Chapter 11
Conserving Digital Art

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Abstract The emergence of digital technologies has impacted not only the nature of museums as institutions, but also the practice of artists. Consequently, artworks which employ digital media (such as video and software) in their access or display are making their way into permanent collections in increasing numbers. These digital media can pose considerable challenges in terms of long-term access and display, due to a changing technological environment and resulting risk of obsolescence. Contemporary art museums are among those leading the way in developing approaches to collecting and caring for these types of object. This accompanies a general shift in conservation theory and practice, from a traditional object-centric approach to one which allows the continued evolution of the work through time. The presence of digital media in collections is also forcing the art museum to look beyond its walls and engage with experts from formerly unfamiliar domains. In this chapter, we will introduce the imperatives driving digital preservation and discuss the state of the art in the field of conserving and preserving digital art. We will then focus on recent research relating to specific digital media types and present a number of case studies from the Tate collection.

Introduction

In this chapter we will introduce the field of digital art conservation within the art museum, including its primary goals and methods, and recent insights from research and practice at Tate and elsewhere. Research efforts in the conservation and preservation of digital media have been gaining momentum over the past few decades. Through new collaborations between disciplines and international partners, considerable progress has been made toward addressing many of the theoretical and technological challenges faced. We will first introduce the fields of digital preservation and art conservation, which while increasingly interconnected in the context of digital art conservation, have distinct origins and patterns of discourse. For each, we will also highlight recent research and its implications for the conservation of digital art. We will then discuss in detail two digital media types – digital video and software – including the preservation challenges they present (illustrated using a number of case studies from the Tate collection) and recent research that has sought to address them.

Much of the content of this chapter builds from our experiences in Tate's Time-based Media Conservation team, a section of the Conservation Department. Tate's mission includes the care of the artworks in the collection and to ensure these can be exhibited to the public in the long-term. Over the last 20 years we have seen wide changes in the technologies used by artists, and the Time-based Media Conservation team's remit has grown from roots in technologies like film, to include digital video, software-based and performance artworks. Tate was the first contemporary art museum to have a time-based media conservation department, and has led in building the expertise required to care for these artworks. These works are mostly technology dependent and can be installed in variable ways. Preserving them requires a continued engagement with the new forms of media being used by artists and with the emerging field of digital preservation. While this new expertise has built on existing experience with conservation of contemporary art, it has also required bringing in technical knowledge from outside the museum to help deal with challenges ranging from cathode ray tube maintenance to digital preservation storage; from analogue video playback to hardware emulation. This has proved to be, like the artist's practice that drives it, an ever-evolving process.

Digital Preservation

Digital Preservation is defined by the Digital Preservation Coalition[1] as "(...) the series of managed activities necessary to ensure continued access to digital materials for as long as necessary" (DPC, 2015). In this section, we will consider what this means in the context of the museum and introduce the ideas from digital preservation which are shaping the way museums care for digital artworks. Following in the footsteps of archives and libraries, museums have begun adopting (and where necessary adapting) standards, best practices, tools and infrastructures developed by the digital preservation community (Fino-Radin, 2018). Digital preservation initiatives must extend across the whole organization. Planning and implementing digital preservation infrastructure therefore requires close collaboration between departments, including those working with the art collection, the archives, photography and records. The development of infrastructure that meets the varied needs of different teams and media types remains an active area of exploration for museums.

The so-called "three-legged stool" model, developed at Cornell University for the Digital Preservation Management training course (Kenney et al., 2003), conceives of digital preservation as supported by three "legs". The "organization" legs represents organizational concerns: what the organization is collecting, the policies in place, and the processes and procedures that support digital preservation. The "technology" leg refers to technological infrastructure: the hardware, software, and skills required to implement the policies and procedures. This also includes the monitoring of the constantly evolving technologies of artwork production and preservation. Finally, the "resources" leg refers the resources that support digital preservation: funding for development, training of staff and perhaps most importantly the operational costs of maintaining preservation activities and infrastructure (McGovern, 2007). The balancing of the stool in relation to these three legs is one way of understanding what constitutes a "fully-implemented and viable long-term preservation strategy" (Kenney et al., 2003). This is not a one-time activity, but demands ongoing engagement and advocacy. It is essential that digital preservation infrastructure receives sustained support at all levels, to ensure that digital objects are preserved, even in the face of significant changes in the technological environment. Fortunately, many years of research in the digital preservation community has resulted in knowledge and tools which offer a head start to organizations approaching digital preservation for the first time.

The formative times in the development of digital preservation were the early 1970s (Day, 2000), when the need to preserve electronic records started to become apparent. As early as 1982, the major international space agencies created the Consultative Committee for Space Data Systems (CCSDS) to provide a forum for discussion of common problems in the development and operation of space data systems (CCSDS, 2017). This collaboration led to the development of the reference model for an Open Archival Information System in 2003 with the last update published in 2012 (Consultative Committee for Space Data Systems, 2012). This model is much debated and critiqued in the digital preservation community, but remains an important de-facto standard and baseline for discussions within the field. The OAIS model does not specify technological solutions; rather it identifies the "functions" required to ensure the preservation of digital records. It places digital preservation at the core of an archive or institution, and makes explicit the importance of the context under which this occurs; the systems and processes needed to preserve the data for the long-term do not exist in isolation, but are intrinsically linked to the *producers* and *users* of the data that the archive holds. Digital preservation is therefore intrinsically cross-disciplinary, offering an overarching set of technical frameworks, with the individual negotiation of what precisely counts as preservation occurring within the sub-field relating to the type of materials to be preserved (Owens, 2018). The field has several other well established standards worth considering, from the relatively simple and pragmatic NDSA Levels of Digital Preservation (Phillips et al., 2013) to the gold-standard Trustworthy Repositories Audit & Certification (Ambacher et al., 2014). These standards can provide useful targets for institutions to work towards when developing their own systems and policies.

