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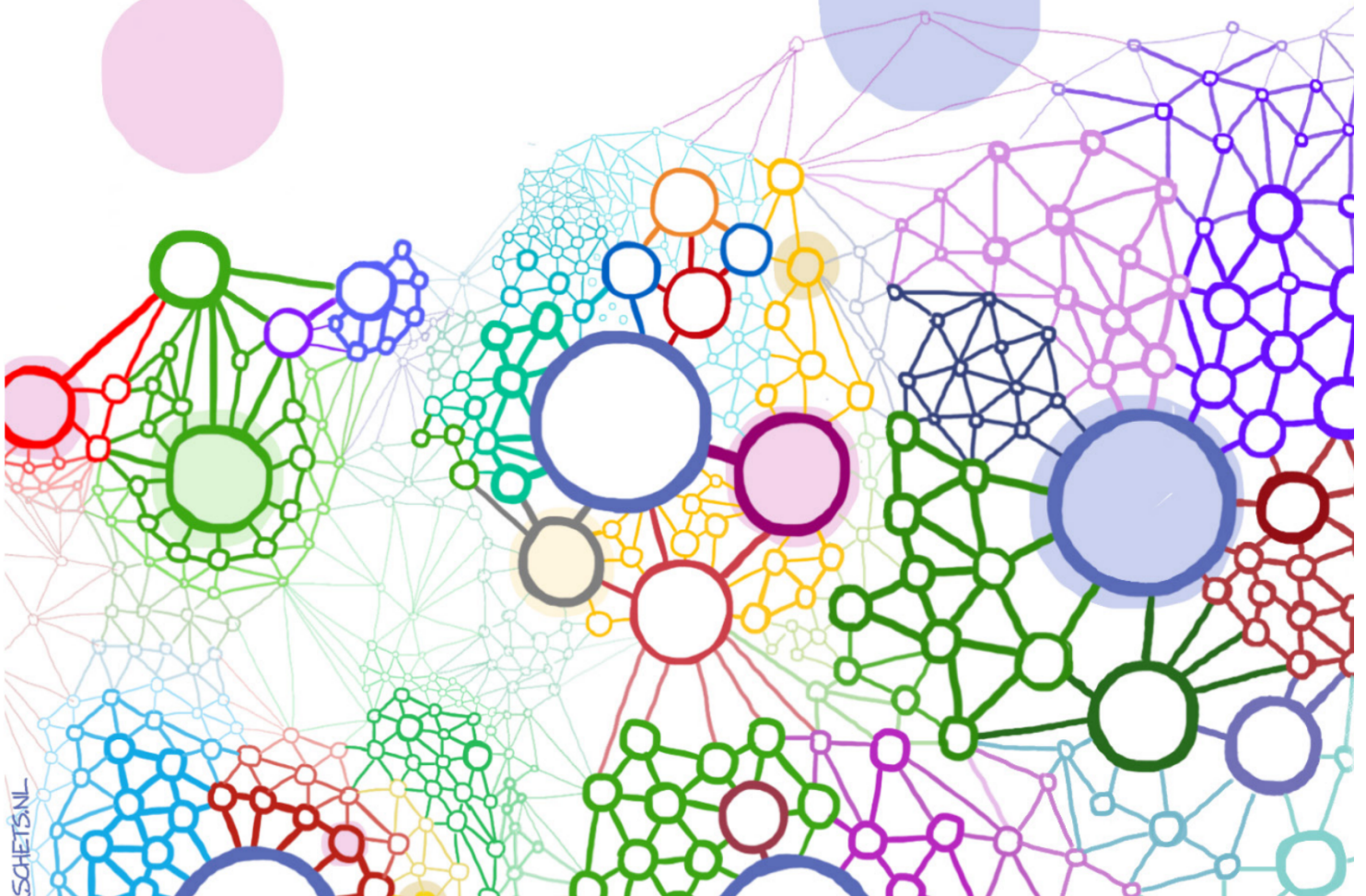
CD-ROM archiving

Archiving and distribution of CD-ROM artworks,
a study of the Emulation as a Service (EaaS) tool
and other proposals

The Hague, 1 November 2016

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ACKNOWLEDGEMENT

This report describes the research into the archiving and long term accessibility of artworks on CD-ROMs. The research was carried out by LIMA within and with funding of the [Dutch Digital Heritage Network](#).

The national Digital Heritage Network was established in 2015. This network's strategy is based on three connected pillars: 1) increasing the visibility of collections, 2) improving the possibilities for using collections and 3) cross-sector sharing, utilisation, and scaling up of facilities for sustainable preservation and access. For each pillar, a work package was devised, consisting of a series of interlinked collaborative projects. The ultimate goal is to arrive at a future-proof and cost-efficient infrastructure that will encompass all of the various domains while meeting the needs of heritage users.

The Netherlands Coalition Digital Preservation was tasked with carrying out the work package "Sustainable Digital Heritage", that includes the study at hand. The aim of this section of the national strategy corresponds with NCDD's mission: to ensure the long-term accessibility of digital information through the establishment of a national network of facilities. This work package runs from September 2015 to May 2017.

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SUMMARY

CD-ROMs were popular carriers for interactive works of art from the early to late 1990s. Unlike mainstream mass-produced CD-ROMs, CD-ROM art was usually published on a very small scale, or even remained unpublished altogether. These artworks were created specifically for this medium, and should not be confused with regular files stored on a CD-ROM. This makes them unique, but also vulnerable. Now that many computers are no longer equipped with optical discs drives, operating systems have become outdated, and files are often unreadable, these works are threatened with oblivion. Emulation is a preservation strategy aimed at ensuring sustained access to CD-ROM art. In this study, we evaluate an archiving strategy for CD-ROM art, partly based on the study of BwFLA's *Emulation as a Service* (EaaS), an emulation tool and service developed by the University of Freiburg.¹ In the first section of this report, we will focus on what is EaaS, and what are the implications of this service for the management and preservation of CD-ROM art collections. In the second section we will set out an archiving strategy composed of three steps: (1) the installation of emulation software; (2) storage and archiving; and (3) access and distribution. In this final step, the potential use of EaaS to enable online access to CD-ROM collections will be explored by formulating an extensive documentation procedure.

This study has produced a clear picture of the current state of affairs in the field, and of the potential for implementing emulation in the management and preservation of CD-ROM artworks as part of our cultural heritage.

Key findings:

- CD-ROM art presents different preservation requirements than regular (mass-produced) CD-ROMs do.
- The workflow and USB-bootable version of Emulation as a Service are suited for further development.
- CD-ROM art should be documented on at least four levels:
 1. Documentation of physical components
 2. Documentation of the work in its original environment
 3. Documentation of its technical specifications and metadata
 4. Documentation for end users
- A Collection Information System must be adapted to fit software-based works like CD-ROMs. The system must provide space for additional metadata and accommodate successive generations or versions of a product.
- Emulators, along with the system files needed to make them work, must also be archived.
- A standard migration procedure must be applied to the entire archive, including virtual disk images and emulators (as these, too, ultimately become obsolete).
- Emulation can cause licensing and legal issues if the user is not in possession of the obsolete software licences (particularly the OS ones). An amendment to the law or a shared license for heritage institutions could be secured in the future in order to apply broadly emulation strategies without any legal risks.

Key project results:

- The sustainable preservation of a small number of CD-ROMs from various Dutch collections, which could become lost and inaccessible to the public without intervention. Through emulation, the works involved in this project can be permanently retained and rendered accessible by the heritage institution.
- An overview of available emulation services, tested for usability and applicability.
- A methodology for ensuring sustained access to CD-ROM artworks, jointly developed, tested and supported by professionals from various institutions.
- An international workshop on Digital Preservation Knowledge Day, organised by the NCDD on 13 June 2016 in the Amsterdam Science Park conference centre.²

¹ Rhizome (US) and iMal (BE) were closely involved with the development of bwFLA, offering case studies, advice and evaluation. EaaS's project leader is postdoctoral researcher Klaus Rechert. See documentation on case studies from iMal and Rhizome collections for online emulation on the website of bwFLA: www.bw-fla.uni-freiburg.de/ [linked checked Sept. 2016]

² <http://www.ncdd.nl/events/goed-kennisdag-digitale-duurzaamheid/> [linked checked Sept. 2016]

METHODOLOGY

This study, conducted by Nina van Doren and Alexandre Michaan, offers an evaluation of the tools and workflows currently available for the sustainable management, preservation and accessibility of digital artworks created for a CD-ROM carrier. Emulation is a promising conservation strategy that has already been examined by LIMA in several earlier projects. By simulating the original environment for which the work was made, emulation allows the better part of its original look and feel to be preserved. Digital art requires an approach that considers the form and content of each individual work. Since individual study of every born digital artwork is time-consuming and impractical, there is a growing demand for easy, ready-to-use emulators. Acknowledging this need, this study is focused on Emulation as a Service (EaaS), developed by the University of Freiburg. Currently, EaaS is the most advanced emulation service on the market, and it simplifies and systematises the sustainable preservation and accessibility of digital heritage material. The aim of this study is to connect to international research into emulation strategies, to contribute to the development of standards, to investigate the potential of EaaS for providing access to LIMA's CD-ROM collection and, in so doing, to provide a use case for other Dutch institutions with a digital art collection.

