Virtualisation as a Tool for the Conservation of Software-Based Artworks

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ABSTRACT

Tate has a small but growing collection of software-based artworks. From the outset basic preservation procedures, like testing equipment, backing up hard-drives and assets or thoroughly documenting the hardware and software were put in place, but it was clear that these procedures would need revising over time and as our experience grew. Tate's earliest software-based artwork was created in 2003 and after 10 years the issues around aging technologies are becoming more obvious and new strategies for preservation are more urgently needed. The number of artworks being acquired and displayed is increasing and therefore better workflows must be developed to accommodate this increase.

This paper describes a short project to scope the use of virtualisation for preserving software-based artworks in Tate's Collection. It briefly explains the tests performed, in terms of the techniques, resources and expertise involved.

Through the tests it was confirmed that virtualisation is a viable strategy for the preservation of software-based artworks, and that it meets our requirement that the artworks be stored as a complete system independent from the original hardware. It was also a main requirement that different virtualisation tools must support the resulting virtual machines. As a conclusion, the workflow currently being developed for the preservation of Tate's software-based artworks will be outlined.

General Terms

Case studies and best practice, communities

Categories and Subject Descriptors

H.3 [**Information Storage and Retrieval**]: Digital Libraries

J.5 [**Arts and Humanities**]: Arts, fine and performing

Keywords

Software-based Art, computer-based art, born-digital artworks, virtualisation, digital preservation, long-term access, museums.

1. INTRODUCTION

This paper discusses a current proposal for virtualising the software-based artworks in Tate's Collection as a preservation strategy. The proposal is defined within the context of the Tate Collection; the current strategies in place for the preservation of software-based artworks, the existing infrastructure and the resources available.

The proposal is the result of a short project[1] in which different departments at Tate worked collaboratively, namely: Collection Care Research, Conservation and Information Systems (IS). This research was done in the context of the Pericles project [1]. The team of researchers set out to create virtual machines (VMs) for two artworks as an experiment to test whether virtualisation is a viable strategy for preservation. The main aim of the experiment was to understand if these artworks could be virtualised and if, once virtualised, the software behaviour remained unchanged.

Based on prior work done on identifying risks for the preservation of these works [2], the team knew features such as processor speed, interfaces with peripherals or connection to the Internet could become problematic, and so the artworks tested included these functions.

Virtualisation has not been previously used for preservation at Tate, however, because Tate's IS infrastructure is based on virtualised servers, there is already the required expertise in-house. The project was an opportunity to start thinking about the preservation of software within the context of Tate's infrastructure, the current preservation practices and most importantly in cooperation with our IS department.

Because VMs are susceptible to obsolescence, creating one to run the artworks must be seen as an initial step. The virtualisation process copies the original operating system and artwork software to a form independent from the existing aging hardware. The existence of the complete system as a file that can be run in the current virtualisation platform, and benefits from the maintenance provided by the IS department, is a promising start. Also positive is the fact that the files created can be saved in a standard format, increasing the likelihood that the virtual machines remain sustainable for a longer period of time.

For the research project, the team tried two virtualisation tools, VMware [3] and VirtualBox [4]. We were interested in questions of long-term sustainability, whether virtualisation could create a functioning copy of the artworks and also how feasible it would be for a non-IT specialist to use the virtualisation tools. Once these issues were investigated, the next question was whether virtualisation could be made part of the preservation workflows currently in place.

The result of the research was the agreement that virtualisation is a valid strategy and that the tools tested partially match the following requirements:

[1] 20 days were allocated across staff in three different departments.

a) The artwork's software is able to run in a form that is as close as possible to the original system.
b) The virtualisation tools support current operating systems, like Windows XP.
c) The virtualisation tool is able to connect easily to different peripherals and networks.
d) The virtualisation tool is easy to use by non-programmers.
e) The resulting files are in a standard format supported by different virtualisation tools.

In preparation for the project, we tried to identify possible emulators to be tested alongside the virtualisation tools. We found some emulators for x86 platforms, such as Dioscuri [5] or QEMU [6]. Testing QEMU would have been interesting, but given the limited amount of time available we opted to test tools that we were already familiar with. Testing QEMU would be the next step in the research.