In working towards any of these standards, it is necessary to understand the risks faced by digital materials, and appropriate responses to these risks. We will now introduce the two primary risks (see Rosenthal et al., 2005 for a more complete examination): the loss of the bits of digital information; and the loss of the means to access information as a result of a changing technological environment. The first of these is perhaps the most apparent risk faced by digital materials, and the failure or loss of storage media will be something very familiar to any computer user. By storage media, we mean the physical carrier for the bits (be it magnetic tape, a hard drive or a USB flash drive) – the fundamental unit of digital storage – which encode the digital materials. Failure can occur for a multitude of reasons and at different rates depending on the type of media–the principle of "inherent vice",

[1] The Digital Preservation Coalition is a UK-based non-profit organization which advocates for digital preservation and supports its members in ensuring long-term access to digital content and services.

or the tendency for all materials to deteriorate over time (American Institute for Conservation of Historic and Artistic Works, 2017), applies just as much to digital storage media as to any other. Fortunately, approaches to dealing with this risk have advanced dramatically since it was identified, and we are approaching a situation in which it is possible to mitigate it – providing the resources are available to implement a solution at the required scale.

At its core, a digital object can be understood as a bitstream: a specific sequence of bits (that is, values of 0 or 1). Bit-level preservation concerns ensuring that the exact sequence of bits that constitute a digital object is maintained through time. By storing identical copies in multiple locations (such as a magnetic LTO tape or a hard disk drive in a data center) and applying fixity checks, the integrity of a bitstream can be verified and monitored. Fixity checks are automated methods which use an algorithm to generate a digital fingerprint from the bitstream, often referred to as a checksum. If any bit within the bitstream is altered, the resulting checksum will change. These checksums can be stored alongside a digital object and used to verify the integrity of the bits whenever they are copied (NDSA Infrastructure & Standards Working Groups, 2014). Various steps can be taken to minimize risks to bit integrity when storage media is accessed and archived. Tools and techniques from the field of digital forensics, which has emerged around the requirement for demonstrable bit integrity in criminal investigations, are increasingly being used in the capture of digital materials in museums (Kirschenbaum et al., 2013). For example, the use of write-blocked disk imaging (shown in progress in Figure 1) allows the capture of a complete bit-for-bit representation of the contents of a hard drive, while mitigating the risk of writing any data back onto the source storage media. At Tate, we have used the free and open-source BitCurator toolset to help us implement digital forensics in our workflows (BitCurator, n.d.).

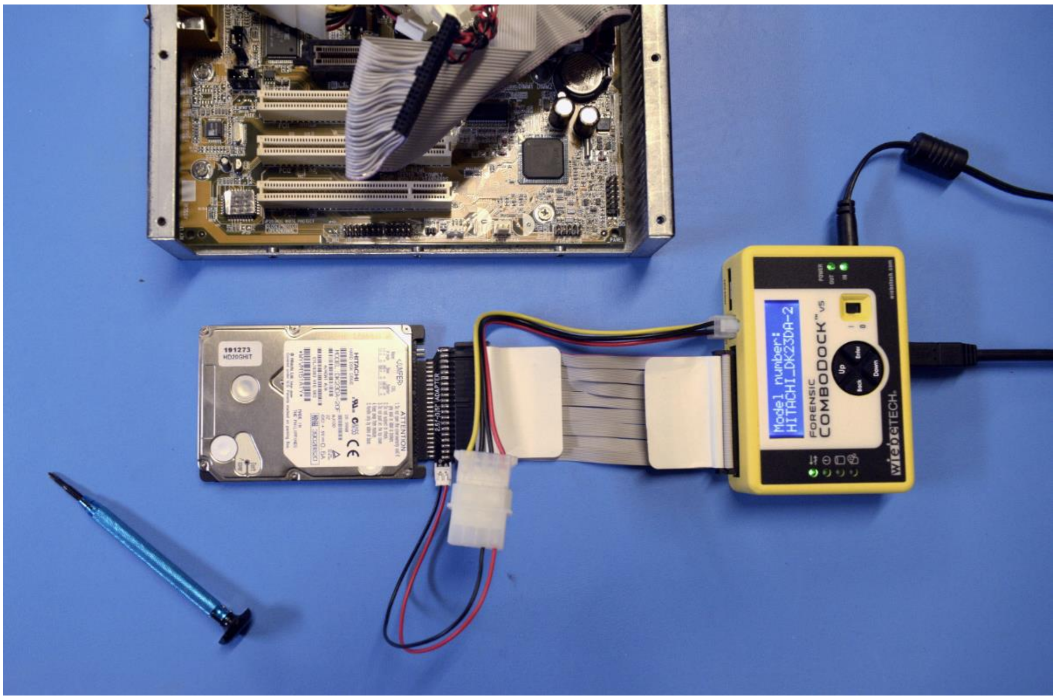

Fig 11.1 Using forensic write-blocking hardware to acquire a disk image of a hard drive extracted from a PC. (Photograph by Tom Ensom)

While frameworks for bit-level preservation are now well established and widely agreed upon, ensuring the long-term usability and accessibility of born-digital materials is a tougher challenge. This problem is caused by technological obsolescence, which can be understood as the decrease in use and availability of a specific technology. A classic example of hardware obsolescence is the 3½″ floppy disk. Once a popular storage medium for which reader devices were ubiquitous, as more efficient forms of storage such as the compact disc became available, interest in the floppy disk declined and production slowed, rendering it obsolete. Software and file formats may also become obsolete, sometimes as a trickledown effect from hardware obsolescence (for example, when a processor architecture becomes obsolete, so too does the software which runs on it), and sometimes independently (for example, where development ceases on a software program which is required to access a specific file format). A considerable amount of research over the past few decades has focused on how we might respond to these problems, and has resulted in several distinct strands of thought, which we characterize as *content-centric* and *object-centric*.