Finally, this report offers a step-by-step manual for emulation, sustained archiving and distribution.

This investigation was conducted by LIMA as a case study within the Sustainable Digital Heritage work package of the Digital Heritage Network collaborative programme.³ The Netherlands Coalition for Digital Preservation⁴, of which LIMA is a partner, is coordinating the execution of this work package.

The CD-ROM artworks fully tested, documented and emulated for this study are: *Person to Person* (Stansfield/Hooykaas, 1998), *The Second* (NIMk/Montevideo, 1997) and *Puppet Motel* (Laurie Anderson, 1994). These works are representative of the most prominent interactive titles in LIMA's CD-ROM collection. They have been selected for their complex structure and high degree of interactivity, key factors in testing the reliability of an emulated environment. A compressed, ready-to-store file was created for each of these case studies, containing a virtual disk image, technical and visual documentation, and a pre-set emulator that allows users to view and distribute the work on current computers (specific to Mac systems).

The study consisted of four stages:

1. Based on desk and field research, an inventory was produced of the existing studies, best practices, tools, standards, protocols and workflows for emulation. This information was analysed, and *Emulation As A Service* (EaaS), developed by the University of Freiburg, was found to be the best and most advanced emulation service available.
2. Using three digital artworks on CD-ROM as a test sample, the EaaS service was critically evaluated, and conclusions were drawn regarding its usability and the potential for applying it more generically as a part of cultural institutions' primary work process.
3. Based on these conclusions, an overview was made of the next steps to be taken. Prominently, a need for an extensive documentation procedure was noted, and an outline of such a procedure was formulated.

³ <http://www.ncdd.nl/projecten/netwerk-digitaal-erfgoed/> [linked checked Sept. 2016]

⁴ www.ncdd.nl [linked checked Sept. 2016]

4. This documentation procedure was implemented for the three CD-ROM case studies, with special attention being paid to documenting the mistakes produced when an emulator is not functioning properly. This was done by recording comparative video footage of the CD-ROM operating both in its original setting and in an emulated environment.

GOALS

With this project, the institutions collaborating within the Digital Heritage Network aim to make the digital works of art on CD-ROM contained in heritage collections more visible, more sustainable, and easier to distribute. In addition, they hope to increase levels of knowledge through the evaluation of existing emulation protocols. Collaboration and communication between museums, libraries, archives and scientists working in the field of digital preservation are necessary if we want to guarantee the long-term sustained accessibility of digital objects.

SCOPE AND EXTENT

The following activities were performed:

- Examining the existing solutions offered by the University of Freiburg
- Testing these solutions in practice using samples from our partners' collections
- Writing a research report covering best practices and offering recommendations
- Organising an international workshop to discuss this study's findings and recommendations
- Formulating a documentation procedure for CD-ROM art
- Applying this procedure by documenting the chosen case studies: media, equipment, metadata describing the nature of the artworks in question, and gathering derivative information such as installation instructions, photographs, fragments and booklet scans.

This project targets the heritage institutions that collect, or want to collect born digital heritage material and art on CD-ROM, but its recommendations also apply to other collections and archives. Attempts were made to connect to existing facilities.

Aside from the project partners – the National Library, EYE, DEN and LIMA – the project also could be extended to other possibly concerned institutions such as DANS, HNI, RCE, RKD, Amsterdam Museum, Fotomuseum, Stedelijk Museum Amsterdam, Kröller-Müller Museum, NIB&G and the National Archives.

SECTION 1: INTRODUCTION

Project background

The National Strategy for Digital Heritage (NDE) aims to develop a coherent, cross-sector infrastructure for born digital heritage by prescribing various work programmes. To accommodate the wide range of users and managers of digital heritage material, the NDE recognises three separate conceptual 'layers': *Service*, *Connection* and *Content*. These layers relate to the 'visibility', 'usability' and 'sustainability' of digital heritage material. The projects in the work package aimed at sustainability are carried out by the partner organisations within the Netherlands Coalition for Digital Preservation (NCDD).⁵ The NCDD's goal is to create a cross-domain organisational and technical infrastructure to ensure the long-term accessibility of digital data in the Netherlands. LIMA is a member of the Cultural Coalition for Digital Preservation, one of the NCDD partners. Users and institutions moving within the three layers differ in their interests, needs and available time. This means that before a cross-sector strategy can be implemented, each institution must clearly formulate its own particular interests and priorities. A major difference exists between a customised approach for small amounts of diverse, complex material on the one hand and a bulk approach for large amounts of uniform material on the other. This difference determines the nature of the workflow.

LIMA manages and maintains a large collection of media art for various museums, artists and private collectors. It is an international platform working to ensure that video art, digital art and performance recordings can still be displayed in the future. LIMA's key activities include active (online) distribution of its collection, involvement with national and international research projects, digital archiving, storage and digitisation. It operates within all of the three 'layers' mentioned above: *Service*, *Connection* and *Content*. Digital artworks, unlike library collections and large-scale archives, require an approach that recognises the form and content of each individual work, as the crucial characteristics of each work of art are unique.

For the CD-ROM Archiving project specifically, the focus is on sustainability. This project revolves around the sustained storage and accessibility of (interactive) CD-ROM artworks. These works are a unique part of LIMA's collection. CD-ROMs are obsolete carriers, and many of these artworks are dependent on operating systems that are no longer in use. CD-ROM artworks are born digital art *par excellence* and specifically software-dependent. For this reason, the CD-ROM collection was chosen to serve as a case study for this investigation.

Most CD-ROM art was produced in the mid-1990s (one of the most early examples is usually known to be Christine Tamblyn's *She Loves It, She Loves It Not: Women and Technology* from 1993). During this period, from the technological constraints imposed by the tools for multimedia content production available in the 1990s (especially *Macromedia Director*, which was widely used by CD-

⁵ The Netherlands Coalition for Digital Preservation was founded in 2008 by a number of public-sector organisations that consider the long-term care for digital information within the public domain to be their primary task. The NCDD acts as a knowledge and expertise-sharing platform, and coordinates the development of a national network guaranteeing access to public digital information. For the National Strategy for Digital Heritage publication, see: <https://www.rijksoverheid.nl/documenten/publicaties/2015/03/09/nationale-strategie-digitaal-erfgoed>. [link checked Sept 2016]

ROM artists) emerged many recurring noticeable forms in early digital interactive art, from the labyrinth-shaped explorable structures (Chris Marker's *Immemory*, Stansfield/Hooykaas' *Person to Person*) sometimes similar to certain tendencies in the 1990s video game culture, to the immersive environments that prefigured virtual reality (Laurie Anderson's *Puppet Motel*, the MonteVideo/NIMk virtualised exhibition *The Second*).

What is emulation?

Emulation is a technique in which the technical environment necessary to run obsolete programs is simulated in software form, so that the computer (or application programme) behaves identically to a different, generally older computer. This allows a Macintosh computer, for instance, to run Windows software using a 'PC emulator'.

What is Emulation as a Service (EaaS)?

BwFLA (Baden-Württemberg Functional Long-Term Archiving and Access) is a consortium that was founded by the University of Freiburg and its partners.⁶ BwFLA is active in developing tools and workflows for the long-term preservation and accessibility of digital heritage material. Over the past few years, LIMA and other heritage institutions, nationally and internationally, have investigated the potential of emulation as a strategy for preserving born digital content. In some cases, institutions develop their own tools, while in other cases, they use well-known open source emulators like SheepShaver, DosBox, Hatari, Basilisk and Qemu. Emulation, then, is not new, but a structural implementation of this strategy has so far not been carried out among heritage institutions. Research reports from various initiatives show that installing emulators is often a labour-intensive and case-sensitive task, and that doing so requires specific technical expertise.

