Digital Preservation

Emulation

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Agenda

- What is Emulation?
- Concept and Definition
- Emulation in Digital Preservation
- Emulation View Path
- Preserving Emulators
- Emulation in Preservation Planning
- Legal Aspects of Emulation

What is Emulation?

- *Emulation* refers to the capability of a device or software to replicate the behaviour of a different device or software
- examples: modem-emulation, terminal-emulation, emulation of computer-systems, video game system emulators
- difference to simulation ?
  - flight simulator does not actually fly

Use in Digital Preservation

- obsolete programs
  - recompilation not possible because of missing source code
  - data cannot be migrated to different format (e.g. scientific analysis)
- multimedia (interactive art, video games)
  - the logic inside a program and the appearance have to be preserved
- preservation of software for historic reasons
  - e.g. early operating systems
- keeping documents authentic (e.g. electronic signatures)
- migration through emulation
- data archaeology

Levels of Emulation

different levels of emulation:

- application (viewer)
- operating system (e.g. Wine)
- computer architecture
  - virtualization (e.g. DOSEMU on Linux)
  - hardware emulation (e.g. Dioscuri)
- interface level
  - output devices (e.g. mobile platforms vs. PC-screen)
  - input devices (e.g. paddle controls vs. mouse)
- environment (e.g. video game arcade in museum environment)

Computer Architecture Emulation

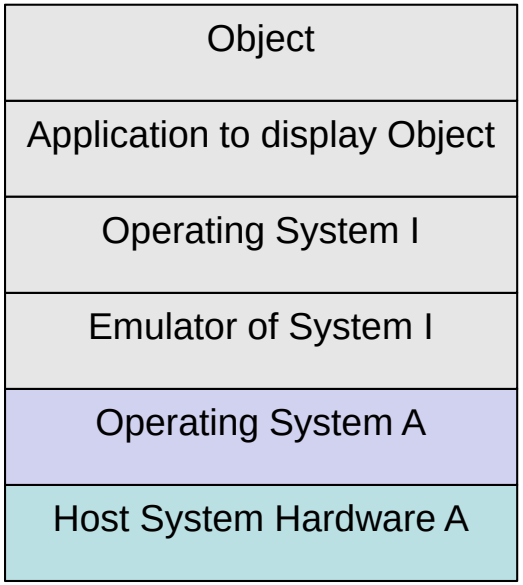
- virtual machine (virtualization)
  - only components are emulated, the code is run on the original CPU
  - can only be used, if the CPU of the host system is the same as the CPU of the target system.

- emulation of the full hardware of a system
  - all aspects of the original system are emulated

- techniques used
  - dynamic binary translation - to optimize speed
  - HLE (High Level Emulation) – to abstract e.g. video hardware to a functional level

Definition

- one possible definition of an emulator:
  - An emulator is a program that runs on one computer (the emulator's ‘host’ system) and thereby virtually recreates a different computer (the emulator's ‘target’ system).



Concept

- emulation is usually done in software, emulation in hardware is also possible, but does not solve digital preservation problems!
- concept: keep the data in its original, unaltered form and keep using the software originally used to display the data
- the software has to be run on the operating system and the operating system on the hardware it was developed for

Requirements for Digital Preservation

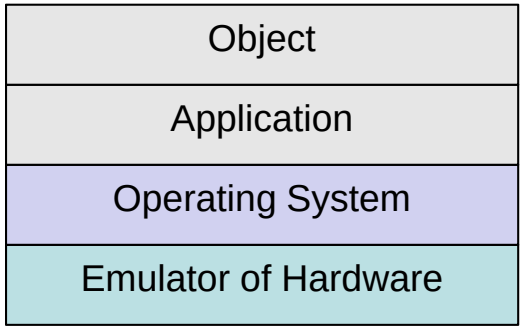
- context documentation of digital objects
- documentation about handling of objects
- not only technical but also social properties are relevant
- data transfer between emulated and host environment necessary (injecting digital objects into environment, extracting data from environment)
- stability more important than speed
- automation of processes (e.g. executing commands in target environment, automated input)

Problems for Digital Preservation

- expert knowledge necessary on how to use systems and programs (e.g. OS)
- not only the digital object, also all the necessary secondary digital objects and their settings have to be preserved (view path)
- emulators are programs that have to be preserved over a long term as well