Content-centric strategies seek to alter the technical structure of digital objects to meet the requirements of a changing technical environment, while ensuring the original content is maintained. For example, data stored in an obsolete file format might be converted to a more stable one. The primary drawback of this approach is that important characteristics of the content may be lost in the migration process, particularly if the new format does not support all the features that the original did. Object-centric strategies seek to maintain a suitable technical environment using emulation (and related technologies) in order to allow continued access to the original unaltered object. Recent advances in emulation technology and the tools to apply it mean that object-centric digital preservation has become more common and usable at scale (von Suchodoletz et al., 2013, Cochrane et al., 2017). However, such an approach can still not be used successfully in all circumstances; it is contingent on a suitable emulator having been developed to support the required technical environment. Both strategy types introduced here are returned to in subsequent sections of this chapter – Conserving Digital Video and Conserving Software-based Art respectively – where specific examples of their application are discussed.

Both strategy types demand a degree of change, either in the digital object itself or its environment, and as a result frameworks have been developed to ensure that the important characteristics of a digital object can be maintained through time. In doing so, we aim to ensure that the digital materials preserved can be considered authentic. This idea is widely understood in digital preservation as preserving "significant properties" (Wilson, 2007). Although significant properties can be problematically vague as a term and hard to implement consistently in practice (Dappert & Farquhar, 2009; Yeo, 2010), it remains a useful way of thinking about the potential appropriateness of a particular preservation strategy and measuring its success if applied. Beyond documentation to support an understanding of significant properties, documentation standards within digital preservation are linked primarily to the metadata which accompanies a particular object in archival storage. There are established standards for this, ranging from the baseline Dublin Core specification (Dublin Core Metadata Initiative, 2012), primarily supporting access, to the specialized PREMIS standard (PREMIS Editorial Committee, 2015), which enables sophisticated machine-driven management of digital objects. Off-the-shelf storage and management systems have also been developed, that provide digital object management, access and information services for collections, such as the free and open-source Archivematica (Artefactual Systems Inc., 2019).

As digital preservation matures, there are a number of challenges on the horizon. One is the sustainability of the field, and its tool and technologies. With this in mind, we are increasingly seeing the favoring of open-source tools to meet digital preservation requirements (Gengenbach et al., 2016). While this may not always be practical, when it can be achieved it helps ensure that development is transparent, can be picked up easily by others and carried out collaboratively. In this chapter we have tried to highlight open-source options where possible. Another emerging challenge is the increasingly common blurring of the boundaries of what we have typically understood as digital objects. The increasing use of software that is cloud-based and dependent on the web for access poses challenges to digital preservation, such as the widespread use of Google Docs (Mitcham, 2017). As a result, there is increasing interest in capturing a record of the subjects' history and context as documentation, as means to extend, augment or event act in place of object-centric and content-centric preservation efforts. This may be particularly important in cases where the subject of digital preservation is inextricable from the networks it occupies – for example, virtual worlds (McDonough et al., 2010) and internet art (Dekker, 2018).

Art Conservation

Conservation "encompasses actions taken toward the long-term preservation of cultural property" (American Institute for Conservation of Historic and Artistic Works, n.d.). The principles and theories that support it as a discipline were shaped over the twentieth century, evolving from the in-depth knowledge of production processes and constituent materials of objects to concerns about authenticity and the ability to study original materials. Principles that have resulted from this evolution include: making any treatment or intervention clearly identifiable and reversible; introducing the least possible change to original materials; and an emphasis on thorough and accurate documentation of actions taken (AIC, 1994). Paraphrasing Jill Sterrett, Director of Collections at the San Francisco Museum of Modern Art, one of the roles of contemporary art conservators is to create finds for future researchers (J. Sterrett, pers. comm., 2016).

Traditionally there has been a strong focus on the materiality of the preservation object, but different specialties in the field – from ethnographic objects to industrial heritage to contemporary art – have widened the scope of conservation to include considerations about the context of objects and their use, that influence or sometimes determine how an object is preserved (Muñoz-Viñas, 2012). Contemporary art – including art with digital components – has, because of its dependency on complex industrial technology, widened the focus of conservation from the physical object to include the artist's intent and the public's experience of an artwork. The principles developed for the preservation of traditional materials still apply, but the outlook of conservation has changed from avoiding change to managing inevitable change (Depocas et al., 2003; Laurenson, 2006; Phillips, 2007).

An important aspect of time-based media art (art involving technology and a durational element) is its often spatial and performative nature, meaning that an artwork only exists if its equipment is running and properly set-up within a space that meets certain requirements. Conservators of time-based media work with artists, technicians, galleries and curators to define what the artwork is, how it should be displayed and how an artist may want to see it preserved. The concept of work-defining properties (similar to the significant properties concept introduced in the Digital Preservation section) provides a framework to support decisions around changes to an artwork. This can vary from changing a specific piece of equipment (for instance, swapping projectors from a technology like LCD to DLP) to migrating to a new medium. While this technical evolution of the artwork is a necessary component of contemporary conservation, the extent to which an artwork may change varies considerably, and conservators and curators are responsible for overseeing these processes within the museum. Negotiating change involves maintaining a balance between changing a work to be able to display it and wanting to be respectful of its technical art history. A strategy to keep that balance is to create thorough documentation of original systems and the changes made to them. If art historians in 20 years' time are to understand a specific artwork, its context, how it has evolved over time, then the focus on documentation is essential, and the effort put into it by teams of conservators fully justified.

A time-based media conservator needs very specific knowledge of the technologies involved in production, but also on the strategies and tools being developed for preservation. Training in this field was first available in 1999, when the first specialization was launched at the University of the Arts in Bern, Switzerland. In the US the degree in Moving Image Archiving and Preservation started in 2005 at the Tisch School of the Arts at NYU, with a broader focus in moving image. The need for further expertise in this field has been acknowledged in the US in the last 5 years, with new positions and fellowships in time-based media conservation in museums like the Denver Art Museum, the Metropolitan Museum of Art, Hirshhorn Museum and the Smithsonian Institution. The National Digital Stewardship Residency has also supported fellows in institutions working with time-based media art collections. There is currently no similar training in the UK, as far as the authors are aware.

