporting as well as contradicting. For instance, it can be difficult to determine whether certain appearances derive from the original production of a work or from its individual history. In such cases, one cannot be sure if one is dealing, for example, with errors or with defects. This applies to phenomena like flicker or image instability, which can be an effect of bad duplication (error) but can also derive from the original recording (defect). In some cases, a lucky restorer might be able to categorize these phenomena unequivocally. Then, the concept of restoration provides clear instructions about how the phenomena should be handled. But if a phenomenon is ambiguous, which is the lesser evil, wrongly eliminating a potential defect from the original or keeping a potential error of history? For such a dilemma, aesthetic considerations can help find a solution. Consider another case: what if flicker and image instability can be defined as defects in the original and therefore should be preserved, but are so dominant that the moving image has lost its readability? Here, ethical and aesthetic concepts contradict each other. The ethically inspired concept of restoration claims the preservation of such defects, while aesthetic considerations plead for their removal.

To find answers to these questions seems difficult. Compromises such as reducing the damage and number of errors instead of removing them entirely is one possible solution. Naturally, reduction implies diminishing these problems to a certain amount that might seem appropriate to the restorer, which is obviously a highly subjective process. I assert that finding definitive answers to these questions is not as important as that they are asked—that the person in charge of a restoration project asks these questions and keeps them in mind during the whole process. In some cases, he or she might be able to find clear answers; in other cases, not. It is vital, however, that the restorer guarantees the transparency of his or her thinking process by articulating all conceptual decisions in the documentation. Recording the decision-making process is especially im-

portant when making subjective decisions about reducing damage and errors. After all, ethical discussion cannot provide clear rules or laws for such tasks. Ethics may influence a law by their plausibility, but they are not irrevocable or legally binding and thus can only appeal to the morality of the restorer.[29]

The following section, on the ethical concept of transparency of restoration, is devoted to documentation, which should be the starting point for any restoration project, whether in fine arts or moving image restoration and whether one is using traditional or modern restoration techniques. The reader will notice that there are two sections dealing with documentation. The first describes the "predocumentation," which is the documentation that should be carried out by the restorer prior to any intervention on the work. The second concerns documentation of the restoration process to be carried out by the restorer, as well as automatic documentation that should be provided by the digital restoration system in use.

THE CONCEPT OF TRANSPARENCY: DOCUMENTATION, PART ONE

Restorers often view digital technology with great suspicion. It is seen as an unpredictable "magic box," as Mark-Paul Meyer once so aptly called it, into which a film or video is inserted at one end and pops out at the other end after having been treated in an unknown and inexplicable way.[30] However, digital restoration does not start with the first mouse click. As already mentioned, the transparency of the restoration process is a principal ethical requirement, and it is essential for the understanding of all interventions and decisions undertaken in a project that claims to be a restoration.

Before any intervention is undertaken, a "predocumentation" of the treatment must be worked out that presents the project's context and the restoration plan, both of which are integral to documenting the process of restoration. The context clarifies the reasoning behind the restoration and its goals, and includes information about the framework of the project, the institutions and individuals involved, and the planned outcome. The last refers to the project's ultimate presentation medium and can play a decisive role in determining the appropriate treatment. For example, the production of a DVD as final product requires a completely different approach in digitization than the production of a projectable film. The DVD medium has a low capacity, so a 4K digitization would not make any sense and a lower resolution could be chosen, unless there are further plans for the digitized material. One might argue that such considerations should not play any role in the decision-making process, because in restoration one should always aim for the highest level of quality. From this point of view, material should be scanned with the highest possible resolution, be restored digitally, and only as a last step of the production chain have the amount of data reduced by converting it down to standard definition (SD) resolution (720 x 576 pixels). However, one has to be aware that scanning at high resolution is very time consuming (and thus expensive) and, furthermore, storing and handling a large amount of data requires hardware capacities that might not be available to every institution. Considering these aspects, it is obvious that the restoration plan must be defined in advance and elaborated in the documentation, to guarantee the project be completed as effectively as possible.