Overall the outcome of the entire project was positive. Virtualisation does make the artwork independent from the original physical machine, therefore reducing the risks related to hardware failure. It became clear that the virtualisation process is straightforward for some works, but that when peripherals are involved issues will arise that will need specialised intervention.

What we suggest is that by keeping software-based artworks running in virtual machines they are rendered less dependent on the original hardware. Once the original hardware stops working it should still be possible to revert to the virtual version. By identifying and documenting the significant properties of the artwork and the artwork software, and by ensuring that the virtual version is an exact copy of the original, we can then use the virtual version of the artwork to compare any new version that may be created. The new version could either be created on new hardware or migrated to a new operating system or programming language.

2. LITERATURE REVIEW

The importance of preserving the functionality of digital files and software was identified by Jeff Rothenberg in his 1995 paper *Ensuring the Longevity of Digital Documents*, within which he proposes using hardware emulation for the preservation of software environments where digital objects were originally created. Around 2000, the CEDARS project highlighted the importance of emulation as a preservation strategy. As a consequence, Leeds University, one of the main partners in CEDARS [7], developed DomesEm, an emulator for the BBC Domesday Project as part of another project, CAMILEON.[2]

Emulation applied explicitly to software-based artworks was first suggested by Richard Rinehart in 2002 [8][9], and in 2006 Rothenberg [10] published his report on the emulation of the interactive work *Erl King* by Roberta Friedman and Grahame Weinbren, where he describes the successful process of emulating the artwork, and illustrates the issues that arise around the process.

Since 2006, the emulation strategy has been further developed by the digital preservation community as a way of providing access to digital files. The most visible result is the DIOSCURI emulator, a collaboration between the National Library of the Netherlands [11], the PLANETS and KEEP projects [12] [13] and the company Tessella [14]. More recently QEMU has been adopted by the KEEP project in their Emulation Framework, but the tool itself was not developed specifically for preservation.

The proposal of 'emulation as a service' that is being developed by the project Baden-Wuerttemberg Functional Long-Term Archiving and Access (bwFLA) [15] sounds very promising. In the case studies published on their website there are examples of emulating artworks on CD-Rom. It would be interesting to test this emulation tool with different types of peripherals, as often required by software-based art installations.

The ZKM Case Studies [16], conducted as part of the project Digital Art Conservation, illustrate clearly the problems faced and resources needed when preserving and migrating artworks that are highly dependent on particular hardware.

Virtualisation has received less attention than emulation from the Digital Preservation community as a whole, but it has been suggested as a possible tool within the field of art conservation. One of the first references was in 2008, by Tabea Lurk and Juergen Enge [17], who tested the use of virtualisation for the conservation of software-based artworks. They defined the concept of *work logic* of an artwork as "the work logic identifies the core components of the artwork and describes the interlocking of the digital modules involved". They also describe the idea of *work relevant components* and *environmental elements*, and suggest creating an encapsulation layer around the *work relevant components* to maintain them. Enge gave the following informal definition of encapsulation in an interview with the PACKED project: "Encapsulation can mean just about anything that can provide a software layer between the artwork and, for instance the runtime environment, the operating system or the hardware." [18]

Emanuel Lorrain, in a case study for Mondophrenetic™ (2000, Herman Asselberghs, Els Opsomer, Rony Vissers), also suggests the use of virtualisation for the preservation of artworks. Lorrain points out several limitations found when using emulators: limited support for peripherals and more recent operating systems, dependence on voluntary work from a community, and therefore lack of reliability in the mid-term. He suggests using virtualisation, but again points to limitations for older operating systems. [19]

The key point that must be addressed to determine the successful outcome of an artwork's virtualisation is the comparison of the significant properties of the original and virtualised versions. The significant properties of commercial software were defined in the report *The Significant Properties of Software: A Study* [20]. Specific research on the significant properties of networked artworks was conducted at Tate in 2010. Kelli Dipple, Frederico Fazenda-Rodrigues and Pip Laurenson analysed the significant properties of networked artworks as part of the New Media Art Network on Authenticity and Performativity.[21] When comparing the categories identified in both reports it was easy to establish parallels. What also became clear was that software-based artworks require more granularity in describing user interaction, provenance and ownership and also functionality.