Artists working with video or software are also confronted with the need to maintain their works, and often they must support collectors and institutions in their preservation measures. This has happened with video from the beginning, with artists migrating video tapes as needed, and the same trends apply to artists who are asked to show now obsolete works. Many artists are interested in approaches to the aging or evolution of their artworks. One accessible introduction has been written by the artist Rafael Lozano-Hemmer, whose "Best Practices" document serves as a guide to other artists interested in the longevity of their work (Lozano-Hemmer, 2015). In this document, among his other recommendations for artists, he suggests that artists trust conservators – and that is good advice if artists are interested in keeping their work alive.

Conserving Digital Video Art

The medium most frequently found in Tate's collection of time-based media art is video. This includes single-channel video works, video as part of sculptural or installed works and as complex multi-channel video installations. It is fair to say that any video work-of-art is the result of four elements: the media, the playback system, the display equipment, and for video installations, the exhibition space and all its elements. Conservators must understand the specificity and relevance of all these elements to maintain the identity of a work. This understanding is a key part of any acquisition process even before a work is fully brought in to the collection. It must be kept in mind that this understanding is also likely to change, at least partially, over the life of the work. The initial questions conservators ask pertain the production process and the media of an artwork along with its display parameters and equipment. Following Tate's usual workflow, we will start by addressing the files themselves and processes around them, and then focus on the display parameters and equipment.

The media is usually the core of a work, and also the object of most of the conservation actions taken. These actions include tape to file migration for obsolete formats, quality control of any files supplied or produced from migration and sometimes file transcoding. It is also essential to have archival digital storage in which to keep them. A good example is *In the Bush* (1972a), by Gilbert & George, which together with *Gordon's Makes Us Drunk* (1972b) and *A Portrait of the Artists as Young Men* (1972c), are the earliest video works in the collection, being acquired in 1972, shortly after their production.

Fig 11.2 Gilbert & George, In the Bush, 1972 (T1702) installed at Tate Britain. (© Gilbert & George and Tate, London 2018)

In the Bush was produced and stored in analogue open-reel tape, then transferred to digital tape formats in 1998, and in 2010 transferred to a file format. By then it was clear that all the tape-based video media would need to become file-based both for preservation and display purposes. At that point it was also clear that more and more artists were working in a fully digital environment and that the production of video art moved from being dependent on hardware and technical facilities to be available on every laptop. This is reflected in the media formats supplied by artists for archiving and display purposes, which ranged from Digital Betacam and DVD in the early 00s to the multiple flavors of Apple ProRes and H264 currently used as master and display formats, respectively. Following the evolution in the entertainment and broadcasting industries, we have seen a shift in resolutions from Standard Definition video to High Definition and more recently 4K, as well as in aspect ratio from 4:3 to 16:9 and now 16:10. It is only a matter of time until we collect our first 3D and Virtual Reality works.

In relation to the media the aim is to preserve both the production format used by an artist and be able to create formats appropriate for display over time, adapting to new playback and display technologies. To decide which formats to preserve it is essential to understand the production process of a video. Did it start as an analogue tape? Maybe the video was made from a low quality Mpeg4 file downloaded from YouTube? The image quality may look terrible to some audiences, but that can be part of the artist's intent and certainly part of the production history of a work. The handling, storage and care of these files must be as careful as for any other artwork. At Tate checksums (introduced in the digital preservation section) are calculated as soon as a file comes in to ensure any issues with file integrity can be easily detected and any unwanted change corrected. Thorough quality control is done when a work is first received, each video is viewed in its entirety, for content and errors that may have been overlooked. Specialized quality control tools for digital video tools, for instance the QCTools software (MediaArea, 2017), are also used to help in this process.

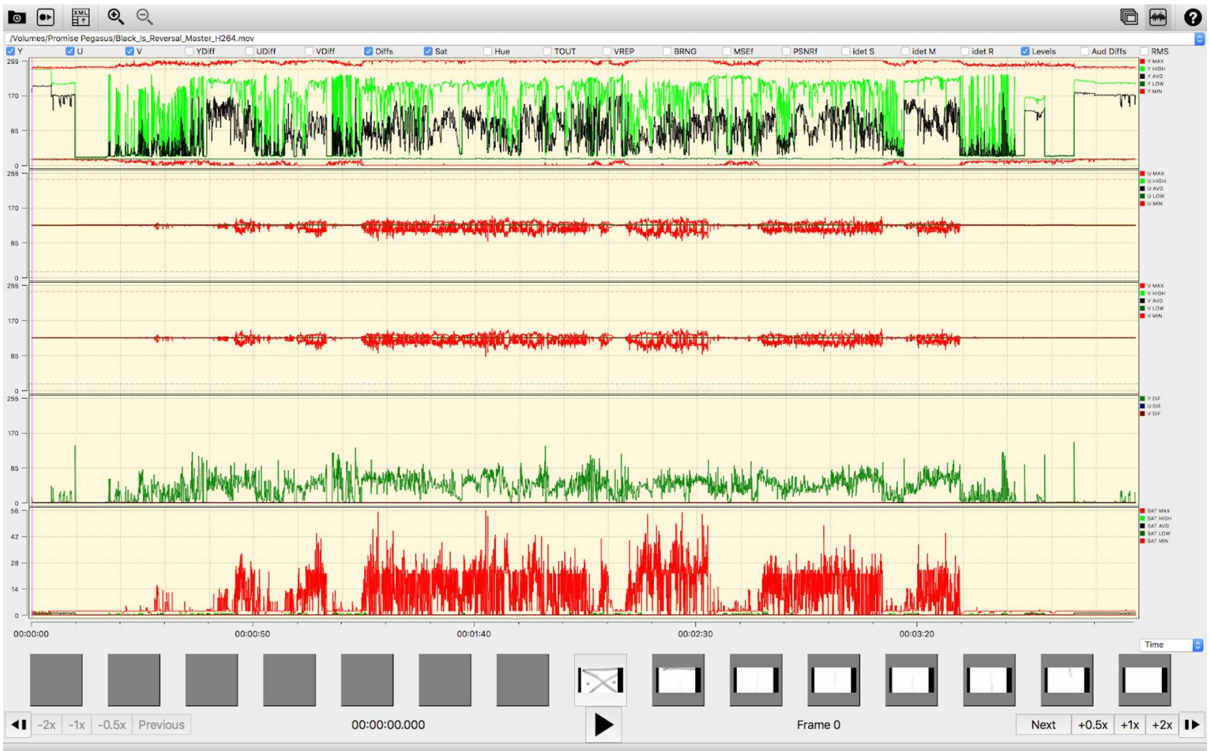

Fig 11.3 Graphical interface for QCTools (MediaArea, 2017), an open-source software tool used to analyze and understand video files, developed by MediaArea.net. (Screenshot by Patrícia Falcão)