Emulation View Path

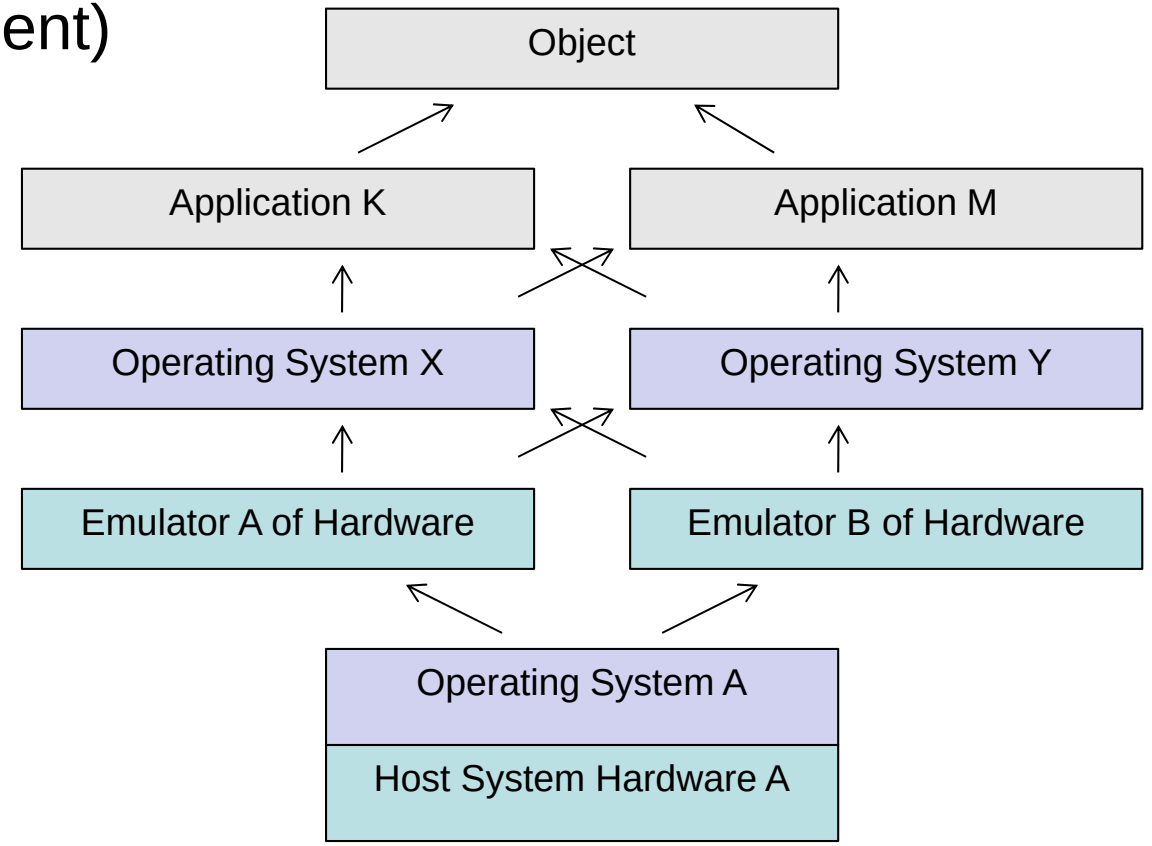
- View-Path: necessary path of secondary objects needed to display an object (e.g. application, operating system, hardware architecture)



- Example: Word for Windows 1.0 in Windows 3.0 on MS-Dos 5.0 using the DOSBox emulator on Windows Vista running on 64bit Hardware

Emulation View Path

- different view-paths are possible (different emulator, different OS, different application to display the same document)



Emulation View Path

- documentation of view path necessary
  - objects in the view path
  - settings of the objects
- storage of objects
  - with the object or separate
  - complete view path (e.g. disc-image) or discrete objects and configure on demand

Emulation View Path

- hardware configuration
  - CPU type, memory, configuration, speed settings
  - gfx-card, physics-card (3D rendering) incl. settings
  - sfx-card, settings
  - input-devices (e.g. light pen, trackball, data glove)
  - output-devices (type (vector/raster), aspect ratio, size, display settings like brightness, colours)
  - additional processing units, memory expansion cards (home-computers, game consoles)
  - depends on the original system, list is by far not complete!
  - tools can be used to determine the hardware and software settings (e.g. *Sigar*)

Emulation View Path

- operating system
  - type, version, system updates
  - font size
  - screen resolution
  - colour depth
  - installed fonts
  - appearance settings
  - installed utilities / applications that influence the appearance of the operating system

Emulation View Path

- necessary secondary digital objects
  - virtual machine (e.g. JVM, .net)
  - database software (e.g. MySQL)
  - software device drivers (e.g. ODBC driver)
  - memory managers (e.g. dos4gw)
  - fonts
  - codecs
  - viewer/editor application (e.g. OpenOffice, PDF-Viewer)

Emulation View Path

- digital object itself
  - settings
  - configuration (e.g. appearance options, message boxes)
- additional objects not in the view path
  - can influence behaviour (e.g. speed)
  - e.g. virus scan software, remote desktop software