Aside from the context, the restoration plan should be based on the originating materials. All available materials must be critically examined to document their nature and condition. This critical examination should help to understand the history of a work before, during, and after its production and distribution.[31] Historical research is indispensable to understanding all the hints moving image materials can give us. Learning about technical and aesthetic standards of a given work at the time of production, including image and sound recording technologies as well as postproduction and presentation, will reveal information that can be vital for the appraisal of what we see and hear in the work. Such research also helps us to determine the source of certain artifacts in the image in order to differentiate between damage, errors, and defects. This evaluation helps a restorer develop a restoration plan based on firm ethical grounds rather than on personal taste. The term "critical examination" also implies the need to critically read the

information provided by a material. As Cherchi Usai puts it, one should "never trust data implicitly," meaning that all material and sources providing information about a work could contain wrong information.[32]

Predocumentation should describe and discuss all possible methods and interventions. By evaluating their positive and negative aspects—their pros and cons—the restoration plan should conclude by providing a detailed list of planned interventions, documenting the conceptual decisions involved in the whole process as well. Rationales should also be provided for possible treatments that were ultimately excluded, naming the factors leading to those decisions.

The restoration plan should then be discussed with all individuals involved in the restoration project; ideally, these will be experts from different, relevant fields of the humanities and the natural sciences, as suggested in the document of Pavia,[33] to guarantee a professional decision-making process in all project-related issues. Should there be conflicting views on the restoration plan, it is better to discuss them before the restoration process has commenced. In this debate, the restorer should advocate for the work under discussion.

Drawing up a restoration plan and strictly adhering to it forces the restorer to critically evaluate every step of the intervention that results in a transformation of the image. This is vital, if only to avoid the routine application of digital tools, which is "easy" and therefore often overdone. The responsibility of working out predocumentation cannot be left to restorers alone; the institutions who commission restoration projects must create general frameworks for projects that allow for preparing such documentation, which can be rather time consuming.

Having discussed theoretical concepts pertinent to moving image restoration, I will now turn to the more practice-related part of this article, the phases of intervention.

FIRST PHASE OF INTERVENTION: DIGITIZATION

Although in practice not often recognized as such, digitization *is* the first phase of intervention, because it determines the technical and aesthetic properties of the newly created digital intermediate and, consequently, the properties of the final product. Indeed, many shortcomings of digital moving image restoration projects originate in the digitization process. Mistakes made at this stage often result from a lack of knowledge of the history of the media and its technology as well as from a lack of understanding of the specifications of the software and hardware employed for subsequent digital image restoration. The choice of crucial scanning parameters such as resolution (the capability to show detail), bit depth (the capability to reproduce gradually changing levels; in case of a black-and-white film, this would be the capability to reproduce the original gray scale), and aspect ratio should aim to maintain the quality and quantity of the material under treatment as well as create data files that allow good and artifact-free further restoration. Naturally, these interests can contradict each other. In practice, decisive factors for choosing the parameters for digitization are the format of the final product and the planned subsequent interventions, as claimed in the FIRST (Film Restoration and Conservation Strategies) Project's final report. For instance, digitizing moving image material at a bit depth of eight bits will not be sufficient for a subsequent artifact-free digital image restoration. The FIRST report suggests at least ten bits for material that is to be treated digitally. For subsequent color regrading, fourteen or even sixteen bits are recommended.[34] To determine the scanning resolution for films, the FIRST report provides tables giving recommendations about resolution requirements for different source materials.[35] The resolution of film material can also be measured by using tools such as the Atomic Force Microscope, which produces a picture of the film image in which the size and form of the image-forming elements are visible and countable.[36] The objective of digitization for a *restoration* project should be to transfer the whole capacity to show detail, which can only be achieved by scanning with a higher resolution than measured in the starting material.[37] This method is the only way to maintain certain image characteristics of a work, such as film grain.

Special scanning techniques can aid in creating advantageous conditions for digital

restoration. Wet-gate scanning (adopted from the wet-gate printing process), for instance, can optically eliminate a great deal of surface damage from a film print, making later corrections of remaining visible scratches much easier.