File headers are investigated to confirm technical metadata and identify possible problems with codecs, using tools such as the open-source MediaInfo (MediaArea, 2018). At this point risks for preservation are identified, and so files that use uncommon or unsupported formats or codecs must be transcoded to a more sustainable format (Rice, 2018; Arms et al., 2017). Once all of this is done the file or files can then be moved to archival storage. An interesting development, somewhat parallel to what happened with artists, is how the technical skills and knowledge about digital video files has evolved with this new digital environment. While in the tape-based environment even an institution with Tate's resources would use external video production services it is now normal that the expertise around video files and how to handle it is available in-house and time-based media conservators are now comfortable working with command line tools and analyzing files. This is based on the work being done in the video and film preservation area around open source tools, open video formats and training. Media archivists and developers are collaborating to create tools to the archivist's requirements, and conservators and conservation students are contributing to the development of their own tools.

The next element that is useful to consider is the equipment, both for playback but mostly the display. Whether an artwork is shown on a monitor or as a projection is usually a very deliberate decision from the artist or possibly curators. Obsolescence of display equipment is the most easily identifiable issue around preserving time-based media – the demise of CRT monitors being a familiar example. This obsolescence process has been very visible and can strongly impact the look of a specific artwork, most clearly when the equipment is meant to have a sculptural effect, as in the work *Joints 4tet Ensemble* (1971-2010) by Charles Atlas, where the CRT monitors are almost like actors in a stage.

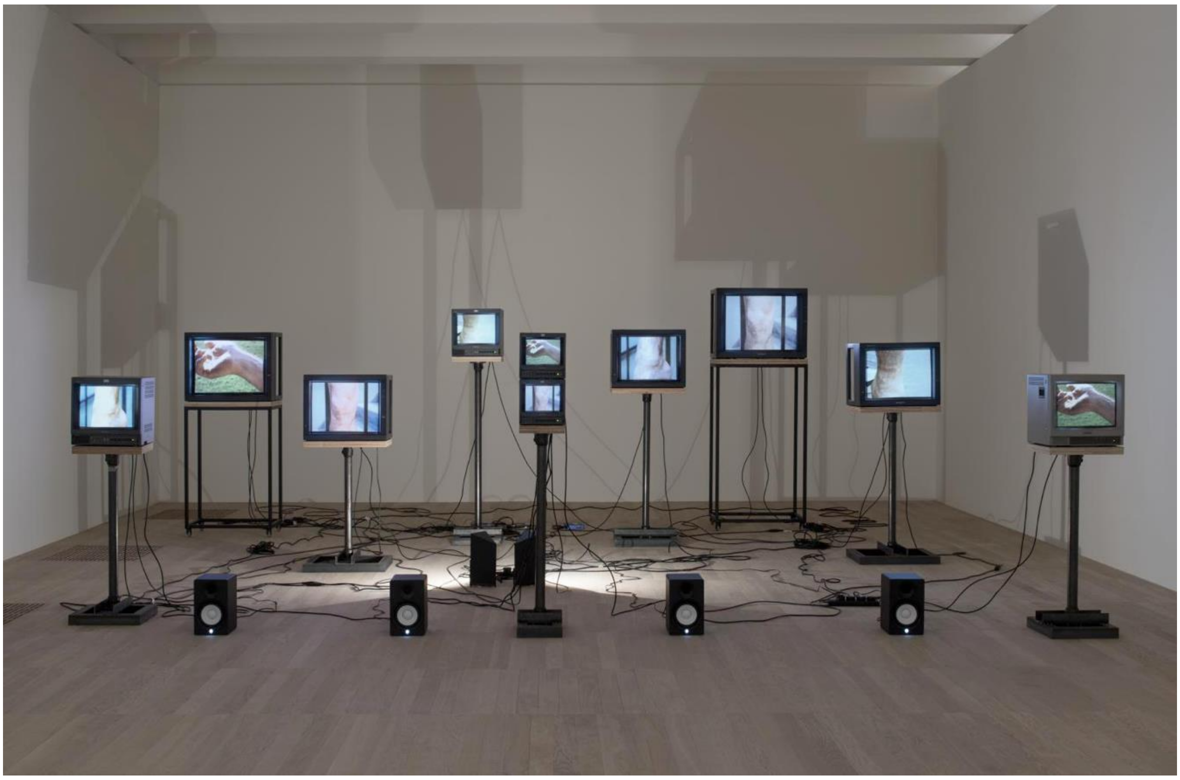

Fig 11.4 Charles Atlas, *Joints 4tet Ensemble*, 1971–2010 (T13849). (© Charles Atlas and Tate, London 2018)

We have seen that often the decline of a technology will drive interest from artists in using it. An example is the use of CRT projectors, which have been discontinued in the early 2000s, but were recently used by Mark Leckey in his work *Dream English Kid, 1964 – 1999 AD* (2015).

Fig 11.5 Mark Leckey, *Dream English Kid, 1964 – 1999 AD*, 2015 (T14213). The CRT projector is visible at the center of the space. (© Mark Leckey and Cabinet, London 2015)

The use of obsolete technology means that conservators and technicians are having to develop networks of experts on the different types of equipment. These experts are helpful not only in maintaining existing equipment but also often in sourcing replacement equipment or parts and most of all in training the conservation team on maintenance and repairs. It is also clear that both new and obsolete technology require conservation teams to acquire new skills.

As mentioned at the beginning of this section, videos can also be part of much larger installations including many different components, such as sculptural elements, photographs or even live performances.