EaaS is the result of a two-year development project by BwFLA in response to these objections. The goal was to provide a scalable, cost-effective, cloud-based model for emulation procedures for use by heritage institutions. Essentially, EaaS comprises the following three components:

1. EaaS API
2. EaaS USB-bootable
3. EaaS Docker

EaaS API

The environment – software and hardware – that needs to be emulated in order to perform digital work can differ significantly from artwork to artwork and collection to collection. This means that the emulator's settings need to be different in each case as well. For this reason, flexibility and standardisation are key to making emulation easier. At the heart of EaaS are 'abstract emulation components'.⁷ This involves different emulators, hiding their individual complexity (hence the 'abstract'). These abstract emulation components are included within a uniform software interface or

⁶ Universität Ulm, Landesarchiv Baden-Württemberg, Staatliche Hochschule für Gestaltung Karlsruhe, Bibliotheksservice-Zentrum Baden-Württemberg and Ministerium für Wissenschaft, Forschung und Kunst Baden Württemberg.

⁷ BwFLA 2015.

Application Programming Interface (API). In essence, then, this interface operates as a communication network comprising various existing and interoperable emulator types. The individual components can also be used on a larger scale through the cloud infrastructure.

EaaS uses existing open source emulators, instead of programming new ones. These existing emulators are contained within a general interface. Currently, emulation components are included for the most prominent processors,⁸ such as PowerPC, Motorola 68k and Intel x86, as well as for the operating systems OS/2, MS Windows, Mac OS 7 and later versions. The diagram below shows a general overview of EaaS's architecture.

Access to the different emulation components is achieved through Virtual Network Computing (VNC), Remote Desktop Protocol (RDP) or network connection (HTML5, WS-API).

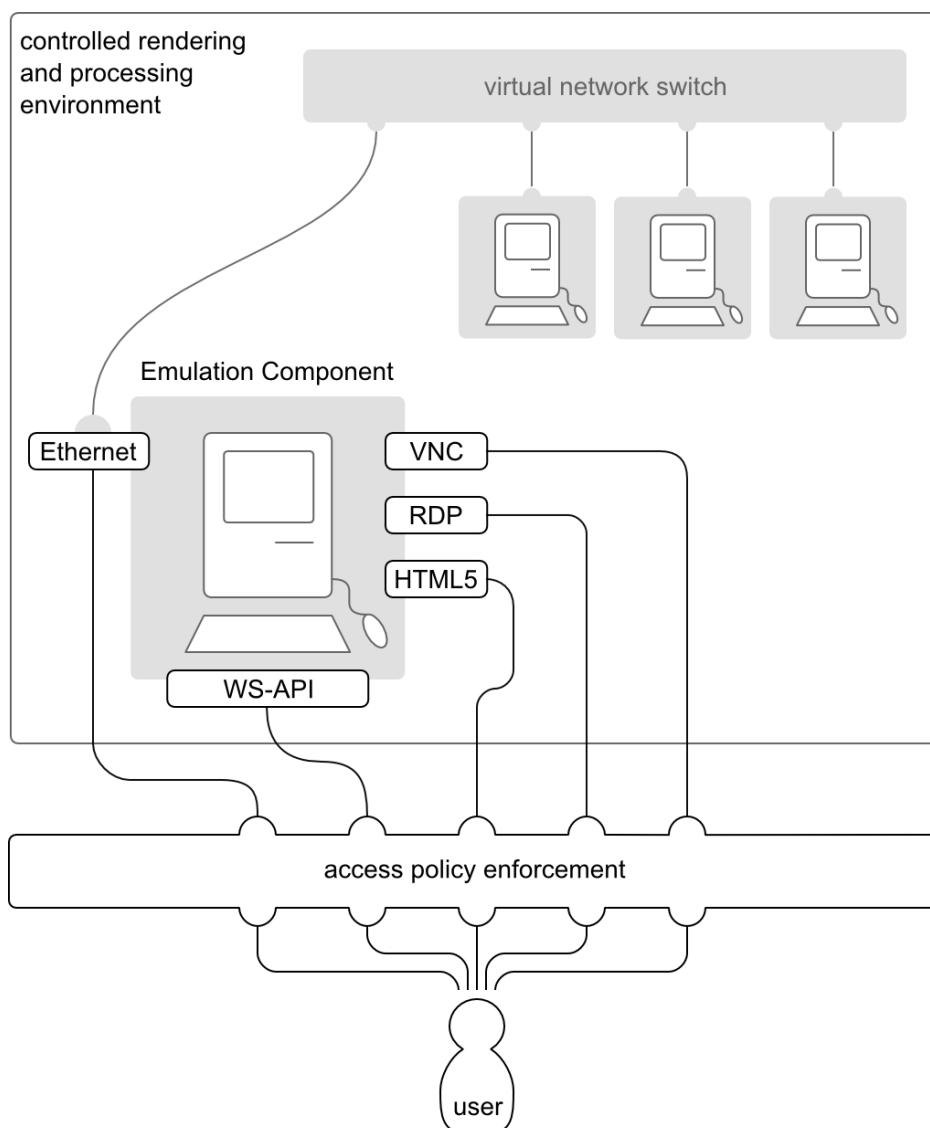


Image: Schematic overview of EaaS, BwFLA. For more illustrative images and diagrams, see: <http://bw-fla.uni-freiburg.de/eaas.html>.

⁸ A Central Processing Unit or CPU.

BwFLA offers an online demo for research and publication purchases. See: <http://demo.bw-fla.uni-freiburg.de/faces/pages/bwfla.xhtml;jsessionid=Rble8t5VzWOK61eLNLJlKkr?windowId=ef2#> [link checked Sept 2016]

Log-in information is as follows:

user: bwfla

password: demo

EaaS requires that disk images have been made of the digital objects in question,⁹ so it is crucial that an institution produces disk images of its CD-ROM archive. These come in various file formats. In a case by case emulation, the appropriate file type is adapted to the emulation environment, but in EaaS, multiple emulators are used. Currently, LIMA uses .cdr or .iso for Mac compatibility, but this matter should be discussed further with other institutions to ensure that common standards are maintained.

EaaS USB-bootable

The cloud service requires an internet connection, and server response is decisive in loading and executing the work in question. As this may be a problem, BwFLA offers an independent 'USB live system', providing an interesting alternative for set-ups and museum displays where cluster and cloud computing are not a viable option. With this system, various software and hardware environments can be directly emulated on available, local computers. An added benefit is the freedom of choice in hardware the system offers, allowing users to plug in joysticks, printers, CRT monitors etc. that may significantly impact their experience of the digital content. Such components can be very important, especially when dealing with works of art.

Although the BwFLA USB live system sounds promising (being distributable, self-contained and not dependent on a network connection), only a demo is currently available. The following components are required to use this demo:

- 2 GB RAM or higher
- USB boot option (preferably USB 3.0)
- a USB drive with at least 8 GB of memory

An image of the USB live system can be downloaded here: <http://bw-fla.uni-freiburg.de/usb-demo.img>. To write the image onto a USB drive, the use of 'dd' or a disk image writing tool is recommended, so that the USB is bootable instead of merely containing a copy of the image.¹⁰ You can also use programs like Disk Utility or Win32DiskImager. The writing process may take some time if you are working with USB 2.0.

The environment being emulated is called 'EMIL'. Currently, the USB demo contains three emulators:

- Hatari (Atari ST/STE/TT/Falcon emulator)
- DosBox (MS-DOS emulator)
- Qemu (x86 and x86-64 system emulator)

⁹An image is a computer file containing an exact copy of a storage medium, such as a hard drive, CD or DVD.

¹⁰ It is then instructed to type the following sudo command in the terminal:

```
sudo dd if=/home/nina/usb-demo.img of=/dev/Apple_HSF USB
```

None of these emulators proved suitable for testing LIMA's case studies, as nearly all CD-ROMs in this collection require a Mac emulator, such as Basilisk or SheepShaver. We were unable to add emulators to the USB demo ourselves. As such, we must conclude that the USB live system is currently a rather limited demo, unable to be adapted to our needs. Inspecting the demo's source code, we found that the path leads to a URL and that the images are hosted on a server. Nevertheless, the demo certainly shows potential in its simplicity, with the user only having to click on the emulator and then the preloaded image.

EaaS Docker

EaaS Docker is made up of source code that can be downloaded from GitHub.¹¹ Installing the BwFLA EaaS framework docker is extremely complicated. The instructions provided are minimal and seem intended more for internal development than external use. It is unclear what installing it will accomplish, and unfortunately neither the blog nor the instructions offer any more information.¹² Since both the online demo and the USB indicate the service is still very much a work in progress, we do not think that emulating this environment will avail us anything. For this reason, EaaS Docker was not included in the remainder of this study.