To preserve a work using digitization techniques, the entire picture area should be scanned. Cropping or framing the image to a new desired format are unacceptable in an ethically sound restoration. Rudolf Gschwind presented a method of digitization in Copenhagen in 2002 that records the film strip in its entire width, not just the image area *(continuous scanning)*.[38] This technique is a great advance for research purposes, since all information that can be found on the strip is recorded and can be easily studied (although in most cases, the examination of the actual film material might still be necessary). It can also provide significant help for digital stabilization of material with weak image stability, since the margins of the image can be used as a reference for the stabilization process.[39]

Digitization is often handled by third parties who are not part of the core restoration team and who may not necessarily know the reasoning behind the project. Thus, the restorer must act as a director, instructing the personnel involved and monitoring all steps undertaken. More than a decade ago, Mark-Paul Meyer already foresaw the pressure that this would impose on restorers, since they must be aware of the functioning, the possibilities, and the limits of all processes involved (digitization, digital restoration, and rerecording to film).[40] Not being the person directly working with the software and hardware systems, the restorer's role will be to supervise an operator, who is comparable to a technician. Naturally, the role of the restorer as the director of the project applies to any cooperation with partners external to the archive or the institution that is executing the restoration project.

Finally it must be noted that transferring the characteristic look in the digitizing process is quite a challenge, even when parameters like resolution and bit depth are chosen adequately. The main problem is that a comparison between a projected film image, for instance, and the picture of the scanned material on the monitor is very difficult. The restorer has to take into account the potential difference in the look of the film image and the digitized one, as well as that between the digitized image and the one recorded back to film material. In order to make sure the appearance of the image remains unaltered through the phases of digitization and rerecording, the restorer will be forced to test these phases with a representative part of the film.

SECOND PHASE OF INTERVENTION: DIGITAL RESTORATION

In the previous sections I have discussed ethical and aesthetic criteria that should be considered when carrying out moving image restoration. The tasks and limits of restoration have been defined clearly: reduce or remove damage and errors of a moving image but preserve its defects and characteristic look. The following section will provide more detailed information concerning the limits of digital restoration. As already stated, digital technology has to be regarded as an additional tool, comparable to traditional moving image restoration methods. Its suitability for a restoration project cannot be assumed but must be evaluated in each case. Until now, this question has been part of the logical procedure in analog restoration; one would not use a wet-gate printer for duplication, for example, if the scratches visible in the starting material were already copied in. Thus, in the age of digital technology, the choice for an appropriate restoration method also depends on its suitability for the given case. The same rule applies to the choice of soft- and hardware systems. If a specific system does not allow the restorer to meet the criteria discussed in this article, it should be considered unsuitable for the restoration work.

As most restorers work under time constraints, one of the biggest requirements of digital restoration systems is their capacity to work at least partly automatically. Yet, the archive's or restorer's ethical stance demands a transparent and individually controllable process. In this context, transparency means that the restorer must be able to check the results of the intervention, ideally by comparing it before and after every step of the process. If the results show unwanted changes in the

image, it must be possible to configure the system or tool in use so that only planned interventions are executed. The DIAMANT software, for instance, provides a very useful combination of automatic, semi-automatic, and manual processes that allow for a scaled use of most of its tools.[41]

To give an example of how the restoration software must be configured, the module for the removal of single-frame damage like dust (being visible in one frame only) can be controlled by the operator with a set of parameters that influence its effect on the image. The operator has the choice to (1) let the software automatically search and remove single-frame damage according to the chosen parameters (if necessary, certain critical areas can be excluded from intervention by defining negative, i.e., excluding *Regions of Interest*;[42] (2) restrict the application of the tool to certain areas, such as to the single-frame damage only (by defining positive, i.e., including *Regions of Interest;* and, (3) carry out manual retouchings using the Moving Image Retoucher (MIR), which is a paint tool that allows the replacement of damaged image portions by tracing information from an undamaged reference frame.[43] In order to control the results, a shortcut can be used to switch between every single frame before and after intervention, making changes in the image easily visible. Since the system is based on several rendered generations of the starting material, it is possible to go back to previously rendered material in any state of the process.

This brief description should just give an example of the capacities of DIAMANT. My personal experience with the software (I have been using it since 2003) is that it can be very useful for *restoration* purposes, since it allows the restorer/operator a highly controlled application of tools on whole moving image sequences, single frames, or even restricted areas on single frames, the latter of which is perhaps one of the greatest advantages of digital moving image restoration technology.[44] Theoretically, with such a system restorers can decide, for example, which kinds of scratches they want to remove (those being damage) and which not (those being defects, if categorization is possible).[45] This approach might seem impractical if used for an entire feature film, as it means working semiautomatically, or even manually, which is very time-consuming, but at least it is possible. In terms of adhering to ethical and aesthetic criteria during the restoration process, this capability is a great advance.