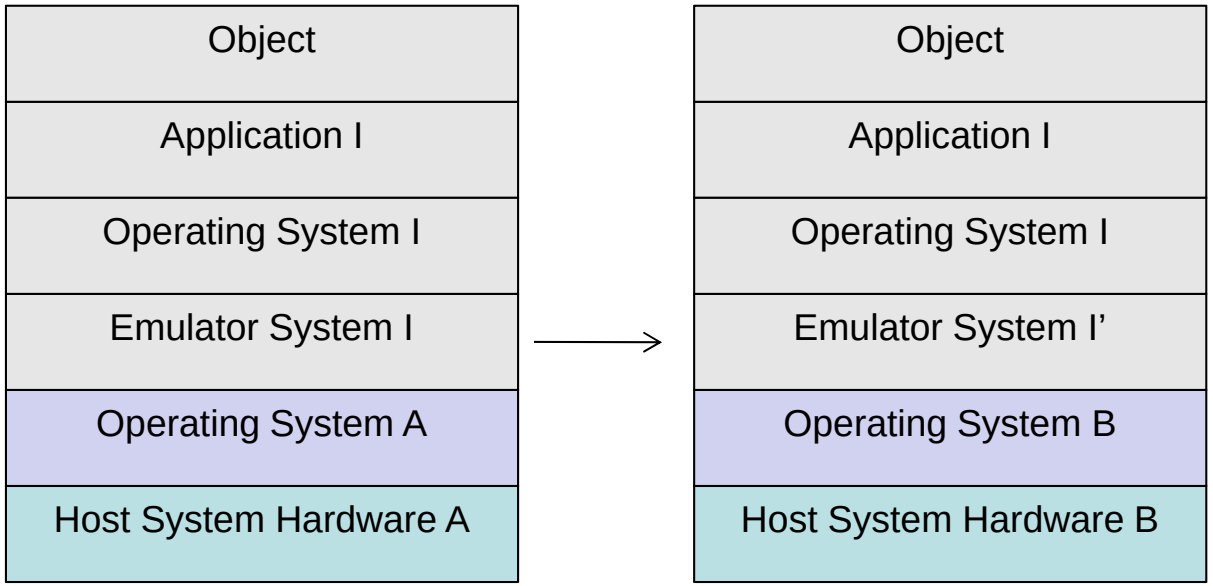
Preserving Emulators

- Emulators get obsolete - software for specific platform (hardware or virtual machine)

- various strategies for preservation
  - re-hosting
  - stacked emulation
  - emulation virtual machine (EVM)

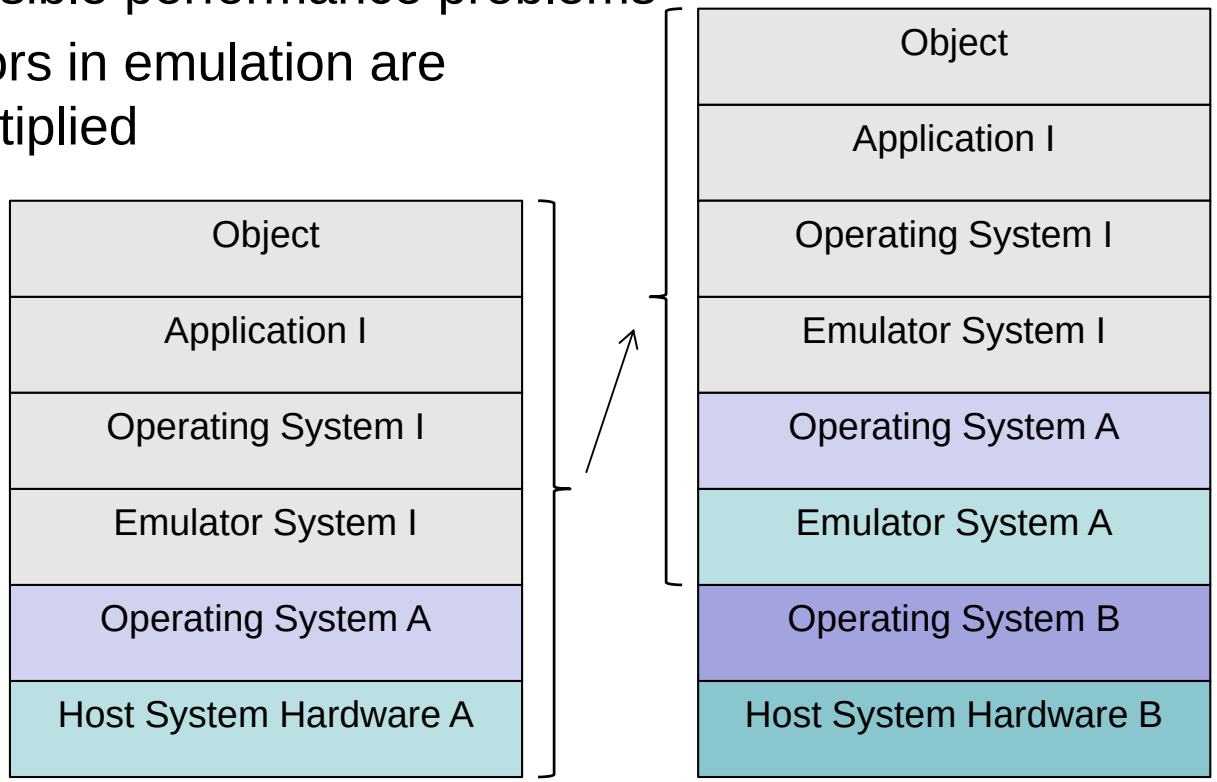
Preserving Emulators

- re-hosting
  - migrating emulator to a different host system
  - has to be done for every emulator when the host gets obsolete
  - documentation of system and expert knowledge about its function has to be available at implementation time