Qualities and limits of EaaS

The most important benefit of EaaS API is the option of embedding the emulated version of a work directly into a web browser through the cloud service. When an institution loads an image of the digital object into the appropriate emulator, for instance, a link is generated that can be shared without allowing the content to be copied. This can be used to distribute artworks to an end user or exhibition. Furthermore, the end user interface is very clear and user-friendly. The online demo is highly advanced and shows a great deal of potential.

Ancillary to the cloud service principle, however, is the fact that the server is hosted by BwFLA and functions very slowly. As a consequence, images load at a very slow pace or not at all, and stammer when played. An internet connection is necessary for the emulated work to function, and different web browsers may affect its performance. It runs counter to the user-friendliness the developers have in mind to require users to install Chrome or update their browser. A poor network connection on the side of the user also results in stammering in the emulated work. These are unacceptable faults in the experience of CD-ROM art. Glitches might be erroneously interpreted as being part of the original work, and the absence of sound may result in a completely different experience. Another important point is the experience of CD-ROM art in a web browser, an environment that is far from authentic. On the other hand, visibly booting up the emulated environment does increase awareness of the fact that the CD-ROM requires a different operating system than the host (when we see Mac OS 9 starting on a Windows 7 OS, for example). These pros and cons must be weighed against each other. What is more important: the correct experience of a work of art, or its accessibility?

¹¹ <https://github.com/eaas-framework/xmount> [link checked Sept 2016]

¹² <http://bw-fla.uni-freiburg.de/wordpress/> [link checked Sept 2016]

Finally, the legality of emulation must be addressed. Emulation remains controversial, and within the BwFLA this is still a point of discussion.¹³ Without involvement from software providers and licensing agencies, an amendment to the law is needed to prevent digital heritage from being lost forever. Emulation and virtualisation are rarely mentioned in the licensing agreements for outdated software. LIMA estimates that due to its ownership of (obsolete) hardware and software it is not particularly at risk legally, but other institutions will have to study their own situation. To be entirely sure, a risk analysis will have to be performed by a legal expert.

Conclusion

Emulation as a Service is as of yet the most advanced system available for rendering CD-ROM artworks widely accessible. It is to be expected that the demo's current faults will be resolved in the future, but for LIMA, being faithful to the authentic experience of these works is of such importance that, for the moment, we are somewhat hesitant to use this tool. LIMA's CD-ROM collection consists primarily of works from the '90s developed for Mac OS. The wide scalability offered by EaaS is impressive but not immediately necessary for LIMA's purposes. This may yet change in the future, and for the moment the option of PC emulation may be investigated further by using open source emulators like Qemu.

Instead, we recommend using the EaaS service as an extended form of documentation, by uploading works to the BwFLA server and adding embedded links to the existing documentation (this notion will be expanded upon in the second section of this report). Although EaaS's web-based emulation can be navigated by a wide audience, LIMA emphasises that this is not the ideal environment in which to experience a work of art. Even if the BwFLA server proved capable of running every emulator correctly, being able to authentically experience the work would remain a crucial requirement. CD-ROM art was not designed to be viewed in a web browser, and doing so may drastically affect the experience of the work. To guarantee an authentic user experience, LIMA prefers the alternative option currently being developed by BwFLA: the self-contained USB-bootable. This option would allow LIMA to keep and maintain the works themselves and to ensure that CD-ROMs function correctly. On top of that, a USB can be easily distributed within LIMA's existing workflow. Direct collaboration with the University of Freiburg or another form of external technical support will be needed for LIMA to develop a self-contained USB-bootable system with user interface.

¹³ Von Suchodoletz, Rechert and Valizada, 2013, p.2

SECTION 2: ARCHIVING STRATEGY

The limitations of EaaS in its current form have led us to develop an alternative strategy, involving an expanded application of the case by case emulation procedure used by LIMA for the past three years. The user-friendliness and distribution potential promised by EaaS also served as the point of departure for this alternative strategy. Since EaaS cannot yet fully guarantee successful server-based emulation, we have come instead to regard emulation as an extended form of documentation. CD-ROM artworks can be uploaded to the BwFLA server, at which point EaaS will generate a link to the work. This (embedded) link can then be stored along with the rest of the work's documentation, and perhaps be given a place in LIMA's online catalogue.

In order to guarantee that the CD-ROMs function correctly, we have preconfigured the emulators on a specific computer or 'work station' at LIMA. In effect, then, this solution operates just like a USB-bootable, except in that the CD-ROM is started from the desktop of this computer. The work station thus created can be used to correctly emulate each of the artworks used in this study, without requiring the user to adjust any of the settings.

Documentation serves to represent the works as well as possible, to introduce the public, researchers and curators to the CD-ROM collection. In order to develop a standard documentation procedure, we have looked at three cases. These CD-ROMs from the collection were documented through video registration, stills and technical metadata (see the appendix for a model of how this form of documentation will appear to the end user).

A visit to LIMA will be necessary to entirely and reliably experience the work for yourself. There, the user can go to the work station and select and explore the CD-ROM. Video documentation and additional information can be found in the LIMA catalogue (see the appendix for the documentation model). This fits within the existing LIMA workflow, since the video collection is also 'for preview only' and can be viewed on request. The CD-ROM collection will operate in the same way. By keeping the works in-house, we can ensure that the user experiences them in the proper way. Distribution of the work station itself and the CD-ROMs emulated on it (for use in exhibitions, for instance) is discussed on page 22 of this report.

Problems with emulation performance¹⁴ are noted in several research reports,¹⁴ and this one is no exception. The proper functioning of CD-ROMs is of critical importance, especially in the case of works of art. The 'look and feel' has to correspond to the original as closely as possible. Often, there is a lack of visual documentation of the emulation's performance. In order to facilitate discussion of this topic, we have tried in this project to shine a light on these issues through the use of video registration. These recordings demonstrate how in various emulators a CD-ROM can function very differently from its original environment. Since it is impossible to take good and reliable screen captures on the native system environment¹⁵, we have chosen during our comparison testing protocol to register the performance of a work in this context through the use of an external camera.

¹⁴ Dietrich, 2015; Rieger 2015.

¹⁵ Old screen capture programs exist for obsolete operating systems but were not powerful enough yet to manage capturing video excerpts from the screen without a very important slowness. Testing on several old software programs for Mac OS 7-9 has led to no result within our protocols.

We then navigated through three CD-ROMs, *Puppet Motel*, *The Second* and *Person to Person*, in a coordinated manner, thus producing comparative documentation through the means of video recordings, highlighting the possible differences in speed and interactive behaviour of the artworks.

Note on the technical scope and extent of this project

The procedure outlined in this section applies exclusively to Mac computers and operating systems, as the great majority of the interactive CD-ROM artworks in LIMA's collection were produced in the 1990s either only for Mac or with both Mac and PC compatibility. As a consequence, we are primarily interested in a user-friendly emulator for obsolete Mac operating systems that can run on a modern Mac host computer. This will allow us to standardise the emulated works in a simpler way than extending the procedure to other systems (thus implying more complicated user actions).

Since none of these artworks turned out to be exclusively PC-compatible during our collection survey phase, it appeared unnecessary at this moment to extend this project to PC emulation. Moreover, PC-exclusive works would be harder to implement within our user-friendly workflow and its pre-set settings files. Nevertheless, for some exceptional cases in the collection, the possibility of developing PC emulation using open source applications like Qemu may be investigated in the future.

Although virtualisation has also frequently been suggested as a preservation strategy, this study is focused exclusively on emulation. Virtualisation (using Virtual Box, for instance) is often considered a far more efficient approach, since the virtual machine is able to communicate instantly with the host machine without the need for translation, connecting directly with the existing hardware. This also means, however, that virtualisation is only viable for machines with a similar architecture, which generally means they need to be from the same historical period.

Emulation, on the other hand, can accommodate an immense difference between the host machine and the emulated machine, even in their architecture and processor types, since it adds a process of translation for each instruction passing between the two, using software that imitates the exact behaviour of the selected (obsolete) machine. In our case, emulation allows us to mimic the behaviour of obsolete Mac computers from before 1998-2000. Unlike virtualisation, though, it requires very specific settings, controls, testing, and the systematic archiving of CD-ROMs as virtual disk images (.cdr files on Mac, or .iso).

Since the CD-ROM artworks in LIMA's collection run only on obsolete computer systems with outdated architecture, the use of emulation was the only viable option.

Emulators chosen and specifications

For this study, we have made use of two different emulators:

Basilisk II (1.0 for Mac OS X on Intel processors, created on 2014-03-01) and **SheepShaver** (2.4.2, created for Mac systems with an Intel processor, 2014). These were selected for their ability to emulate older Mac computers and operating systems between versions 7.5 and 9, matching the historical range of hardware environments for which the CD-ROM artworks in LIMA's collection were created (between 1992 and 2000). Both these emulators are open source and have the advantage of being developed by active communities, who offer a wealth of resources and recommendations on online forums dedicated to Mac emulation.