In regard to the third phase of intervention, the rerecording of the digitally restored image material onto film, I cannot provide any technical information due to a lack of experience. I can only state that this procedure should follow the same theoretical criteria as the digitization process, maintaining the quality and quantity of the material. If the final product will not ultimately reside on film, compression of data may be inevitable in order to transfer the work to the desired final media. For all video formats, lossless compression should be chosen whenever possible.[46]

LIMITS TO DIGITAL RESTORATION OF MOVING IMAGES

While criteria for moving image restoration should be equally valid for both analog and digital methods, limits exist—particularly for digital technologies. Limits for analog restoration usually arise from technical possibilities. Since most technical processes were adapted from the commercial film and television industry, every newly developed preservation method for our audiovisual heritage was warmly welcomed. With the advance of digital technologies, these limits have started to vanish, making room for a considerable number of possibilities that are enthusiastically embraced by some, while frightening others. Due to the lack of ethical guidelines for the use of digital technologies, restorers may often find themselves in situations where they must be sensitive to the ethical quandaries involved. In these cases, restoration theory must determine new limits and standards and give restorers parameters for acting in an ethical manner.

The theoretical limits for the digital restoration of moving images are the same as those for traditional film restoration. Thus, the characteristic look of the image and the defects inherent to the original production have to be preserved as individual characteristics of the work. Digital systems offer some tools that violate this principle, such as digital noise reduction and sharpening tools for digitized film

material. By affecting film grain, the reduction of optical noise destroys one of the most important characteristics of film material, smoothing out the image. Such an intervention decreases the aesthetic value of the work under restoration and, therefore, is inappropriate. The same applies to sharpening the image to a brilliance never attained before. The outcome of a restoration shall not be a commercialized, "altered for the better," or modernized product that caters to the viewing habits of contemporary audiences. Such an "improvement" is equal to a falsification, which, unfortunately, has a long tradition in the restoration discipline. As Raymond Borde argued, "respect for the wishes of the film makers," "the artistic product," and the "historical environment and the cultural context" from which a work arose must condition any intervention carried out during analog as well as digital restoration, not the available technical possibilities.[47]

Furthermore, it has to be pointed out that digital moving image restoration is not a mature technology; certain procedures still cannot be carried out without creating digital artifacts, which are created by the system in the process of correcting phenomena that are erroneously interpreted as damage or errors.[48] If intended corrective interventions also result in the creation of digital artifacts, this technical limitation of the system should be recognized, and the restorer must refrain from applying a tool that does not lead to the desired result. This conclusion seems only logical if we imagine the case of an audience sitting in a cinema and seeing line scratches on the screen, on one hand, and pixel irregularities caused by a badly carried-out line scratch removal procedure, on the other hand. Most spectators have seen line scratches before, thus they can recognize it as such and understand it, while incorrectly placed pixels cannot be comprehended that easily. Spectators will only be irritated during their viewing experience, without understanding the nature of the disturbance. Thus it is better to keep an original's damage or error rather than to produce a new digital artifact that may have a much more annoying effect on the viewer.

Digital moving image restoration limitations are defined not only by theoretical and technical concerns, but also by financial restrictions, which affect first and foremost the time frame of the project. It is often assumed that working with digital technology is a fast procedure, but in fact a cautiously executed digital *restoration* is anything but fast. If one follows the suggestions made in the previous sections, including preparing proper documentation and evaluating each and every aspect with great care, it can be very time consuming and costly. Meanwhile, restorers often face serious time constraints.[49] Although the industry is developing means to make fully automatic, fast, and cheap digital restoration possible, the ethical and aesthetic criteria described in this article preclude many of these methods for the near future, since they often alter the characteristic look of the original and result in the formation of digital artifacts.