Fig 11.6 William Kentridge, *I am not me, the horse is not mine*, 2008 (T14213), installed at Tate Modern, South Tank. (© William Kentridge and Tate, London 2018)

Commonly these works will be video installations for which video projections have a relationship with the space where they are being shown. For example, William Kentridge's *I am not me, the horse is not mine* (2008) when installed in the space of the South Tank at Tate Modern in 2012/13, created a different impression to the same work as shown at Inhotim in 2015/16. Information about the exhibition space, the size of the projection, whether the space should be dark and more cinema-like or lighter and whether the work can be shown with other artworks, are all questions that help define the artwork and the requirements for its display. Often it will also highlight the need for specific playback, display or audio equipment.

Some artists will simply request that a work is projected or shown on a monitor (with varying levels of specificity), where others may require that a particular space is built. To ensure that this happens according to their requirements, artists will often create extensive drawings and plans, provide precise dimensions and specify the type of equipment to be used. Conservation teams will usually collect and keep this information, track it over time and highlight changes and the reasons for them. These are likely to be the finds for many later researchers.

Conserving Software-based Art

The term software-based art has emerged from museum conservation practice over the past decade to describe a group of artworks for which software forms the primary artistic medium. For these artworks, software is not only employed in the display of the artwork in a functional sense (that is, software is being executed when the artwork is displayed) but is also utilized by the artist as a means of expressing an artistic statement. Software has been used in such a way by artists since the early days of the technology. The cybernetic sculptures of Nicolas Schöffer (Dreher, 2014) and Edward Ihnatowicz (Mundy, 2012) for example, both utilized computers developed by the Phillips Company to control a set of sensors and motors which allowed these works to respond to their environment. While these early experiments stemmed from collaboration with industry, the increase in access to computers over the following 50 years, culminating in the personal computer, saw software becoming more accessible to artists (Taylor, 2014). Since the early 2000s, software-based art has begun to enter the collections of museums of contemporary art, with Tate acquiring its first – Michael Craig-Martin's *Becoming* – in 2003. The collection remains relatively small today, but shows signs of an increased rate of growth in the last few years. Frances Morris, Director of Tate Modern, said in 2016 that, "for the collection, the next big challenge is going to be digital. In the 19th century we didn't buy photography. It took us over 100 years to catch up. Let's not be in that position again" (Higgins, 2016). As a result, identifying strategies for preserving these works has become a pressing concern for conservators of time-based media.

Fig 11.7 Michael Craig-Martin, *Becoming*, 2003 (T11812). This work was the first software-based artwork to enter Tate's collection. (© Michael Craig-Martin and Tate, London 2018)

The materials acquired for software-based artworks can vary considerably, ranging from portable storage media (such as external hard drives and USB sticks), to complete computer systems, to digital downloads (for example, from an artist web server). In all cases however, some kind of executable code is at the core of the work, the execution of which results in the experiential qualities of the artwork. Much like digital video, the display of software-based art is often contingent on hardware components which may become increasingly difficult to replace as they become obsolete. These problems are often magnified for software-based artworks, which may employ many interrelated components, including both bespoke and off-the-shelf software, in order to achieve particular behaviors and characteristics. It can therefore be difficult to predict how change will affect these complex systems without regularly revisiting the work in question (Falcão, 2010). Furthermore, software-based art is often diffuse (Laurenson, 2013) – that is, it extends into its technical environment. Most commonly this is observed in linkages between the software and the computer system which supports it, but in some cases the connections may extend beyond the gallery walls and into networks and the internet. These make for some of the most challenging cases for conservators, as the longevity of the artwork involves responding to unpredictable forms of change in external resources – a challenge we will return to later in this section.

For contained software-based artworks (i.e. those for which the technical system does not extend beyond the gallery walls), content-centric and object-centric approaches to digital preservation outlined in an earlier section (see Digital Preservation) can still be applied successfully, although their application may be challenged by certain characteristics of software-based art. Unlike digital video, software is hard to understand simply by examining the digital object which is acquired. This is usually a package of executable software (or 'binaries'), a compiled form of software, the internal data structure of which is designed to be understood by a machine rather than a person. Therefore, gathering information about what it does and how it does it becomes much more challenging using this object alone. This has led to new collaborations with experts from the fields of computer science and software engineering, and work to incorporate this new knowledge into the existing frameworks of conservation. In this section we will highlight research and case studies relating to several complementary approaches to software-based art conservation.

The first is to focus on ensuring that a suitable technical environment is maintained in the long-term. In these cases, the emphasis is on preserving the digital object as-is (without altering the bits) and understanding its links with other components to ensure these links can be maintained. As a starting point, digital forensics tools can be used to capture a complete bit-for-bit copy of the storage device acquired as part of a computer system. This encapsulates all of the software contained, without impacting its internal structure. This can be examined as a virtual device, or if paired with information about the hardware configuration, can be used as the basis of emulation or virtualization strategies. The latter are powerful techniques for preservation, which allow one operating system (i.e., the one encapsulated within the disk image) to be executed on another of a potentially completely different architecture. In this way, the content of a Windows 95 PC hard disk drive could be booted on a contemporary Linux host. The utility of this approach has been explored in recent research at Tate (Falcão et al., 2014; Rechert et al., 2016) and elsewhere (Lurk, 2008; Rechert et al., 2013). There remain issues in the legality of approaches which rely on archiving third-party commercial software – a problem affecting software preservation broadly. Recent developments in the United States, including an exemption to the Digital Millennium Copyright Act (Albert, 2018) and work toward a Code of Best Practices (Association of Research Libraries, 2018), are promising signs of progress.