Generally speaking, Basilisk II is known to emulate older Mac operating systems (versions 7.5 to 8) and Mac computer models from before 1998 (Quadras and Power Macintoshes) better than SheepShaver does. The latter is generally considered to be more suited to Mac OS 9 system emulation, and models dating from after 1998 (G3/iMacs, G4). Tests conducted for this study, however, demonstrated that most of the works in our collection can be run using SheepShaver, even if they were designed for Mac OS 7.5. Nevertheless, to avoid faults and glitches it is preferable in theory to use Basilisk II for older works (from before 1997).

In the future, it may prove worthwhile to consider extending the installation procedure for SheepShaver and Basilisk II to other host computer types, as both emulators are available for Windows and Linux as well. Alternatively, a current Mac OS (10.7-10.9) could be loaded onto a virtual machine, and then an emulator could be run in that environment (emulators can be run within other emulators or in a virtual machine), allowing the user to maintain the exact same settings while avoiding the risk of future versions of the OS making the system obsolete.

With regard to the time period in which the artworks were created, we have decided to consider a "range of acceptability" of the various hardware elements and operating systems. This means that some differences are estimated allowable between the dates of origin of various system environments and various computers that would have been compatible with the artworks in their original form. This notion follows the ideas developed by Jeff Rothenberg on a "*representative range of original platforms and system configurations*"¹⁶ and reflects the reality of various types of hardware and versions of operating systems being used in parallel at any one time. It also makes the process of emulation more flexible.

Documentation and distribution

In order to preserve the artworks in their emulated environment and to ensure that they remain accessible, detailed and complete documentation is of the utmost importance. This applies in equal measure to the physical carrier and to the technical system specifications. If these are not documented and future computers fail to present the work correctly, the integrity of the original work may be irreparably damaged. Users must be able to compare the precise image definition or aspect ratio, interaction speed and fluency, and general look and feel of an emulated work with the original. In the absence of comparative evidence, the work will present the risk to appear corrupted and become gradually more different from the original, thus being possibly misunderstood by the public even in its very concept.¹⁷

In this study, we have identified several layers or levels of documentation to be presented alongside the emulated work. The aesthetic aspects (the 'look': aspect ratio, resolution, colours, display technology – CRT screens being the most commonly used type of monitor in the mid-1990s – etc.) and operational behaviour of the work (the 'feel': reaction speed, interaction with ancillary equipment, cursor etc.) should be recorded on video, while the physical elements of the work (the CD-ROM itself, instruction booklets etc.) are photographed.

This documentation is then distributed online, similarly to how our 'for preview only' video collection is distributed. If and when online access through EaaS is possible and acceptable, the

¹⁶ Rothenberg, Jeff, *An Experiment in Using Emulation to Preserve Digital Publications*, RAND-Europe, 2000.

¹⁷ Jeff Rothenberg refers to this principle as "vernacular renditions" and "accumulated corruption". See: <http://www.clir.org/pubs/archives/ensuring.pdf> [link checked Sept 2016]

documentation will include an embedded link, allowing users to navigate through the work themselves. We deem it important in this context to add a disclaimer explaining the work's original environment and warning of any faults which may occur. LIMA must provide full, controlled access to its emulated CD-ROM collection and allow the public to view its contents on request.

Levels of documentation

What follows is an outline of a documentation method for CD-ROM artworks consisting of four levels of documentation. It is intended both for preservation purposes and to ensure end user access through online distribution. These levels refer to both physical components and technical metadata.

Level 1: Documentation of the physical components

- The whole CD-ROM 'object': the disc itself, its packaging, booklets etc. In order to avoid damaging the original, the CD-ROM and other physical components will be physically handled as few as possible in the future (only for research or exhibitions, for instance). The original packaging can be documented with photographs and colour scans, and digitally stored in that form.



- Contextual ancillary equipment, such as CRT screens, specific mouse or keyboard, or joysticks. Documentation of these components serve as an illustration of the original hardware environment.



Level 2: Documentation of the work in its original environment

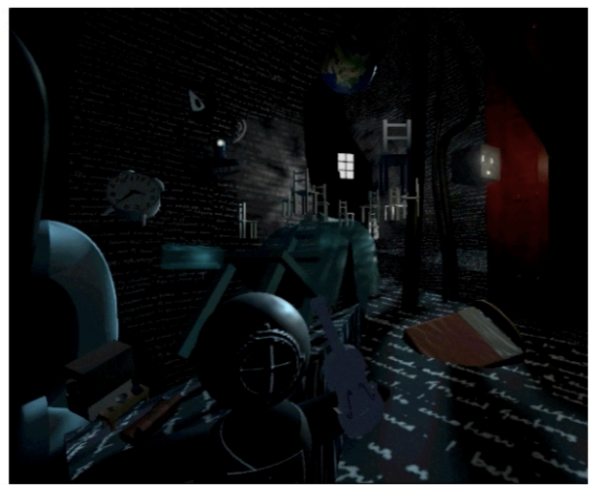
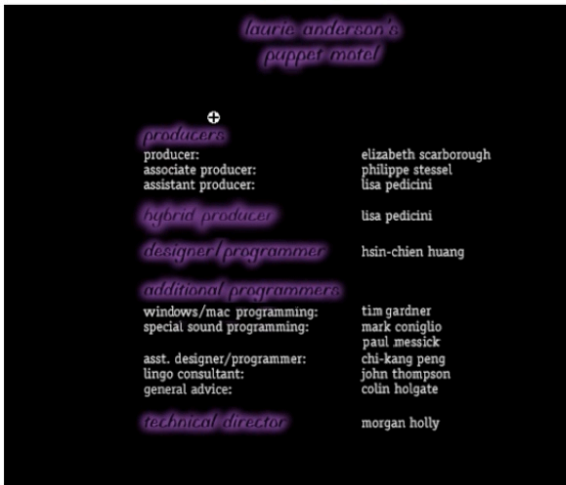
- Video screen recordings of the work running on suitable native hardware and on the original operating system, or an environment resembling the original as closely as possible and falling within the historically coherent range of equipment of that time (for this study we used a 1998 G3 iMac with Mac OS 9).
- Video screen recordings of a brief exploration of the work by a user (as comparative material for preservation/emulation reliability testing purposes).
- Video recordings of the work being used and explored, with the obsolete hardware and interfaces visible in the frame (contextual using video documentation).

Level 3: Technical specifications and metadata

- Textual information regarding the necessary runtime environment. This includes:
 - > A range of compatible operating systems, especially if the work was developed for both Mac and PC. For LIMA's CD-ROM collection, the operating system is usually Mac OS 7 to 9.
 - > Necessary software, if applicable (usually media players such as Quicktime).
 - > Type of CPU (PowerPC G3 to G4 for Mac, for instance) and architecture (32 bit, 64 bit) of the original environment.
 - > RAM specifications.
 - > Image resolution.
 - > Colour levels.
- Information regarding the software used to create the work, if known. For the works in LIMA's collection, this is usually Macromedia Director.
- A recommendation on the type of emulator to use (currently, SheepShaver for Mac OS 9 and Basilisk II for Mac OS 7.5 to 8), with a note of the date on which the recommendation was made (as emulators may become obsolete).

Level 4: Documentation of the work in an emulated environment

- Screen captures or stills.
- Video screen recordings of a brief exploration of the work (as comparative material for preservation/emulation reliability testing purposes).