DOCUMENTATION, PART TWO

In this second section dedicated to documentation, I outline the restorer's duties to document the restoration process, as well as the automatic documentation faculties that should be provided by the digital system used for restoration. As already mentioned, during digital restoration the restorer or operator should stick as closely as possible to the restoration plan previously worked out. In many cases, however, revising the restoration plan will be unavoidable, mostly due to aesthetic considerations or technical necessities. For instance, the system in use might be unable to remove all damage, as foreseen in the restoration plan. Or, after having corrected part of the visible damage, certain remaining damage might not be that disturbing anymore to the eye of the restorer. In the latter case, he or she could make the aesthetically motivated decision to not remove it. All changes of the restoration plan must be recorded in the documentation, however, and if a change is severe, it should again be discussed with the persons involved in the project.

Additionally, every intervention and its related technical information should be documented as part of a permanent record, such as a journal (as, for example, suggested in a draft of a film restoration charter proposed by the Cineteca del Comune di Bologna in 2001),[50] since most of the present technology cannot as yet do this automatically. The lack of such a

documentation tool as part of the restoration software is a serious drawback. For years, film archivists such as Meyer have demanded digital systems that are capable of documenting restoration processes automatically.[51] Today, such demands are still of high importance and restorers working with a specific digital restoration system should insist on the development of automatic documentation facilities, if they are not yet provided. Furthermore, restorers should take part in the development of those tools, since they know best what kind of documentation their archive or institution requires. The DIAMANT usergroup, for instance, has developed the concept of a *restoration report* and a *project file* for automatic documentation. The *restoration report* should contain information about which tools of the system have been applied to which parts of the work (sequences or single frames), accompanied by statements of the restorer/operator. Additionally, a *project file* must be created that contains more detailed information about parameter settings of the applied tools, the exact locations of application and all metadata produced during the process. The *project file* does not have to be "human readable" but must allow the exact re-creation and repetition of the restoration project; in other words, it must be possible to reload the file into the system for future restoration purposes.[52]

The written documentation of all interventions and actions executed should be accompanied by image material showing representative frames before, during, and after intervention. Additionally, since we are dealing with *moving* images, the documentation should also show the work or an exemplary part of it in motion, because certain conditions and changes in the image can only be seen in sequence. This could be accomplished, for instance, by producing a DVD that presents "before" and "after" examples of the restored material or even several stages in the restoration process. Furthermore, as proposed in another draft of a film restoration charter by the Scuola Nazionale di Cinema—Cineteca Nazionale, Rome, the audience viewing the final product should have information about the processes and techniques used in the restoration. To achieve this aim, titles must be added to the beginning and/or end of all projection prints of the restored work, which will inform the audience about the presented version and the restoration.[53]

Any documentation of a restoration project should be shared with other restorers and interested individuals by publishing details of the restoration and distributing them widely. A detailed presentation of the restoration is desirable when the final product is presented in the context of special events, like archival film festivals. A restoration is always an intervention that transforms the work, a fact that has to be communicated.

CONCLUSION

If we apply digital technology to moving image material while respecting the concept of restoration and the theoretical criteria pointed out in this article, we can speak of *digital restoration*. Concerning film material, we can further speak of *digital film restoration* if the final product of a restoration project is a projectable film. According to Michele Canosa, a restored film must be projectable: "Cinematographic restoration . . . must re-establish the functionality of the film."[54] Thus, in the process of digital restoration, if one loses the capability to project a film—which is part of its authenticity—the object in the hands of the restorer cannot be called a *film* anymore; consequently we cannot speak of *digital film restoration* in this instance. The product of a digital restoration of a film must be recorded back onto film material, since "only in the projection will the restoration come to completion."[55]

Application of digital methods to moving image material that does not meet the theoretical criteria discussed can be termed *digital treatment*, which, of course, offers a wide range of possible interventions on moving images. Sadly, many of those *digital treatments* performed today claim to be *restorations*, while in fact they fall short of being restorations according to the definition provided in this article.[56] The nature of an application of digital methods to a moving image will depend on the context of the project and the desired final product; on the audience it is made for; on the institutions and individuals involved; on the technical, financial, and temporal limitations;

and—last but by no means least—on the moving image itself.

Finally, we must note that special digital systems have been developed that allow interventions on digitized moving image material by using automatic, semiautomatic, and manual procedures. In other words, digital technologies can be applied in various degrees for many different purposes, among them *restoration* purposes. They offer new possibilities that demand work that closely follows ethical and aesthetic criteria. On the other hand, if applied cautiously, they allow restorers to adhere to these criteria in a way that, to a certain extent, is not possible with analog techniques.