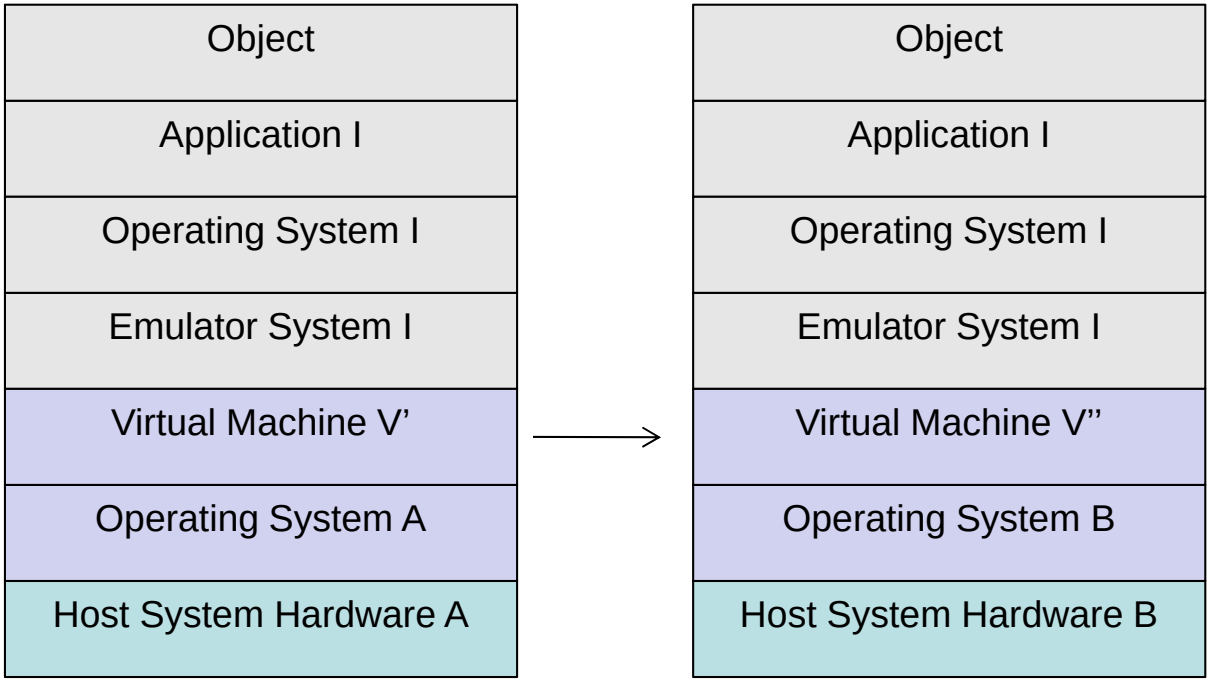
Preserving Emulators

- stacked emulation (*Russian Doll Syndrome*)
  - emulating the emulators host system
  - possible performance problems
  - errors in emulation are multiplied



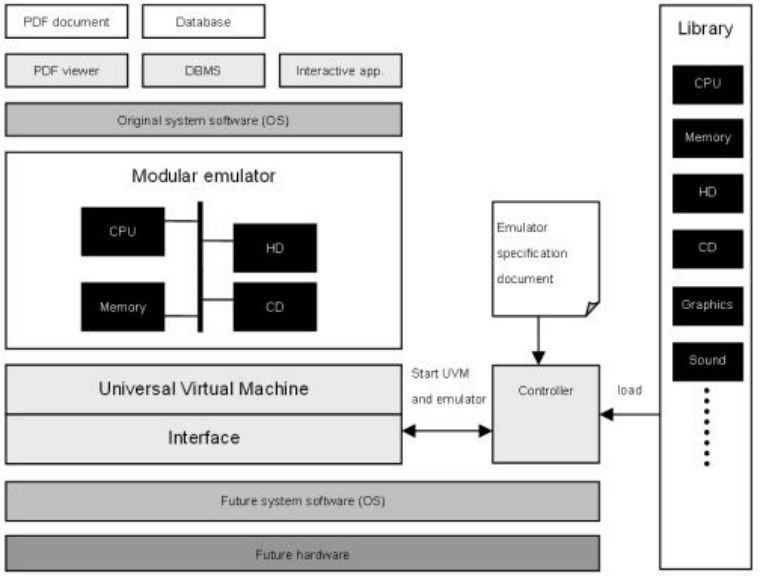
Preserving Emulators

- emulation virtual machine
  - creating emulators for a virtual machine which is ported to a new host when the original host gets obsolete
  - only the virtual machine has to be ported to the new host



Modular Emulation

- component based development
- specific machines are built from the components through configuration
- some examples:
  - Dioscuri (Java, emulates x86 PCs) http://dioscuri.sourceforge.net/
  - JPC (Java, emulates x86 PCs)
  - IronBabel (.NET, emulates modern video game consoles)
  - MAME/MESS (C, emulates video games, arcade machines, home computers)



UVC – Universal Virtual Computer

- developed by IBM / KB Netherlands for DP
  http://www.alphaworks.ibm.com/tech/uvc
- not a “real” hardware platform
- simplified design, open specification -> virtual machine easy to implement on future host machine
- Components:
  - Universal Virtual Computer (UVC) (future)
  - Logical Data Schema (LDS) with type description (now)
  - UVC program (format decoder) (now)
  - Logical Data Viewer (future)
- mixed migration/emulation approach

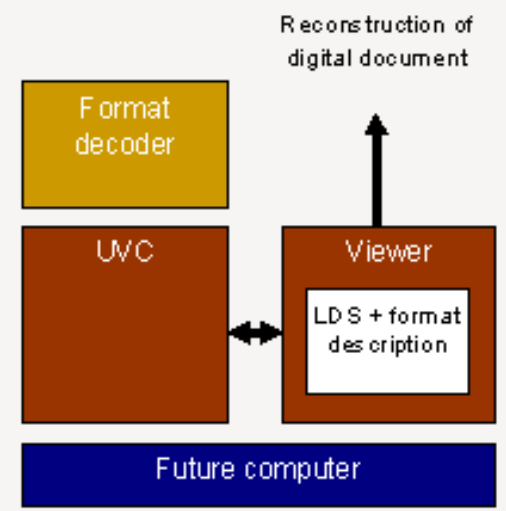


Figure 1: components of the UVC

Significant Properties

- properties of a digital object that are considered significant and as such have to be preserved
- Examples
  - image width, colour depth
  - page breaks, font, character encoding
  - relative speed
  - ...
- Preservation action should preserve the important significant properties
- importance of properties differ for institutional settings

Preservation Planning

- Consistent workflow leading to a preservation plan
- Analyses, which solution to adopt
- Considers
  - preservation policies
  - legal obligations
  - organizational and technical constraints
  - user requirements and preservation goals
  - Describes
    - the preservation context
    - evaluated preservation strategies
    - resulting decision including the reasoning
- Repeatable, solid evidence
- Requirements tree
  - preserving significant properties, tool, process, costs

Why Preservation Planning?