Examples of stills extracted from browsing sessions through Laurie Anderson's 'Puppet Motel', emulated with SheepShaver (Mac OS 9)

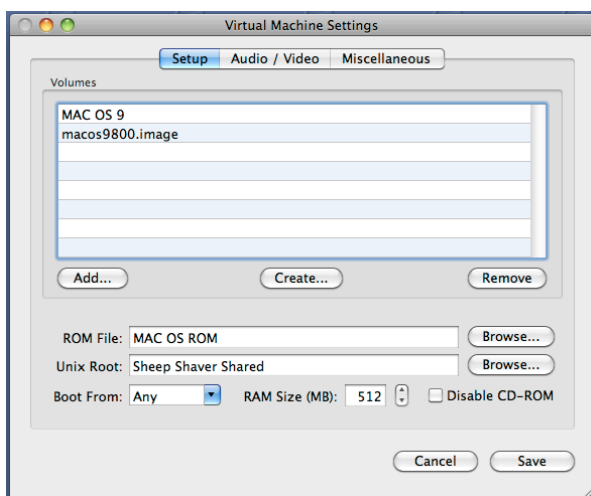
STEP-BY-STEP MANUAL

Step 1: Installing SheepShaver

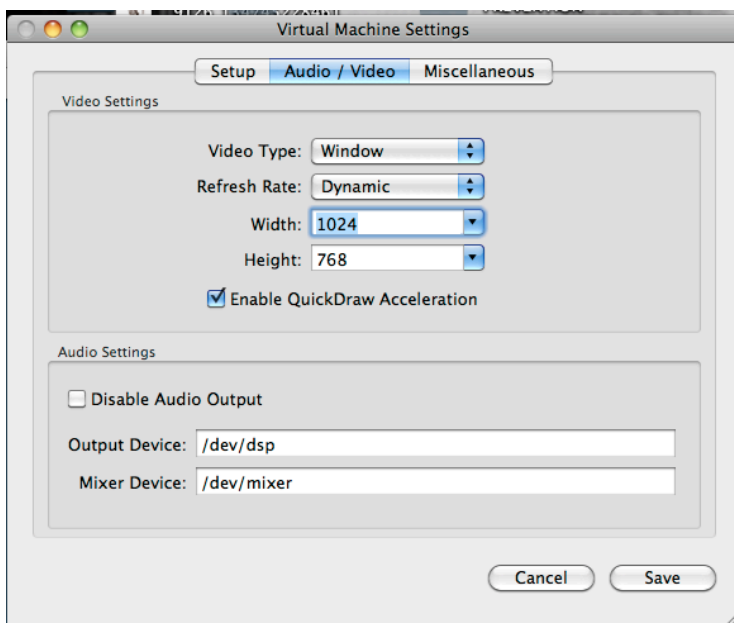
This first step describes the installation procedure for the SheepShaver emulator. This procedure only needs to be followed once. The second and third steps that follow refer to the workflow and describe the archiving, access and presentation of CD-ROM artworks within a collection.

[All links tested on Sept 2016]

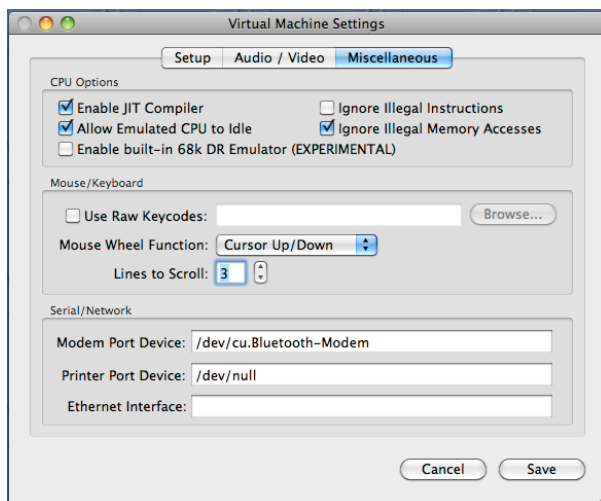
- Download a SheepShaver pre-built binary on their website :
(*SheepShaver website* : <http://sheepshaver.cebix.net/>)
Download link for a pre-built version for Mac OS X :
<http://www.emaculation.com/forum/viewtopic.php?f=20&t=7360&sid=c8a54981f8749282c3b4cf58fc9e6e39>
- Download a ROM file (the « New World PPC ROM » works with SheepShaver)
<http://www.redundantrobot.com/sheepshaver-tutorial/>
- Download a bootable disk image version of Mac OS 9.0.4
<http://osvirtual.net/en/mac-os-9-0-4-with-additional-software/>
and use the direct « *download link* » on top of the page.
[7zX may be needed to unpack the file :
<http://sixtyfive.xmghosting.com/products/7zx/>]
- The ROM and the bootable disk image must be put in the same « SheepShaver » folder than the application.
- Rename the ROM file « MAC OS ROM » so that SheepShaver can be started, in order to access the virtual machine settings
- Start SheepShaver and go to « preferences » in the menu.
- In the main directory in « Setup », add the mac os 9 bootable disk image « macos9800.image »



- Then create a new empty disk image in order to activate a recognisable hard drive image when the virtual machine is started (we tried it with a 1 GB disk image). The two drives will appear together in the directory.
- Select the proper renamed file in the « Rom file » field to be able to restart the virtual machine.
- Create a new folder named « Sheep Shaver Shared » anywhere on the computer (on the desktop for instance) and then select it in the « Unix Root » field.
- Select « Boot from any » and a RAM size for the virtual machine (512 Mb is usually enough)
- In the « Audio/Video » section, select « Dynamic » for the refresh rate ; select the resolution and set the audio outputs as seen in the example below:



- In the « Miscellaneous » section, uncheck « Ignore Illegal Instructions » and check only « enable JIT Compiler », « Allow Emulated CPU to Idle » and « Ignore Illegal Memory Accesses » as below:



- Save the settings
- Force SheepShaver to close with COMMAND+ALT+ESC and restart it. It should start directly with Mac OS 9 running, and extensions needed for playing the media material, like Quick-time player, are normally already included.
- The virtual machine can now be closed normally using the Special button in the menu at the top of the screen.
- When starting, SheepShaver will ask to reformat the new virtual drive, press OK.

Step 2: Ingestion/storage/archiving of CD-ROM art

Following the installation procedure described above, the next step is an ingestion/storage/archiving procedure to ensure the sustained storage and preservation of the CD-ROM artworks. Here, we explain how these works connect to LIMA's database and e-depot.

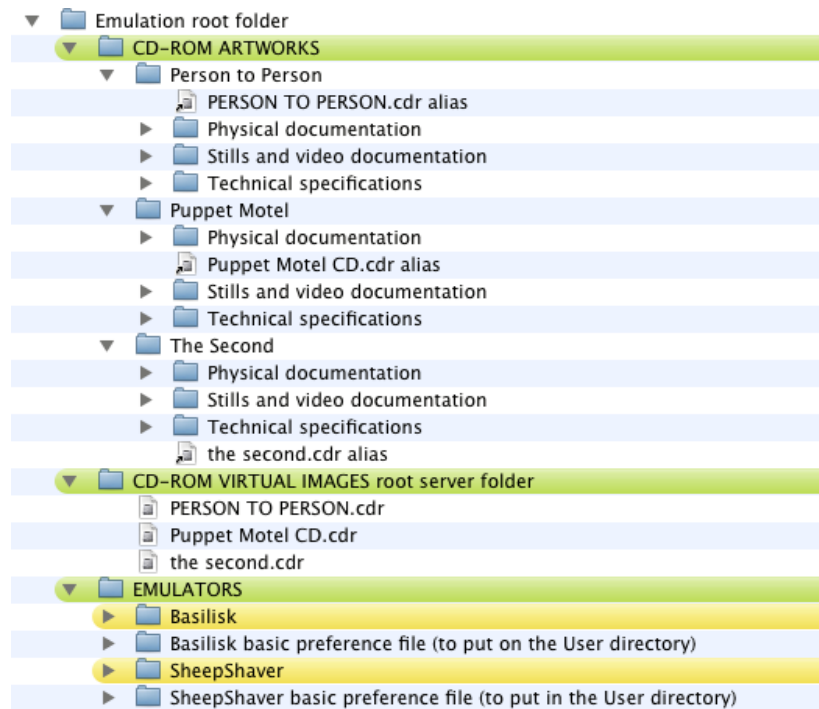
What to archive?

An exact copy of the CD-ROM should be created (as a .cdr or .iso image), that can be stored as a digital single file. Ideally, these files should be stored alongside the full range of documentation, visual and technical, as described previously. On top of that, a clear link must be provided to the necessary emulator (in this study, SheepShaver or Basilisk II). The emulator folders with all the required settings, images and virtual drives should all be archived together.