Of course, "cautious application" of the new tools is not included in the software package but must be demanded from the restorer as well as from the archives and other institutions commissioning such projects. One thing should be incontestable, however: the individuals who call themselves *restorers* should always consider themselves advocates of the work under their care. Whether they are in charge of a *digital film restoration* or a *digital treatment* of a moving image, they should make every effort to meet the demands of a *restoration* in respect to the given circumstances.

NOTES

1. The term *work* can be understood as film (a projectable succession of photographic images on a transparent carrier) or any other type of moving image. Whenever using the term *moving image*, I refer to a sequence of images presented in motion. Like *work*, it can stand for a film, a video, a digitally produced film, or any sequence of moving images (whether part of a motion picture film or merely a fragment of footage). I have to point out to the reader that my article, as well as most of my research, is focused on film material. Nevertheless, since my discussion will remain rather theoretical, I will use the term *moving image* instead of *film*, hoping that readers who focus on other types of moving images can adapt it at least partly for their own interests.

2. Michele Canosa, "Per una teoria del restauro cinematografico," in *Storia del cinema mondiale*, vol. 5: *Teorie, strumenti, memorie*, ed. Gian Piero Brunetta, 1094–97 (Turin: Giulio Einaudi editore, 2001); and Gian Luca Farinelli and Nicola Mazzanti, "Il restauro: metodo e tecnica," in ibid., 1171–72. For a short extract of the contents of these texts in English, see Nicola Mazzanti, "Footnotes (For a Glossary of Film Restoration)," in *Restauro, conservazione e distruzione dei film*, ed. Luisa Comencini and Matteo Pavesi, 26–27 (Milan: Editrice Il Castoro, 2001).

3. Translation into French and Portuguese was proposed by Alice de Andrade and Antoine Filippi. If the reader feels that inappropriate terms were used or wishes to make additions, please do not hesitate to contact the author: wallmueller@gmx.net.

4. Canosa, "Per una teoria," 1094. Although I find this distinction very useful, in this article *change* will be considered *damage*, since the term could not be found in other texts as a separate category for describing the condition of moving images.

5. Farinelli and Mazzanti, "Il restauro," 1120.

6. Paolo Cherchi Usai, "La cineteca di Babele," in *Storia del cinema mondiale*, vol. 5: *Teorie, strumenti, memorie*, ed. Gian Piero Brunetta, 1037–38 (Turin: Giulio Einaudi editore, 2001).

7. By including *changes* (as proposed by Canosa) as part of the category of *damage*, the concept of restoration comprises their reduction or removal. However, an interesting approach could also be to remove only *damage* and preserve *changes*, at least if they do not contradict certain aesthetic demands, which will be discussed below.

8. Mazzanti, "Footnotes," 30. See also Fédération Internationale des Archives du Film/ FIAF, *Code of Ethics*, Article 1.5, http://www.fiafnet.org/uk/members/ethics.cfm.

9. Mazzanti, "Footnotes," 30–31.

10. Ray Edmondson, *Audiovisual Archiving: Philosophy and Principles* (Paris: United Nations Educational, Scientific, and Cultural Organization/UNESCO, 2004), 20, Article 3.2.6.3. See also Cherchi Usai, "La cineteca," 1037.

11. Katrin Janís, *Restaurierungsethik* (Munich: Martin Meidenbauer Verlagsbuchhandlung, 2005), 137.

12. Ibid., 136.

13. I am aware that in terms of authenticity the object and the image cannot be separated, because each is conditional upon the presence of the other. Nevertheless, I would like to point out that preserving the authenticity of an object means something different than authentically restoring an image.

14. Walter Benjamin, "The Work of Art in the Age of Mechanical Reproduction," in *Illuminations* (London: Fontana Press, 1992), 214.

15. Benjamin, "The Work of Art," in ibid., 217.

16. Mansfield Kirbey Talley Jr., "Introduction to Part I," in *Historical and Philosophical Issues in the Conservation of Cultural Heritage*, ed. Nicholas Stanley Price, Mansfield Kirbey Talley Jr., and Alessandra Melucco Vaccaro, 18–19 (Los Angeles: The Getty Conservation Institute, 1996).