- Several preservation strategies developed
- For each strategy: several tools available
- For each tool: several parameter settings available
- How do you know which one is most suitable?
- What are the needs of your users? Now? In the future?
- Which aspects of an object do you want to preserve?
- What are the requirements?
- How to prove in 10, 20, 50, 100 years, that the decision was correct / acceptable at the time it was made?

Emulation in Preservation Planning

- problems with dynamic and interactive content:
  - to get reproducible results the digital object has to follow a deterministic behaviour:
    what are the factors that influence the objects behaviour?
  - continuous rendering of objects:
    when should object properties be extracted?
    where can properties be extracted from the running system?

Emulation in Preservation Planning

deterministic behaviour:

- view path has to be constant to compare behaviour
- input has to be constant
  - macros
  - remote access
  - “hardware” (read input on hardware level on original system, apply on hardware-layer of emulator)
- external factors that influence deterministic behaviour have to be constant (e.g. date/time, network activity, random number seed)
- not every object‘s behaviour can be made deterministic! (or not with justifiable effort)

Emulation in Preservation Planning

how to extract significant properties:

- not from the object, from the environment (object is rendered by the environment)
- environment has to support extraction ideally in extraction language (e.g. XCL) (not supported by emulators yet)
- properties have the dimension time (e.g. frames/second, cycles per second, number of file access operations per minute)
- properties change over time (e.g. frames/second min, average, max)

Emulation in Preservation Planning

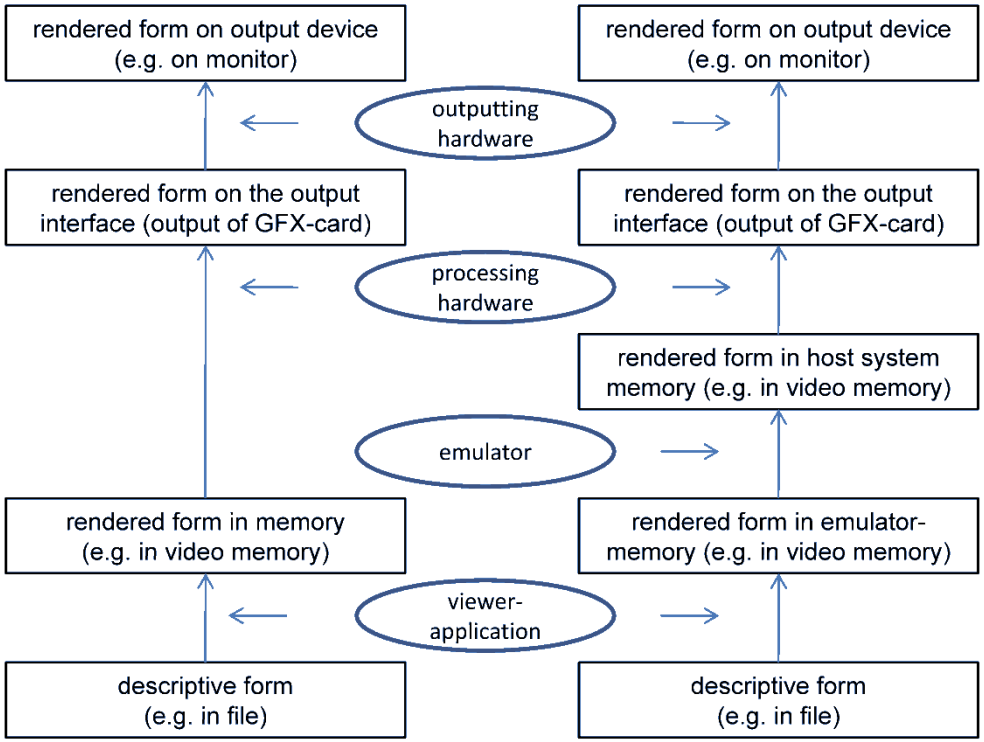
when to extract properties:

- not every state in an objects rendering process is significant
- depending on the object
  - target state: only one state after initially rendering the object or after applying a certain series of input events (e.g. rendering a static object)
  - series of states: only certain states after certain events (e.g. web site after each click on a link)
  - continuous stream: every rendered state of the object is important (e.g. video game, sound stream)

Emulation in Preservation Planning

where to extract properties:

- rendered form of a digital object exists on various levels in a system:



Emulation in Preservation Planning

where to extract properties:

- descriptive form
  - before rendering, useful for migration, no change in emulation
- rendered form in memory (original system)
  - both original system and emulator memory of host system
- rendered form in memory (host system)
  - exists only on host system, no comparison possible
- rendered form on output interface
  - signal analyzed by comparator (e.g. digital video signal, analog audio signal)
- rendered form on display device
  - influence of display device options (e.g. brightness settings)

Emulation in Preservation Planning

where to extract properties:

- depending on the tests where to extract:
  - screenshot level after applying input: is the emulation working correctly ?
  - comparison of output: is the transformation from emulated system to host system working correctly ?
- depending on the original system:
  - screenshot only possible if not a single process system like video game device
  - output signal only possible if output device is not part of system (e.g. built-in speakers)
  - after output device always possible, additional factors influencing the signal