One example we will briefly highlight is the application of virtualization to John Gerrard's *Sow Farm (near Libbey, Oklahoma) 2009* (2009), an example which demonstrates some of the considerations involved when taking this kind of approach. Gerrard is an Irish artist who works in a medium he calls real-time 3D. This involves the use of technology more familiar from video games and architectural visualization to render 3D imagery from a collection of data assets (including meshes and textures) in a scene dynamically controlled by a simulation model. In this work, a camera orbits a complex of buildings modelled on a real pig farm in the Great Plains of the USA. This scene was painstakingly reconstructed in 3D, based on extensive on-site photography. As the camera slowly orbits the buildings, day and night cycles unfold in real time over the course of 365 days. Once every 156 days, a truck drives up to the buildings and waits for one hour, symbolizing the moment of exchange as the mature pigs are collected for slaughter.

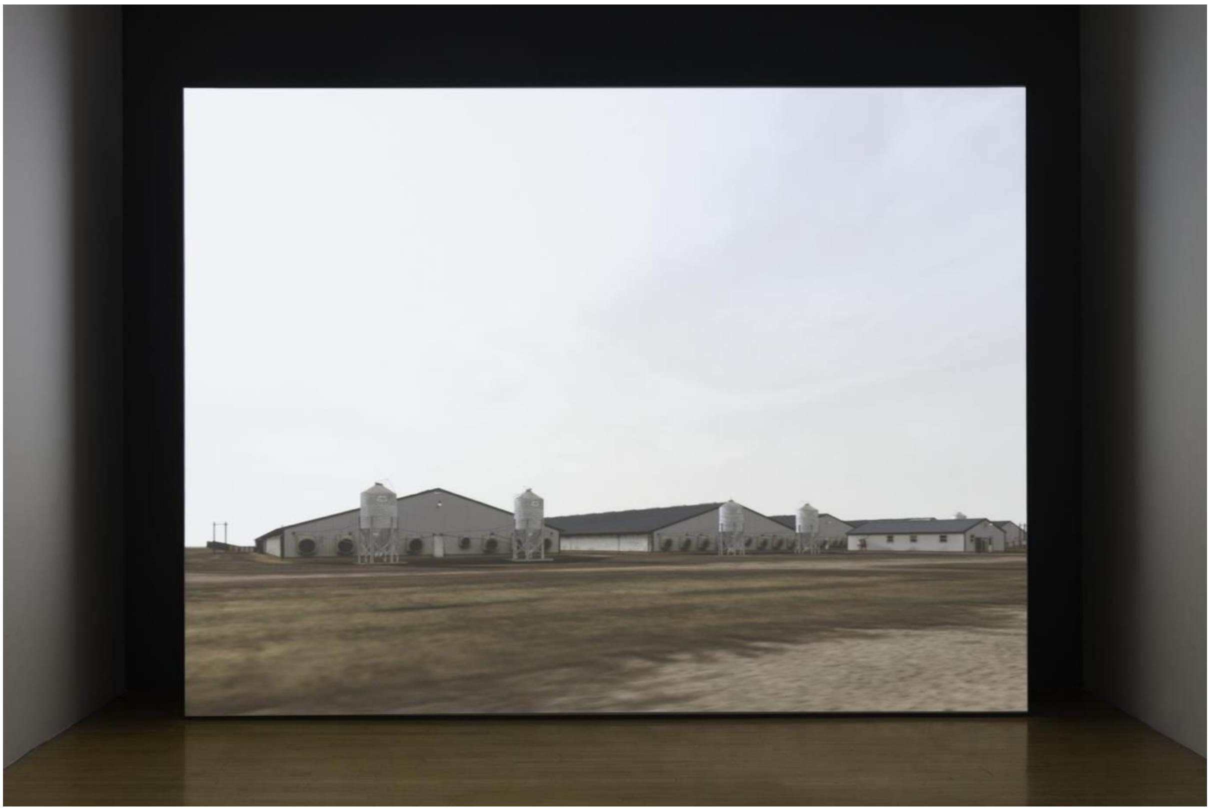

Fig 11.8 John Gerrard, *Sow Farm (near Libbey, Oklahoma) 2009*, 2009 (T14279), installed at Tate Britain in 2016. (© John Gerrard and Tate, London 2018)

In this case, the software is much more than just functional - and the nuances of the lighting and processing of the rendering engine make the work-defining characteristics of this work difficult to separate from specific software binaries acquired. Furthermore, the engine on which the software is based is no longer commercially available. Moving the simulation to a new 3D engine would be a high-risk option, and the precise qualities of the rendered image specified by Gerrard could be lost. As long as existing hardware supports the specific Microsoft DirectX API employed, the work can be migrated to new hardware. In the longer term, using emulation or virtualization would be a suitable way to recreate this specific technical environment, a process which was tested at Tate in 2015 with promising results (Falcão & Dekker, 2015).

For this work, the graphical fidelity of the rendered image is paramount, and the artist has specified particular performance and quality parameters to be maintained when it is displayed. This includes the requirement of smooth camera movement (measured in respect to the frames generated by the host system) and the application of specific rendering effects using the graphics card driver. In this case it was found that when running in a virtualized environment, these characteristics were lost (Ensom, 2018), which thus prevents the use of the strategy until the technology allows them to be applied. This example demonstrates the caution required in applying emulation and virtualization, and how problems may emerge where issues of performance are not completely identified. Such strategies must be carefully applied to ensure that the characteristics of the original ‘performance’ are maintained. This idea of integrity of performance runs through all software preservation work and achieving this could be considered one of the conservator’s main goals.

Another approach is to focus on the code – the set of instructions on which the computer system acts when the artwork is realized. Here emphasis shifts from understanding technical environment, to understanding what the software *does* and how this might be changed or reimplemented in order to avoid obsolescence. The utility of source code in conservation and technical art history has been championed by Professor of Computer Science at NYU Deena Engel, in a number of collaborations with Glenn Wharton from New York’s Museum of Modern Art (Engel & Wharton, 2014, Engel & Wharton, 2015) and Joanna Phillips from the Solomon R. Guggenheim Museum (Dover, 2016). While many museums had already been seeking to acquire source code with accessioned artworks, this research has demonstrated the value of source code as a key tool in the conservation of software-based artworks, providing a complete description of the functionality of the work, which can then serve as documentation, and allow troubleshooting when applying preservation strategies. The latest strand of this research, conducted by Engel in collaboration with time-based media conservator Joanna Phillips, applied an approach that reframes ideas of minimal intervention for software, by leaving the original code of a website intact (as code comments) while adding new lines in order to reimplemented original functionality in newer frameworks (Engel and Phillips, 2018). Further collaborations of this kind are likely to be very important in continuing to keep museums at pace with fast moving technology.