17. Riegl describes three commemorative values: *age value*, *historic value*, and *deliberate commemorative value*. In relation to restoration, *age value* forbids any restoration and preservation activities, while *historic value* claims the preservation of monuments in their status quo. *Deliberate commemorative value* names restoration as its fundamental requirement. Alois Riegl, "The Modern Cult of Monuments: Its Essence and Its Development," *Historical and Philosophical Issues in the Conservation of Cultural Heritage*, ed. Nicholas Stanley Price, Mansfield Kirbey Talley Jr.,

and Alessandra Melucco Vaccaro, 72–78 (Los Angeles: The Getty Conservation Institute, 1996).

18. Ibid., 75.

19. This statement is valid if we assume that the term *authentic* focuses on the original characteristics of the work. To include the traces of individual history in the concept of authenticity would require duplication in order to produce a facsimile that corresponds to the copy used for duplication, and that contains all damage and errors.

20. Cherchi Usai, "La cineteca," 1033.

21. Wendelin Odermatt, "Reversibilität: eine nachhaltige Strategie, Beispiele restauratorischer Umsetzung," in *Nachhaltigkeit und Denkmalpflege, Beiträge zu einer Kultur der Umsicht,* ed. Marion Wohlleben and Hans-Rudolf Meier (Zürich: Institut der Denkmalpflege, ETH-Zürich, 2003), 127.

22. Paul Read and Mark-Paul Meyer, *Restoration of Motion Picture Film* (Oxford: Butterworth-Heinemann, 2000), 134.

23. Ibid., 71.

24. This approach can also be found in fine arts preservation, for example by the German term *Wiederbehandelbarkeit* (retreatability) proposed by Odermatt, "Reversibilität," 127.

25. Read and Meyer, *Restoration of Motion Picture Film,* 100.

26. Cesare Brandi, *Theory of Restoration* (Rome: Nardini Editore, 2005), 18–19.

27. Riegl, "The Modern Cult of Monuments," 72–75.

28. Brandi, *Theory of Restoration,* 29–30.

29. Guido Carducci, "Ethics, Law and Heritage," *ICOM News* 58 (March 2005): 5.

30. Mark-Paul Meyer, "Film Restoration Using Digital Technologies," *Journal of Film Preservation* 57 (December 1998): 33.

31. Mazzanti, "Footnotes," 26.

32. Paolo Cherchi Usai, *Burning Passions* (London: British Film Institute, 1994), 88.

33. The document of Pavia was written by experts concerned with conservation and restoration of cultural heritage (scientists, curators, art historians, cultural heritage directors, teachers, representatives of conservation institutes, and international organizations, as well as conservator-restorers) that met in Pavia in October 1997. See http://museumsnett.no/nkf_n/pavia.html.

34. FIRST Project, *European Film Heritage on the Threshold of the Digital Era: The FIRST Project's Final Report, Conclusions, Guidelines, Recommendations, Part I* (CD-ROM) (Brussels: FIRST Project, 2004), 25.

35. Ibid., 38.

36. Ulrich Messerschmid, "HDTV und digitaler Film—ein gemeinsamer Weg in die Zukunft?" in *Digitaler Film—digitales Kino,* ed. Peter C. Slansky (Constance: UVK Verlagsgesellschaft mbH, 2004), 65.

37. According to the Nyquist-Shannon scanning theorem, a fine pattern of *N Lp/mm* (any amount of lines per millimeter) has to be scanned with a sensor of at least *2 x N Pixel/mm.* Hans Bloss, "Die digitale Netzhaut—Bildsensoren für eine digitale Filmkamera," in *Digitaler Film—digitales Kino,* ed. Peter C. Slansky (Constance: UVK Verlagsgesellschaft mbH, 2004), 138.

38. Rudolf Gschwind, "Restoration of Movie Films by Digital Image Processing," in *Preserve Then Show,* ed. Dan Nissen, 168–178 (Copenhagen: Danish Film Institute, 2002).

39. The DIAMANT system, for instance, offers a stabilization tool that uses the frame margins as reference for the stabilization process. In this way, the typical artifact of moving margins after image stabilization can be avoided. For product information on DIAMANT, see http://www.hs-art.com.