3. CONTEXT

[2] In February 2014 the webpages for both CEDARS and CAMILEON were no longer online.

Year Acquired	Year Produced	Artwork	Artist	Type	Operating System	Programming Language
2003	2003	Becoming	Michael Craig-Martin	Software, colour, monitor	Windows XP	2003 Director version (Executable) 2010 – Flash version (Executable)
2007	2005	Subtitled Public	Rafael Lozano-Hemmer	Software, interactive, colour, computer and video projections	Windows XP	Delphi (Executable)
2008	2007	Things Change	Michael Craig-Martin	3 wall-mounted LCD monitors and software	Windows XP	2003 Director version (Executable) 2010 – Flash version (Executable)
2009	2005	Limac shop	Sandra Gamarra	Installation with access to Website	Web based	Wordpress website (php, html, css, mysql database).
2010	2007	Brutalism: Stereo Reality Environment 3	José Carlos Martinat	Fibreboard, 3 printers, paper, tracking system, central processing unit, cables and web search program	Linux Ubuntu	Java (with mysql database)
2012	2005	Colors	Cory Arcangel	Software, Video, projection, colour and sound (stereo)	Mac OS	Objective C / C++
2012	2006	Astrophotography...The Traditional Measure of Photographic Speed in Astronomy...' by Siegfried Marx (1987)	Cerith Wyn Evans	Glass chandelier, flat screen and morse code unit	Windows XP	Commercial Software Morse Translator V12
2013	1997-2002	Adji- part of Library from Museum of Contemporary African Art	Meshac Gaba	Online Game	Web-based	Shockwave, Html, Css

Table 1. Software-based artworks in the Tate Collection

Artists have been using computers to produce artworks ever since software started being developed in the 1960s [22]. Since then, as in all parts of our culture, software has become another tool, amongst many, that artists use to create artworks.

Software-based art has its own circuit of festivals, like the Transmediale in Berlin [23] and collecting institutions, like Ars Electronica in Linz (which started as a festival but became a Centre in 1995)[24] and the ZKM- Centre for Art and Media Karlsruhe [25]. These are still very important hubs for the field. In the 1990s the mainstream contemporary art world also started to collect these types of works and nowadays, major art galleries, like the Lisson Gallery, London, sell software-based artworks by Cory Arcangel alongside sculptures by Ai Wei Wei, for example. Contemporary Art Museums also slowly began acquiring software-based artworks in the 90s and early 2000s.

In 2003, Tate acquired its first software-based artwork, *Becoming* (T11812*)* by Michael Craig-Martin. Since then another five works have been brought into the collection, and two more are in the process of being acquired. Table 1 lists these works.

Eight may seem like a small number of artworks to preserve, particularly if you compare it with around 400 Time-Based Media (TiBM) artworks, or the 70,000 works in the whole of the Tate Collection. Yet currently, the amount of resources needed to preserve one software-based artwork is much higher than the resource needed for an average TiBM artwork. This is due to the technical complexity of the artworks, their uniqueness, but also because the workflows required are not fully established.

The conservation section responsible for the preservation of software-based art at Tate is TiBM Conservation. This team, which is currently made up of eight members of specialist staff, is part of the Conservation Department. It is responsible for the conservation and installation of artworks using video, audio, film, slides, light-boxes, software and performance. TiBM Conservation was established as an independent section within the Conservation Department in 2004. The first TiBM conservator—

Pip Laurenson—was appointed within sculpture conservation in 1996.

The TiBM Conservation team is experienced at managing a variety of technologies and issues of obsolescence, and working with artists to understand both the requirements of an artwork, and the artist's attitude to change. For the TiBM Conservation team, software-based art is a challenge which is best met by both drawing on their existing experience of working with technology-based artworks; and by developing a new set of practices, technical skills and tools - and crucially an additional network of specialists.