Emulation in Preservation Planning

Emulation Validation Workflow:

1. Describe the original environment
2. Determine external events that influence the object's behavior
3. Decide on what level to compare the digital object
4. Recreate the environment in emulation
5. Apply standardized input to both environments
6. Extract significant properties
7. Compare the significant properties

Legal Aspects of Emulation (1)

- European regulations, legislations of France, Germany, Netherlands researched by KEEP
- Legal impact on media transfer
  - Multimedia works protected by intellectual property rights (EC Information Society Directive)
  - reproduction/representation of a protected work must be authorized
  - copyright protects content, independent from the physical medium
  - exception authorizes reproduction and representation of protected works by institutions responsible for legal deposit (e.g. national libraries) in some European countries (e.g. DE, FR, NL) -> allows migration or media refreshment
  - Copy protection: circumvention legal for memory institutions in some countries (e.g. FR), not legal in others (e.g. DE (specifically not allowed for games), NL)

Legal Aspects of Emulation (2)

- Emulation software
  - Decompiling computer program environments (operating systems, firmware (e.g. BIOS) and applications)
  - Article 6 of the Computer Programs Directive: not subject to prior authorization if (i) intended to create interoperability; (ii) performed by a licensee or lawful user; (iii) necessary information not quickly and easily accessible, and (iv) limited to the portions of the code required
  - decompilation of certain parts of software code allowed for e.g. development of emulation platform, not for research (interoperability between old Multimedia Works and current computer environments)
- Emulation of hardware
  - Patent protection: no reverse engineering allowed if patent in force
  - Emulation of semi-conductors (computer chips): reproduction of semi-conductor chip masks likely allowed (analyzing/evaluating/teaching)
  - Use of emulated hardware from third parties: use under respective licenses

Legal Aspects of Emulation (3)

- Conclusions
  - legal risk of transferring data relatively limited as long as conservation only done at cultural heritage organizations, access only granted to individual researchers
  - research exceptions are not applicable if made available to the public at large to give access to digital objects
  - copyright law would have to be adapted to fit the Information Technology age: focus on protecting against unauthorized usage of Multimedia Works rather than prohibit to transfer to new media
  - exemptions for memory institutions are necessary to protect digital cultural heritage (long-term)
  - negotiations with software manufacturer and hardware manufacturers enabling emulation (mid-term)

Digital Preservation

Preserving Interactivity

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Agenda

- objects & motivation
- alternatives
- software preservation
- interactive art preservation
- video game preservation
  - case study for video game preservation
  - video game archives
  - video game preservation projects
- virtual world preservation

Objects

- documents
  - authenticity & accessibility
  - boundary document/application is fuzzy (e.g. scripts/macros embedded in documents)

- software
  - keep original proprietary software running and data accessible
  - distributed software is hard to preserve
  - scientific software for research
  - business software for legal obligations (safekeeping period)
  - computer museum (cultural heritage)

Objects

- interactive art
  - authentic look & feel
  - hardware proprietary
  - documentation not available
  - can be a mix of analogue and digital installations

- video games
  - same problems as interactive art (-> “art games”)
  - legal problems
  - proprietary media
  - companies are not supportive
    (yet? -> Digital Game Preservation White Paper at Game Developers Conference 2009)
  - distributed games

Alternatives

- emulation
  - application level (documents)
  - OS level (software)
  - hardware (documents, software, interactive art, video games)
- migration
  - source ports (software, video games, interactive art)
  - static binary translation (software, video games, interactive art)
  - documentation on video, paper (documents, software, interactive art, video games)
- reinterpretation
  - interactive art
  - video games

Software Preservation

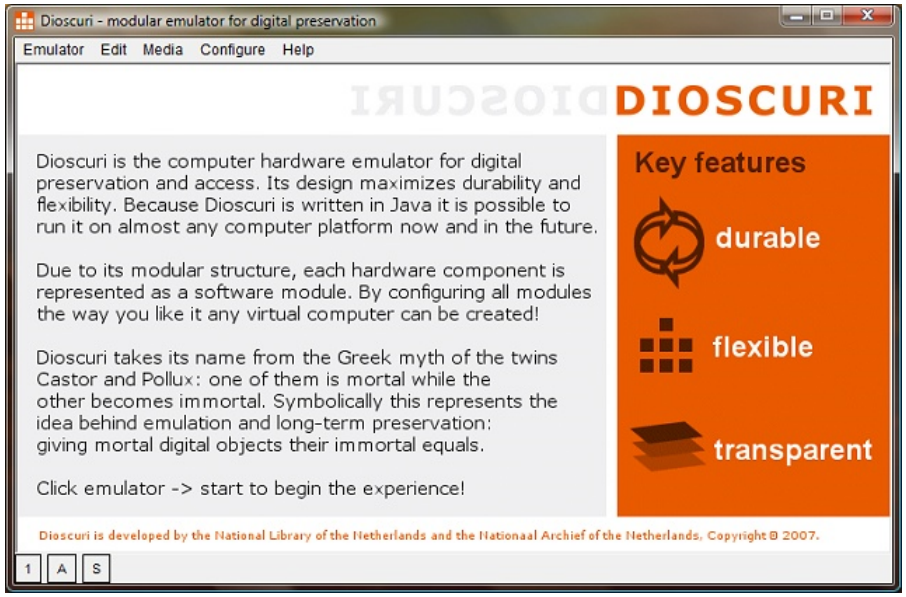
- short term
  - “XP-Emulator” on Windows 7
  - DOS-compatibility-mode on Windows XP
  - Rosetta on Intel-based Apple Macintosh (dynamic binary translation)
- long term
  - hardware emulation
  - migration (reprogramming, porting) to new platforms