José Carlos Martinat Mendoza's *Brutalism: Stereo Reality Environment 3* (2007) is an installed software-based artwork, the formal focus of which is a scale replica of the 'Pentagonito', a building in Peru that housed the secret service during the Fujimori presidency. Sitting on the surface of this sculptural element are a set of thermal printers, connected to a computer by visible cables which sprawl across the gallery floor. This computer is connected to the internet, and behind the scenes is searching the internet for terms relating to the word 'brutalism' (or 'brutalismo' when exhibited in Spanish-speaking countries), forging serendipitous connections between the various meanings of the word. Fragments of these search results are printed out, falling onto the gallery floor and accumulating during the time the work is active.

Fig 11.9 José Carlos Martinat Mendoza, *Brutalism: Stereo Reality Environment 3*, 2007 (T13251) installed at Tate Modern in 2012. (© José Carlos Martinat Mendoza and Tate, London 2018)

For Brutalism, we can understand many of the artwork's work-defining characteristics as residing in the underlying concept and the instructions that were encoded in its binaries when the source code was compiled. In this case, the source project files (which contain the human authored representation of the code, pre-compilation) acquired with the work might be used, altered or even reimplemented in another language should Java become obsolete. Reworking of the code has already happened once for Brutalism, as the artist and programmer worked remotely on a development machine to update the code to add support for the USB communication protocol, replacing the obsolete parallel port module used in the original version to connect to the printers.

However, the connection with the internet results in a vulnerability that extends beyond what can be understood simply through functionality expressed as code. The artist and programmer originally utilized the Google Search API, the ubiquitous search engine of the time, through which to harvest internet search results. Changes to the Google Search API are likely to render this component of the work non-functional in the short term as the API changes, requiring continued work on the code (this has already occurred once in preparation for display at Tate Modern). What happens if search engines close off their public APIs? What if search engines as we know them cease to exist? In these easily imagined futures, the artwork is not something which can be fixed in terms of digital object or code – rather, it must continue to evolve in order for it live. The museum therefore faces difficult decisions in the long-term care of this work. Does the work become static, the live link to web severed and the database remaining a historical artifact? Or should the work be reinterpreted in some way to meet the changing world in which it is situated? In this case, future conservation treatments may need to be more drastic in its departure from earlier versions. There are no easy answers to these questions, and museums are having to negotiate them on a case by case basis as they arise.

What we can do however, is document the rich technical history of these works, their variable installation and their shifting relationship with a broader socio-technical context. Forms of documentation that support this may engage directly with process and change. Documentation best practices for software-based artworks now include video recordings of the functioning work and interactions with visitors, acknowledging the limitations of text and still image to document dynamic works. For internet art, tools like Rhizome's Webrecoder have been developed to capture website documentation (crucially including traces of user interaction with the site) in contained archival file formats which can be replayed in the future (Kreymer, n.d.). Museums are now experimenting with forms of process documentation such as the use of version control systems to capture changes in source code as software-based artworks evolve (Haidvogl, 2015; Paul & Mancusi-Ungaro, 2018). This provides a rich record of the development history of the software, which as we know from research into source code analysis can provide considerable insight into an artist's working practice (Engel & Wharton, 2015). Looking beyond technical approaches, the notion of 'artwork biography' has been developed by a group of scholars based in the Netherlands (van de Vall et al., 2011). This philosophical perspective on conservation posits the idea that artworks be considered biographical subjects. We might therefore want to generate rich accounts of their life histories, through an "interweaving [of] partial biographies with different beginnings, itineraries, dynamics and endings" (p.6). How this desire might mesh with the pragmatism demanded in conservation practice remains an open question, and one that museums may seek to answer in the years to come if they are to help ensure a historical record for this rapidly evolving medium.

Conclusion

In this chapter, we have introduced the fields of digital preservation and art conservation, and their intersection in the long-term care of digital art. We have examined some of the primary challenges in the conservation of digital art, and highlighted some of the recent research (at Tate and further afield) that is being undertaken in order to meet them. Among the insights gained, it is clear that there is no silver bullet solution nor any one-size-fits-all method for conserving digital art. The process of conserving digital art is driven by the characteristics of the artwork and its relationship with the particular technologies employed in its realization, resulting in a variable set of considerations in each case. Even within a particular digital media type there may be considerable variation in approach taken: an internet artwork experienced through a web browser, for instance, demands very different considerations to an interactive installation realized in a gallery environment – despite both being dependent on computer systems running software.

As illustrated in the examples discussed in this chapter, developments in preservation technology are also shaping how we approach the preservation of digital art. For example, the growing maturity of emulation and virtualization tools has resulted in a growing interest in their application to digital artworks, particularly as they become more feasibly applied at scale. Collaboration is also proving to be essential in order to address the challenges presented by digital technologies as they enter museum care. Having already helped museums meet the requirements of digital video and its display, we are now seeing new connections forged between conservation practice and expertise in computer science, leading to pioneering new research. Nowhere is this clearer than in preserving software-based artworks, which have required the conservator to engage with expertise outside the museum in order to understand the role of code and programming in the care of such works.

Looking more broadly, it is evident that the practice of art conservation has evolved from object-centric origins towards an acceptance of the evolution of the artwork over time. Thus a significant part of the conservator's role becomes managing this process, documenting its phases and brokering collaborations. Within this model for conservation practice, the artwork is not simply collected and stored, but enters a phase in its life of custodianship, in which the museum negotiates its continued placement within an evolving socio-technical environment. For institutions starting out with the conservation of digital art, we recommend an engagement with the established communities who have been involved in the field as it has developed. While the field is always developing to meet the new challenges posed by technologically-engaged artistic practice, many of the common problems faced are surmountable with existing approaches.

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