Given the permanent technological evolution, and consequent broadening of the range of media in the collection, ongoing engagement in research and active collaboration is required to keep abreast of all the developments but also to devise new strategies to manage dying technologies.

Until recently, there was little collaboration between the conservation and the IS teams regarding the conservation of artworks, mostly because the conservation department had its own infrastructure and processes. This has changed significantly with the need to preserve high value digital information at all levels in the institution, not only for software-based artworks but also video and photography. We now have the opportunity to work with the IS department, who have made the engagement with conservation part of their strategic plan.

Institutions with different departmental structures, capacities and levels of institutional support have found other ways to ensure that they have the technical support they need. For example, some institutions have identified individuals who work on a freelance basis to act as the conduit between conservation and IS.

3.1. The Artworks

Software-based artworks are usually supplied to Tate on a computer, ready to be installed in the galleries.

Each of the eight software-based artworks has a programmed element that is bespoke; however, in the majority of cases the artist did not programme them themselves. The exception is *Colors* (2005), by Cory Arcangel an artist who does his own programming. The other artists in the collection have worked with a programmer to develop a system that will perform a series of actions. Some of the actions performed include: analysing video, mapping the location of visitors in a gallery, or displaying randomly composed tableaux of vector images.

All the artworks have different hardware requirements, and both computers and peripherals are usually supplied by the artist when the work is acquired.

The details of the Operating Systems, software elements and programming languages are provided in table 1. The table illustrates the variety of systems used, and why a network of specialists in different programming platforms is required.

4. CURRENT PRACTICE

4.1. Conservation Strategies

The goal of conservation is to ensure that artworks remain exhibitable within the defining parameters of the work, which are often tightly specified by the artists. To achieve this end, when an artwork comes into the collection, conservators work closely with the artist to identify the significant properties of the work and define what measures are appropriate for preservation. This is done by examining the artworks as they are supplied by the artist or gallery, requesting any additional information needed from the artist, and discussing (with the artist and programmer) what the issues for preservation are likely to be. At this stage possible preservation strategies are also discussed. The documentation of this process forms part of the artwork's conservation record.

Within the conservation of software-based artworks, to date, we have used three possible strategies:

1) Managed Storage- By keeping the hardware in good storage conditions and creating exhibition copies we are prolonging the life of the artwork in its original form.

2) Re-coding or replacing software elements – Conservators work closely with the artist/artist's programmer to re-code the work to a new platform. Another type of migration would be to replace one commercial software by another that has the same function, like a morse code translator in the work "*Astrophotography...The Traditional Measure of Photographic Speed in Astronomy...' by Siegfried Marx (1987)"* (2006) by Cerith Wyn Evans.

3) Virtualisation/Emulation- by this term we are referring to the creation of a virtual machine to run the original software, either by means of an emulation or virtualisation tool. In the next sections the virtualisation process is discussed in more detail.

The applicable strategies are dependent on the value attributed by the artist to a particular component of the artwork. For example, if a computer is designed by the artist and the object itself is the artwork, conceived of as a sculptural object, then storage is the only option. This is the case with Richard Hamilton's Diab DS-101 Computer (1985-9, T07124).

Some artists will define the source code as the artwork, for example Hans Diebner's Liquid Perceptron (2000), as documented by Tabea Lurk [17]. In this case the computer itself may be replaceable, but migration of the code is not an option. A combination of storage and virtualisation/emulation becomes the logical choice.

Across the artworks currently in the Tate collection, the software itself is predominantly considered a tool to produce a particular effect by the artist. Consequently, the preservation of this behaviour is identified as paramount rather than maintaining the original code. It is therefore appropriate to consider migration as a conservation strategy.