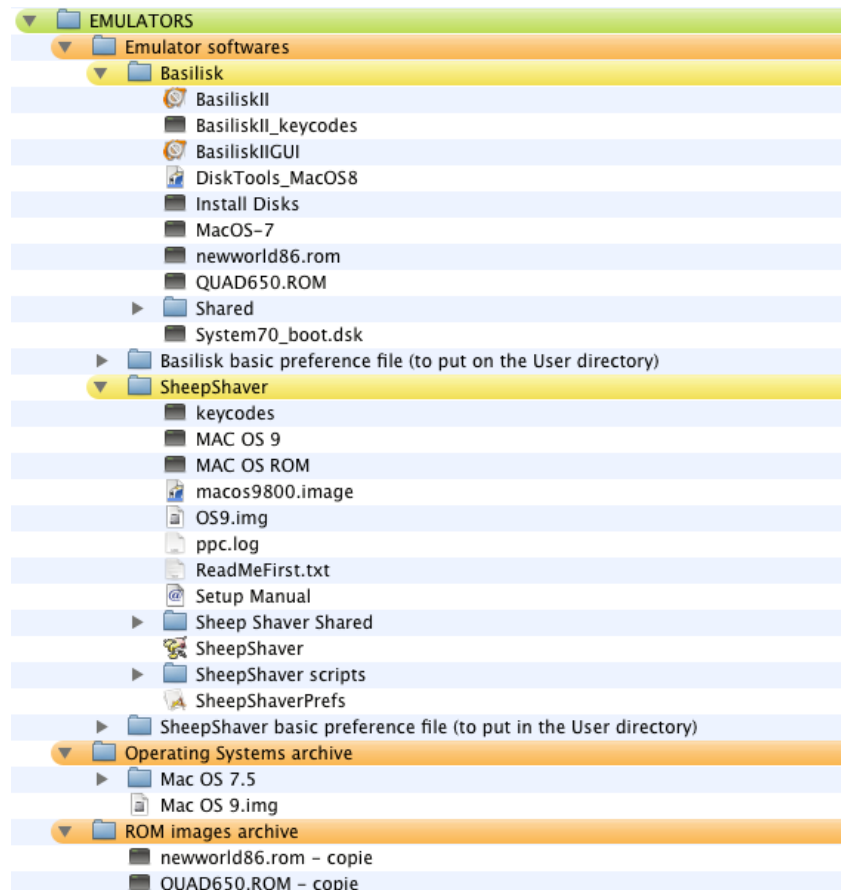
For legal reasons, we recommend archiving all original OS and software installation disks alongside the artworks as well. Apple officially does not allow users to run older versions of Mac OS, except when they own an original or official installation disk.

All of these components may now be stored in a root folder, including a sub-folder for the emulator files, as seen in the images below. (see next page)

The root folder structure can be presented that way:



And the sub-folder for emulators that way:



In the 'CD-ROM ARTWORKS' folder may also be archived the pre-set packaged emulated artworks each time one is created for distribution purposes, as .DMG files, as described in the 'Distribution' section of Step 3 below.

Metadata

Many institutions use database systems or Collection Information Systems (Adlib etc.) to record metadata in connection to works of art. For the ingest of software-based art, a system has to be designed to accommodate a range of generations or versions. Within such a system, space must be allotted to the following metadata:

- > *Original mode of consultation:*
 - Controls (mouse, trackpad and/or keyboard)
 - Type of display equipment (CRT computer monitor)

- > *Original carrier (CD-ROM)*

- > *Captured as virtual disk image (.cdr or .iso)*
(Any further carrier migrations may be mentioned as a third, fourth or fifth generation.)

- > *Type of CPU (PowerPC G3 to G4 for Mac, for instance)*

- > *Original CPU architecture (32 bit, 64 bit)*

- > *Operating system dependency*

- > *Software dependency (Media players such as Quicktime, browsers etc.)*
(For example, this field is included in the interface of MoMA's Binder database and e-depot. It allows users to list specific technological dependencies of software-based works in a global Supporting Technology Relationships field¹⁸)

- > *RAM specifications*

- > *Image resolution*

- > *Colour levels*

- > *Type of interactivity*
(A brief description. Examples include: "*point-and-click exploration of a 2D environment*", "*point-and-click exploration of a 3D environment*", "*simple slide shows*", "*exploration of a textual archive*" etc.)

¹⁸ http://moma.org/explore/inside_out/2015/05/13/open-sourcing-momas-digital-vault [link checked Sept 2016]

Technological dependencies

Adding the specifications listed above to the database provides users and researchers with insight into the technological dependencies of CD-ROM artworks. Metadata input concerning hardware (computer systems, displays, interfaces etc.) and software (operating systems, media players, browsers etc.) may allow users in the future to search the database using these factors as a query. This, combined with the works' year of origin, could even result in the creation of an art-historical/technological timeline. Potentially, researchers and members of the public could use these fields to search for a certain technological time period, or a specific type of operating system or hardware.

Sustainability of emulators and disk images, anticipation of emulators obsolescence

Realistically, we must expect emulators, virtual disk images and the host systems running the emulators to eventually go out of date themselves. Just like any other type of software or data file, they require a specific system environment, but these environments are constantly shifting. When one component changes, its dependent components may cease to function. With this in mind, in order to ensure the long-term preservation of CD-ROM art, a standard migration procedure must be applied to the entire archive, including both virtual disk images and emulators.

When a work is ingested into the database, notice is taken of its original carrier (in this case a CD-ROM), in the same way, for example, as when a work of video art is ingested that was originally recorded on Betacam. The virtual image (.iso or .cdr) is an exact digital copy of the CD-ROM, and can be regarded in this sense as a *migration* of the original CD-ROM. The disk image, as a migrated version or second *generation* of the original work, is stored on the server, and a backup is created on LTO tape (as with works on video).

As a new generation is created every time a work is migrated, it is crucial to duplicate the files beforehand by creating a backup, and subsequently to check for any corruptions in the new version. In a Collection Information System, different generations of disk images and emulators can be maintained simultaneously. Naturally, this does place increased demands on the available storage space.

Since the emulators themselves eventually grow obsolete, they too should be archived, along with all the system files and programs needed for them to function. Furthermore, we recommend storing these on the server next to the artworks, and including detailed technical documentation regarding the emulator itself. For example, a notice along these lines might be included: "this emulator requires a Mac OS 10.6-10.9 on a computer with an Intel processor".

In the future, this will enable the possibility for newer emulators to recursively emulate older ones which cannot be used on the latest computers (for instance if their updates for newer OS are discontinued). The technique of running an emulator within another emulator is already commonly practised in the field of archiving and has been noted in several studies. In principle, it is done by following the same procedure outlined in Step 1. Crucially, every step that is taken in emulating a given work should be documented in detail. Doing so will save a lot of time in the future.

Even when the emulation procedure has been followed to the letter, you should regularly check for new versions or updates to the emulators you use through a survey on the developers' website. This should be done each time there is a change to the computer or work station used to view the works, or when its operating system is updated.

These recommendations regarding the management and maintenance of emulators are aimed at preparing for the time when our current systems become outdated, but they serve another purpose as well. Indeed, following these guidelines enables the emulated works to be run in environments other than the one they were first tested in. If, for instance, an institution transitions from a Mac operating system to Windows, the method of recursive emulation can be applied to make the Windows PC emulate or virtualise a current Mac OS environment in which to view archived works of art using our pre-set emulated packages made for Mac systems.

Follow-up research on metadata

In further research projects, the possibility of automatising the process of collecting technical metadata could be investigated. Archivematica (used by MoMA) and EMIL (developed by the University of Freiburg) are two examples of software tools used to analyse disk image files and extract technical metadata, such as the original operating system or ancillary program requirements. Tools of this sort could eliminate the need to manually research and record technical metadata, and in so doing save a great deal of time.

Step 3: Distribution

Distribution procedure for museums and institutions

In Step 1, an emulator was installed on the computer of your choice, allowing CD-ROM artworks to be run within an emulated environment. In Step 2, these works were then stored and archived. A potential final step is to convert them into a user-friendly and easily accessible package to be distributed to other users.

The key to creating a ready-to-use emulation solution (with a simple drag-and-drop to the "application" folder) is to duplicate the 'prefs' data file containing the emulator settings pre-set by us. This file should then be manually moved to a folder with the emulator, all of its associated components and the CD-ROM disk image in it.

This folder can thus easily include all the needed elements to access and browse through the work on an emulated environment after a short installation time and without too many technical troubles. The long installation and settings procedure described below can therefore be avoided for the next users, and a pre-set emulator associated with the ISO image of an artwork can then be possibly transferred, once created, to other institutions for distribution use, while keeping control on some precisely anticipated settings (chosen relying on the comparison tests). The only remaining need to

communicate to the host institution for exhibition is then the short instructions regarding the range of possible host machines to use in the exhibition space.

These are the steps followed to create the pre-set emulated usable versions of the artworks:

- Once Basilisk or SheepShaver is set up correctly and running on your host machine, use the terminal to make 'invisible files' visible by typing in the following command:
defaults write com.apple.finder AppleShowAllFiles YES
- Restart Finder and check to see if any new files are now visible.
- A "sheepshaver_prefs" or "basilisk_prefs" should have appeared in the User directory. Copy this file into a new 'final folder'. Then copy all the files in the emulation folder (including applications, ROM images and virtual drives) into the final folder as well.
- The folder is now ready and can easily be converted into a .dmg file using the Disk Utility application. This will turn the folder into a ready-to-use disk image.
- The .dmg file (or disk) can then be distributed to the end user by means of a USB drive, WeTransfer or other service.
- The end user copies the folder into the Applications directory on his or her computer and the "sheepshaver_prefs" or "basilisk_prefs" file into the User directory. The work is now ready to run.