- JISC-study on significant properties of software
  - properties necessary of reconstruct software from source

    http://www.jisc.ac.uk/media/documents/programmes/preservation/spsoftware_report_redacted.pdf

Software Preservation

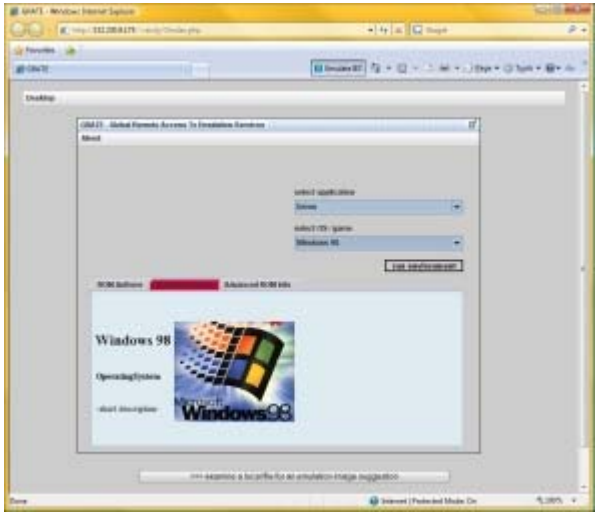
- Dioscuri
  http://dioscuri.sourceforge.net/
  - Intel x86 PC emulation
  - emulator specific for digital preservation purposes
  - features copy/paste from emulated environment
  - stable solution (Java VM, modular emulation)



- Qemu
  http://www.nongnu.org/qemu/
  - emulation and (x86 only) virtualization
  - different target CPUs supported (ARM, SPARC, PowerPC, MIPS etc.)

Software Preservation

- Grate (Global Remote Access to Emulation-Services)
  - TightVNC technology (Virtual Network Computing over web-access)
  - different emulators supported
  - transfer speed of input/output usually not fast enough for video games but sufficient for applications
  - can be used for remote migration: transfer local file into emulated environment, migrate, transfer back to local system (without installing emulator locally)
  - uses DROID / PRONOM services for recognizing file formats

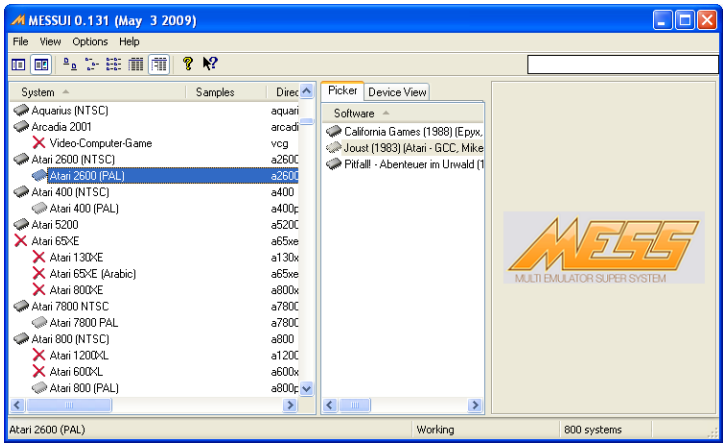


Video Game Preservation

hardware emulators (multiple platforms)

- MAME
  Multiple Arcade Machine Emulator
  http://mamedev.org/
  - arcade machines
  - modular concept
  - open source (C)

- MESS
  Multiple Emulator Super System
  http://www.mess.org/
  - based on MAME source
  - emulates home computers & video game consoles



Video Game Preservation

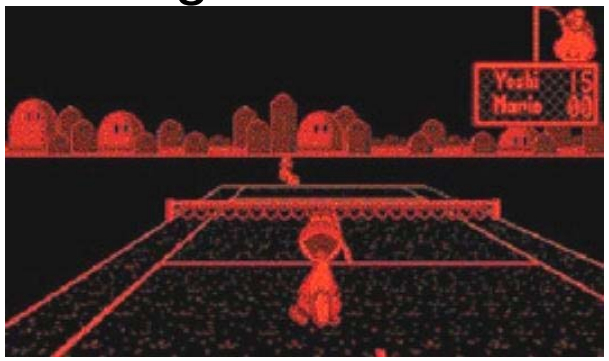
hardware emulators (single platforms)

- available for almost any system (from early home computers and video game console systems to Nintendo Wii)
- pro:
  - more feature complete emulation than multiple system emulators
  - better compatibility
  - more user friendly (less options, usually auto detection of some game settings like region)
- con:
  - typically platform dependent
  - usually single person development and not always open source

Video Game Preservation

hardware emulators (single platforms) – some examples

- Atari 2600 - Stella
  http://stella.sourceforge.net/
- Commodore Amiga – WinUAE
  http://www.winuae.de/englisch/main.html
- Sony Playstation 2 – PCSX2
  http://www.pcsx2.net/
- Nintendo DS – no$cash
  http://nocash.emubase.de/gba.htm
- Nintendo Virtual Boy – Red Dragon
  http://rdragon.vr32.de/
- Sega Dreamcast – nullDC
  http://www.emudev.org/nullDC-new/