4.2. Significant Properties

When acquiring an artwork it is essential to identify its significant properties, as only by defining those is it possible to determine the best combination of conservation strategies to apply. In the *Final Report for the New Media Art Network on Authenticity and Performativity* [21] Kelly Dipple et al. categorises the possible Significant Properties of networked art as:

- Content and Assets
- Appearance
- Context
- Versions
- Formal and Structural Elements
- Behaviour
- Time
- Spatial or Environmental Parameters
- External Links or dependencies
- Function

- Processes
- Artist's Documentation of Process,
- Rules of engagement
- Visitor Experience
- Legal Frameworks

These significant properties are discussed in detail by P. Laurenson in *Old Media, New Media? Significant Difference and the Conservation of Software Based Art.* [26]

The significant properties will vary with the artwork, and are very closely related to the artist's intent. The same property can be significant or not depending on the value an artist attributes to that particular property. Defining them and finding ways of evaluating these properties in both the physical and virtual machines is in our opinion, the main challenge and the most important step in the process.

For *Becoming,* which is described in more detail in the next section, the artist's programmer, Daniel Jackson from AVCO, wrote a script to measure the speed at which images appear and disappear from the screen. For this one work this tool provides a concrete way to measure speed – a significant property of this work. However, this tool is specific to this artwork, and it is unlikely that its usefulness would be applicable to a different work. This indicates that there may be the need to write specific tools for other artworks as well. How to measure quantifiable significant properties is one further strand of research that we need to develop.

Further to the artist intent, it is also important to consider the technical history of the artwork. Migrating the software may be an option if we are presented with the loss of functionality of an artwork, but conservators must also consider the preservation of the production history of the artwork. Emulation or virtualisation may mean that the original program can be kept along with the functionality, and this would be a great advantage.

4.3. Existing Workflow

Before an artwork enters the Tate's collection Time-based Media Conservation creates a report containing a basic technical description of the artwork and a preservation plan. For this an initial discussion takes place with the different stakeholders; the artist and his programmer, curators, conservators and sometimes also technical staff in galleries.

Once the acquisition is approved and the actual work is received a more detailed analysis of the different software and hardware components is created.

At this point it is also standard practice to create an exhibition copy (on hardware as close to the original as possible) in house. This exhibition copy is created to protect the original from the wear and tear problems that arise when equipment is running for 70 hours a week in the museum gallery. In addition to these practical concerns, creating an exhibition format is also a way of understanding the work better, as issues always arise during the process of replication. This step also often requires the involvement of the artist/programmer, and is a moment when the initial description of the software is verified. By creating the exhibition copy we are reducing the risk of failure by wear and tear for the original systems of hardware and software.

In summary, the current approach for preservation focuses on two points:

Documenting the system and the artist's intent:

a) Creating and keeping system reports on the hardware and operating system, along with their specifications and any particular settings.
b) A narrative account of what the software does, and how it does it.
c) A stored copy of the source code, when the program is bespoke.
d) Communication with the artist and programmer about the artist's intent, significant properties, technological choices, preservation risks and the artist's preferences in terms of preservation. This process usually starts with an interview but then develops over time as needed.

Preserving the hardware:

a) Storing original hardware in appropriate environmental conditions.
b) Maintaining the equipment as required
c) Backing up hard-drives.
d) Creating an exhibition copy

Yet, these processes still leave the artworks highly dependent on particular equipment and therefore under threat of equipment failure. By virtualising the artwork, we can remove the dependency on physical hardware to reduce the risk of loss by equipment failure.

5. THE PROJECT

As previously stated, this collaborative twenty day research project was instigated to investigate virtualisation as a preservation tool for Tate's software based artworks.

Given the time-bound nature of the project, we opted to virtualise two artworks at each end of the complexity spectrum: *Becoming* (T11812), by Michael Craig-Martin; and *Brutalismo: Stereo Reality Environment 3* (T13251), by Jose Carlos Martinat Mendoza.

Figure 1-Michael Craig-Martin, *Becoming*, 2003

Becoming is a Windows XP executable that presents eighteen vividly coloured vector line drawings of everyday objects fading randomly, slowly in and out against a fuchsia pink background. It is presented in a custom-made monitor with an in-built computer.