This procedure has been tested for Mac computers, and the end user will be able to use a wide range of Mac operating systems to access the work. If the end user is not in possession of a Mac system, LIMA can provide one on request, for a fee.

Online access model (public)

In the appendix to this report, we outline a model containing all the documentation components pertaining to a CD-ROM artwork for the purposes of public or online distribution. This practical example follows the documentation procedure described on pages 13-14.

EPILOGUE: insights from the NCDD expert meeting

While this study was being conducted, the EaaS USB-bootable was undergoing further development. A new version was demonstrated by Klaus Rechert during a meeting prior to the NCDD's Digital Preservation Knowledge Day.¹⁹ The same version was briefly discussed in the CD-ROM archiving workshop led by Nina van Doren and Alexandre Michaan, where Rechert distributed five USB-bootable versions to attendees. As this version was shown to be a marked improvement over the one discussed in this report (see pages 8-9), this epilogue will serve as a reflection on this study. Below, we outline the steps that you should follow if you want to study or use this USB-bootable for yourself. It should be noted that this application is better suited to presentation purposes than to archiving.

In essence, BwFLA's new USB-bootable provides the same solution described in Step 3 of this study: a simple, accessible form of emulation aimed at distribution and exhibitions. The CD-ROM artwork is opened directly in full screen with the settings, resolution etc. appropriate for that work. The user experiences the work exactly as it originally was, just on newer hardware.

The procedure to start using the USB-bootable is as follows:

- Plug the USB drive into your computer (ideally using a USB 3.0 connector) and reboot the computer from the USB by holding the ALT key (on Mac) during the booting process. Two volumes should now be visible.
- Click on the 'emil-data' volume, followed by image-archive / images / base / objects. Then move the virtual disk images of the CD-ROM artworks (.iso or .cdr) into the Objects directory.
- Go to image-archive / meta-data / base and look for the system environment required by the CD-ROM. In our case, we needed Mac OS 9: 'macos9.env'. Duplicate this file and open it in TextWrangler or another application so you can modify its code (TextWrangler can be downloaded online for free).
- View the file code in TextWrangler and search for this paragraph:

```
<binding id="cd">  
<url>imagearchive:objects/INSERT VIRTUAL DISK IMAGE NAME HERE</url>  
<access>cow</access>  
</binding>
```
- With the disk name added to the code, go to the next paragraph to enter the correct resolution for this CD-ROM artwork. Search for this paragraph:

```
screen dga/640/480[[nl]]
```
- You are done adjusting the settings. Now, run the emulated work again by rebooting the computer and holding the ALT key.
- Click on the 'Emil' booting drive.
- The disk image of the selected CD-ROM artwork should now appear in the list. When you click it, the emulated system environment will open in full screen with the correct resolution.

¹⁹ This meeting took place on 13 June 2016 at the University of Amsterdam (Room 2.11, BG2, Turfdraggsterpad 15-17). Present were Nina van Doren, Paul Jansen Klomp, Klaus Rechert, Claudia Roeck, Alexandre Michaan and Wiel Seuskens.

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Gaby Wijers, 'To Emulate or Not', in *Inside Installations. Theory and Practice in the Care of Complex Artworks*, edited by Tatja Scholte and Glenn Wharton, Amsterdam University Press, 2011. <<http://nimk.nl/files/Files/page81-90.pdf>>

Tate concept report on emulation (draft), Tate Modern, 2016. [internal concept report]

The Signal: 'Emulation as a Service at Yale'. <<http://blogs.loc.gov/digitalpreservation/2014/08/emulation-as-a-service-eaas-at-yale-university-library/>>

Online documentation

Basilisk II
<<http://basilisk.cebix.net>>

BwFLA Emulation as a Service
<<http://bw-fla.uni-freiburg.de>>

BwFLA Blog
<<http://bw-fla.uni-freiburg.de/wordpress/>>

Emaculation Wiki
<<http://www.emaculation.com/doku.php>>

List of ISOs for CD-ROM artworks at Internet Archive
<<http://archive.org/search.php?query=CD-ROM%20cabinet>>

Laurie Anderson's 'Puppet Motel' at The Internet Archive
<<https://archive.org/details/puppet-motel-1998>>

SheepShaver
<<http://sheepshaver.cebix.net>>

Macintosh Garden
<<http://www.macintoshgarden.com>>

DRAFT FOR DOCUMENTATION ACCESS ONLINE

Puppet Motel

By Laurie Anderson

Co-author : Hsin-Chien Huang

Interactive work for CD-ROM, 1995



Artwork description :

- Copied text from the booklet or original box

- short description of the interactive behavior

Date: 1995

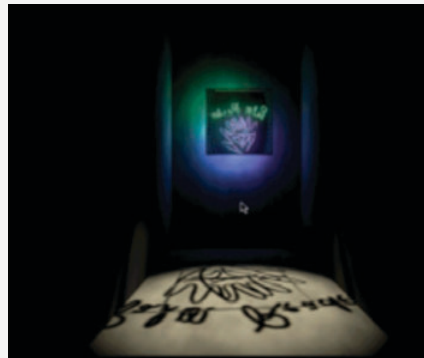
Type: software-based work for CD-ROM

Copyrights: (c) The Voyager Company

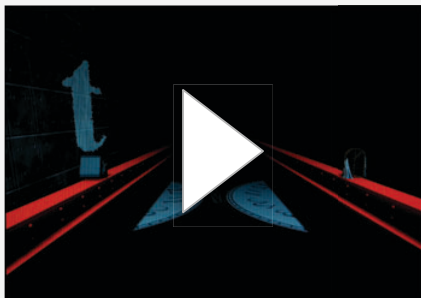
Genre: labyrinth exploration

Keywords: CD-ROM, interactive, labyrinth, time

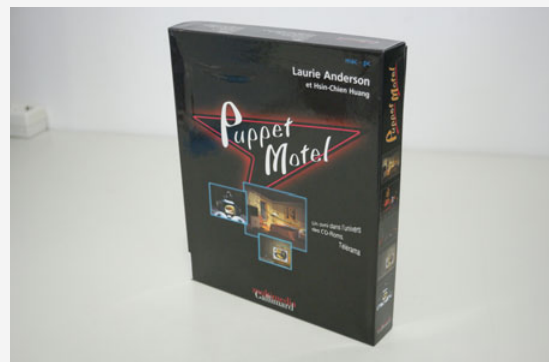
STILLS :




VIDEO DOCUMENTATION :



PHYSICAL DOCUMENTATION :



Technical specifications :

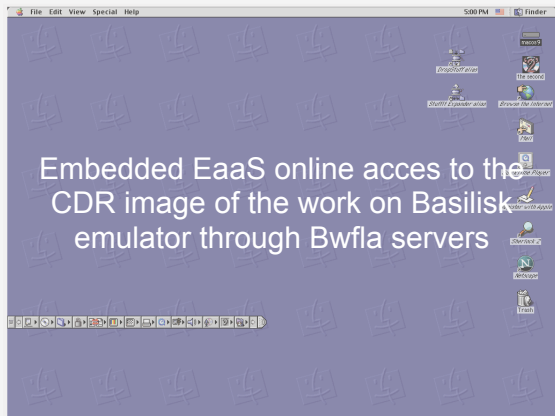
 <ul style="list-style-type: none">• pcPentium 90,16 Mo recommandés,écran 640x480, 256 couleurs,30 Mo disponibles sur le disque dur,lecteur double vitesse, Windows 3.1 ou 95	<ul style="list-style-type: none">• macProcesseur Power PC,16 Mo de RAM,écran 640x480, 256 couleurs,30 Mo disponibles sur le disque dur,lecteur double vitesse, système 7.1
---	--

Historical range of original equipment : For Mac : Quadra / Power Macintosh / iMac G3
Historical range of original systems : For Mac : Mac OS 7.1 to Mac OS 9

Example of original equipment :



PREVIEW EMULATED ACCESS :



Warning : This tool is for preview browsing only. LIMA does not ensure the reliability of the interactive behavior, display, or speed, of the consulted work.

Consultation of the original work on a controlled emulated environment possible at LIMA, on request.

Needed conditions to specify for the preview : Chrome browser etc.