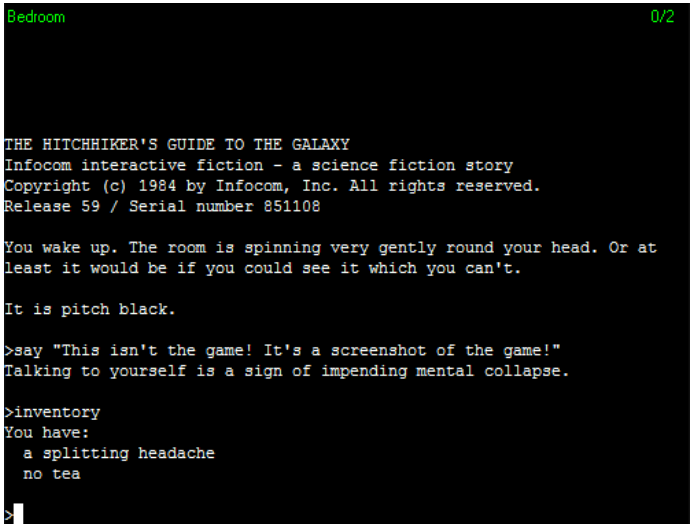


Video Game Preservation

game engine interpreters

- SCUMM-VM
  http://www.scummvm.org/
  - “Script Creation Utility for Maniac Mansion”
  - various engines supported (e.g. LucasArts Games, Sierra)

- Frotz
  http://frotz.sourceforge.net/
  - Infocom Z-Machine
  - text-adventures
  - not true to original appearance



Video Game Archives

- Private collectors
  - very active communities
    http://www.digitpress.com/
    http://www.atariage.com/
  - not relying on public funding
  - longest running initiatives
  - problem: lots of very rare specimen only in private hands, no consolidated preservation efforts
- Computerspielemuseum (Berlin, Germany)
  http://www.computerspielemuseum.de/
  - huge collection from USK (Unterhaltungssoftware Selbstkontrolle)
  - relies mainly on donations for obsolete games/systems
  - exhibitions (e.g. Pong Story http://pong-mythos.net/)
  - Permanent museum in Berlin since January 2011

Video Game Archives

- DiGA – Digital Games Archive
  http://www.digitalgamearchive.org
  - raise public awareness concerning the cultural significance of entertainment software
  - guarantee its long term preservation
  - create a legal and dependable base for the preservation of games (legislative proposals etc.)
  - digitally donated games free for download
- National Video Game Archive (UK)
  http://www.nationalvideogamearchive.org/
  - National Media Museum and Nottingham Trent University
  - “celebrate video game culture and preserve its history for researchers, developers, game fans and the public”
  - preserve, analyze and display the products of the global videogame industry

Video Game Preservation Projects

- Preserving Virtual Worlds (US) (2008-2010)
  http://pvw.illinois.edu/pvw/
  - preserving American art awards by Library of Congress US in 2007 - also for video games
  - two year project led by University of Illinois' Graduate School of Library and Information Science (GSLIS)
  - explored methods how to preserve digital games and interactive fiction
  - case studies on: Spacewar!, Second Life, Star Raiders, Doom, Warcraft
  - Final Report
    http://pvw.illinois.edu/pvw/?p=224
- Preserving Virtual Worlds (US) (started 2010)
  http://pvw.illinois.edu/pvw2/

Video Game Preservation Projects

- KEEP - Keeping Emulation Environments Portable (EU-project) (2009-2012)
  http://www.keep-project.eu/
  - 3 year project specifically about emulation
  - Partners included Computerspielemuseum Berlin, National Libraries (Fench, Dutch), European Games Developer Federation (EGDF),
  - KEEP Emulation Framework
    http://emuframework.sourceforge.net/
  - TOTEM - the Trustworthy Online Technical Environment Metadata Database
    http://keep-totem.co.uk/
  - Transfer Tool/Media Carrier Knowledge Base
    http://mediabase.keep-totem.co.uk/
  - Research on legal aspects of emulation
    http://www.keep-project.eu/ezpub2/index.php?/eng/content/download/20703/103715/file/D2.6_laymansguidelegalstudies_final.pdf
  - Emulation Virtual Machine

Video Game Preservation Projects

- Play It Again: Creating a Playable History of Australasian Digital Games, for Industry, Community and Research Purposes (AU/NZ) (2012-2014)
  - First project specifically funded for Video Game Preservation

- IGDA (International Game Developers Association) Game Preservation SIG (Special Interest Group)
  http://www.igda.org/preservation
  - GDC 2011: Saving Videogames from Certain Doom (6th annual meeting on Game Developers Conference)
  - White paper on Digital Game Preservation: http://wiki.igda.org/Game_Preservation_SIG/White_Paper/Before_It%27s_Too_Late:_A_Digital_Game_Preservation_White_Paper
  - Active mailing list, wiki pages, projects...

Virtual World Preservation - Approaches

- Extracting the world
  - user generated content
  - preserve interactivity with the world
  - convert to different format (e.g. Second Life -> OpenSimulator)
  - looses events, people, actions ... everything that makes a world feel “alive” ?

- Recording events
  - interactions with the world
  - Interactions between users
  - “real-life” approach
  - either manually or automatic
    (e.g. http://www.ifs.tuwien.ac.at/dp/second_life)

Virtual World Preservation - Examples

- Second Life
  - Virtual Conferences (Posters, Presentations)
  - User generated art
  - Events

  http://www.archive.org/details/SL_AvatarIslandIntroduction

- World Of Warcraft

  http://www.archive.org/details/Wow_ShattrathTour

- EA-Land (The Sims Online): The Final Countdown
  - "Lost Server Connection“

  http://www.archive.org/details/EALand_FinalCountdown