40. Mark-Paul Meyer, "Work in Progress: Ethics of Film Restoration and New Technologies" in *The Use of New Technologies Applied to Film Restoration: Technical and Ethical Problems,* ed. GAMMA Group (Bologna: GAMMA Group, 1996), 16–17.

41. Automatic processes can be understood as interventions applied to a sequence that, apart from choice of parameters and control of results, require no further interference of the operator and are completely carried out by the system. Semiautomatic processes are basically automatic processes that are restricted to certain areas defined by the operator. Manual interventions are treatments like "manual" (still digital) retouching, where the operator is using a paint tool to remove visible damage from the image.

42. The tools to remove single-frame damage compare every frame of a sequence with the two adjacent frames in order to find objects extraneous to the image (like dust), which usually appear at a particular location on one frame only. Thus, critical areas in the removal of single frame damage are, for instance, scenes with fast-changing image content such as reflecting and glittering surfaces (water, glass, etc.) and fast-moving objects.

43. MIR was featured for the first time in DIAMANT Version 2.

44. This is not meant to be a commercial for the DIAMANT system, it is merely the only digital system I have worked with so far. The software is in a state of continuous development, partly influenced by the DIAMANT users who work in cooperation with the software producer HS-ART. In order to optimize the development, connect users worldwide, and discuss (digital) restoration issues in general, the DIAMANT usergroup was founded in 2005 by European DIAMANT users. For further information on the usergroup, please e-mail the author at wallmueller@gmx.net.

45. To a certain extent, even some automatic functions can be configured in such a way that only special types of scratches will be detected and removed.

46. Paul Read, "Film Archives on the Threshold of a Digital Era: Technical Issues from the EU FIRST Project," *FIAF: Journal of Film Preservation* 68 (December 2004): 35.

47. Raymond Borde, "The Moral Responsibility," in *Archiving the Audio-Visual Heritage: A Joint Technical Symposium, May 20–22, 1987* (Berlin: Stiftung Deutsche Kinemathek, 1988), 141.

48. Giovanna Fossati, "From Grains to Pixels: Digital Technology and the Film Archive," in *Restauro, conservazione e distruzione dei film,* ed. Luisa Comencini and Matteo Pavesi, 135–36 (Milan: Editrice Il Castoro, 2001).

49. Real-time digitization and processing is currently only possible for Standard Definition (SD) and High Definition (HD) image material. In case of films, including digitization (2K or 4K, 12–16 bit depth), digital restoration, imports and exports between workstations, final recording onto film, and decision time, the total time needed for a digital restoration project can be up to 500 times the running time of the film. Read, "Film Archives on the Threshold," 36.

50. Cineteca del Comune di Bologna, "Draft of a Film Restoration Charter 2001," in *Restauro, conservazione e distruzione dei film*, ed. Luisa Comencini and Matteo Pavesi, 151–53 (Milan: Editrice Il Castoro, 2001), article VI.

51. Meyer, "Work in progress." GAMMA Group (1996), 17.

52. This concept for automatic documentation was developed at the first DIAMANT usergroup meeting (Amsterdam Filmmuseum, March 16–17, 2006), based on models developed by users of the software. It is a good example of the profit our field can make out of individual users undertaking to improve digital restoration technology. The DIAMANT *restoration report* is created by simply clicking on an icon and can be individually modified. Although it still has to be optimized, it can be regarded as a great advance.

53. Scuola Nazionale di Cinema—Cineteca Nazionale, "For the sistema cinetecario italiano," in *Restauro, conservazione e distruzione dei film*, ed. Luisa Comencini and Matteo Pavesi (Milan: Editrice Il Castoro, 2001), 155, article VI.

54. "Il restauro cinematografico . . . deve ristabilire la *funzionalità* del film," quoted in Canosa, "Per una teoria," 1082.

55. Read and Meyer, *Restoration of Motion Picture Film*, 72.

56. An instance of such a misnomer would be the colorization of black-and-white films, like the colored version of Hitchcock's *Vertigo* as described by Leo Enticknap in his article, "Some Bald Assertion by an Ignorant and Badly Educated Frenchman: Technology, Film Criticism, and the 'Restoration' of *Vertigo* (1996)," *The Moving Image* 4, no. 1 (Spring 2004): 130–41.