Figure 2- Jose Carlos Martinat Mendoza, *Brutalismo: Stereo Reality Environment 3,* 2007

Brutalismo is composed of both a sculptural and a software-based component. The work is described within Tate's online catalogue as follows: *"This sculpture is a scale model of the Peruvian military headquarters, an example of 'brutalist' architecture it was nicknamed the 'Pentagonito' (or 'little Pentagon'). During the Fujimori presidency, the building became notorious for the torture, murders and disappearances conducted by the secret service. The sculpture incorporates a computer which has been programmed to search the internet for references to 'Brutalismo / Brutalism', picking up extracts about Latin American and global dictatorships but also on architecture, forging associations between different kinds of 'brutalism' which it spews out onto the gallery floor."*[27]

Technically the work is composed of different software elements embedded in the shell of an Ubuntu operating system. It requires an internet connection to connect to Google and outputs to either RS232 or USB printers. We knew that interfaces with external systems cause the most problems for emulation and virtualisation, and therefore expected *Becoming* to be simple to virtualise, unlike *Brutalismo.*

Brian Jones, from Tate's IS department, created the test virtual machines using Virtual Box and VMware.

In considering the different tools the following criteria were used for evaluation :

- Sustainability- is the tool and industry standard or in widespread use?
- Interoperability-what file formats are supported, and are they supported by different platforms?
- Expertise and Infrastructure- is there any expertise in-house, and if so is it possible to use the existing infrastructure? Both tools support OVF, a widely adopted open standard for virtual machines.
- Costs- what are the costs involved?
- Features- can the tool create, open and convert virtual machines?
- Supported Operating Systems- which operating systems are supported?
- For how long has the tool been in use and development, is it a mature technology?

We chose Virtual Box because it is in widespread use and is a free, open source option, and VMware because it is the tool already being used by our IS department for the virtualisation of Tate's servers. They both allow the export of virtual machines in the Open Virtualisation Format (OVF), *a packaging standard designed to address the portability and deployment of virtual appliances* [28]. A further advantage of the OVF format is the metadata included, which describes the virtual machine's properties.

We started by creating a virtual machine, installing the operating system, and copying the software executable into the virtual machine. At Brian Jones' suggestion we then tried using a physical to virtual process, which proved to be more advantageous, as it captures all the information of the original system supplied by the artist, which often contains more than just the artwork.

A good example of where valuable information was retained by using the physical to virtual process was in the programming tools contained in one of the computers, which still contained the source code for the work, but also other code that had been adapted from other artworks. These are very interesting traces of how the software was developed. By looking at the programming tool we learned that the same source code had been used in a series of artworks, with minor adjustments. None of this information would have been captured if we had simply re-installed the software.

At the planning stage we expected problems when setting up the printers for *Brutalismo,* but because they already use a fairly recent type of connection, namely, a USB connection, this proved to be straightforward. It was also straightforward to open the OVF files created in VMWare using Virtual Box, which we had suspected could cause problems.

In discussions over the longevity of a virtual machine, we tried to identify the most likely cause of the virtual machine running Windows XP failing to run. We expect that VMware or any virtualisation platform will eventually stop supporting Windows XP, or 32-bit software. From these discussions it became clear that it is crucial to monitor the evolution of VMWare and the OVF format and their continued support of Windows XP and the 32-bit software. In addition new options for virtualisation and emulation that are likely to appear in the mean time will also be monitored.

5.1. The proposal

As a result of these investigations, the project team proposed adding virtualisation to the current preservation workflow for software-based artworks at Tate. The current procedures will be maintained, with the steps related to virtualisation being added to it in the following way:

1. Description of the artwork.
2. Documentation of the hardware and software environments.
3. Identification of the artwork's significant properties and associated risks for long-term preservation, in discussion with the other stakeholders.
4. If software is bespoke, analysis of the function of the source code supplied, by someone other than the original programmer
5. Creation of exhibition copy. If any extra software must be added to the physical computer (e.g. libraries or drivers for

particular printers) then this should also be made a documented component of the artwork.

6. Creation of virtual machine using the physical to virtual process
7. Compare the significant properties in the physical and virtual machines. Specialist technical support is likely to be required to identify the less visible differences between the physical and virtual machines.
8. Add virtual machine to the virtualisation platform running the other Tate servers.
9. Create OVF file and test it on Virtual Box.
10. Add the OVF file to Tate's High Value Digital Asset (HVDA) storage system

All the new elements created must be tracked in the Tate's Collection Management System, "The Museum System" (TMS)[29], so a component with a unique identifier is created for the following elements:

- physical back-up machine,
- virtual machine on virtualisation platform
- OVF file on the HVDA system
- Individual software required, for example the operating system and particular libraries or drivers.

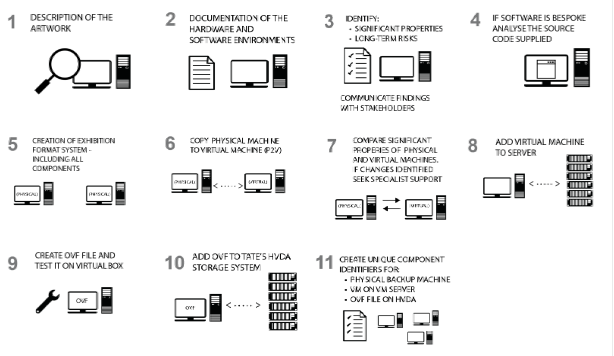

Figure 3-Workflow Diagram

5.2. Maintenance

General maintenance of the virtual machines would be carried out by the IS department, which maintains Tate's servers. This means the conservation department can rely on the pre-existing IS experience, infrastructure and maintenance protocols, avoiding the costs of creating a new infrastructure.

Conservation retains responsibility for testing the virtual machines at regular intervals and any major upgrades of the virtualisation platform. This testing involves comparing the significant properties identified at the beginning of the process and ensuring they remained the same, or within the agreed parameters.

6. CONCLUSION

The project identified virtualisation as a step towards a viable strategy for the preservation of our software-based artworks. Virtual machines will also in turn become obsolete. It may be that the virtual machines can be migrated, or that alternative strategies may be developed in the future to keep the software-based artwork operational. As with any digital object, preservation will need to involve the active monitoring and management of material to ensure that it remains accessible.

Virtualisation provides a complete environment within which the software runs, this enables comparison with our original systems; making it possible to check that they behave in the same way. An important aspect of this strategy is creating a virtualised version of the work, whilst the original can be confirmed as still running correctly.

Each software-based artwork is different, and it is an important aspect of the challenge of conservation to identify the significant properties of a particular artwork. Finding the best way to compare physical and virtual machines will also have to be decided on a case by case basis.

VMware would be our virtualisation platform of choice because it is already part of the infrastructure at Tate, and so procedures for maintenance have already been developed and put in place. Consequently conservation could utilise the expertise and resource already available in house, and did not need to create a parallel system. It is also a more mature tool and has been developed over a longer period.

VirtualBox was not completely discarded, as it is useful for creating exhibition copies, by running the original software in a new individual computer, not a server as required by the VMware tool used in Tate's IS department. It is also a good tool to test the compliance of the VMs created with VMware.

Given the advantage of emulation in running software independently of the underlying system architecture, and also the quick evolution in the tools available it is relevant to research the use of the tools available, namely QEMU.

The preferred method for virtualisation is to create a physical to virtual transfer, as this method captures all the contents of the computer, providing more information about the systems and processes used. Additional testing is required to establish the best method to carry out this transfer, as the tool used during the current tests installed an additional piece of software in the original machine. This is not considered best practice by the digital forensics community, as it introduces a change in the original system. We are therefore considering creating an initial disk image and then using the virtualisation software on the disk image. This method would avoid the need to make any changes in the original computer.

One of the main limitations identified was the virtualization of Apple Macintosh systems. As of this moment Apple Macintosh limits the running of Mac operating systems to Mac hardware, and circumventing this is possible, but raises a host of legal and copyright issues beyond the scope of this project.

Finally, one major outcome was the development of a scenario for the preservation of the software-based artworks, where we defined the steps we think will need to be taken. This scenario was made available to the partners in the Pericles project, and we are collaborating with them to develop useful tools that can help us with this workflow. One example is defining parameters for the Pericles Extraction Tool, which will help us automatically extract environment information, not only the usual system information but also software dependencies.

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