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

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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 ?
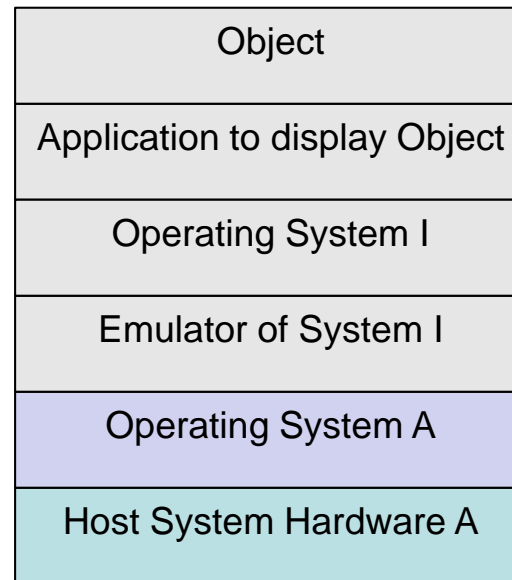 - flight simulator does not actually fly

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- **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**

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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)

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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

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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).

| Object |
|---|
| Application to display Object |
| Operating System I |
| Emulator of System I |
| Operating System A |
| Host System Hardware A |

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- 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

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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)

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- 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

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

Object
Application
Operating System
Emulator of Hardware
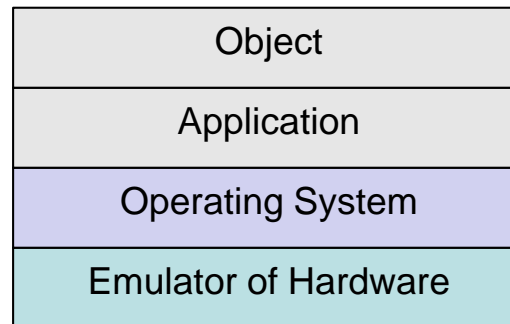
- Example: Word for Windows 1.0 in Windows 3.0 on MS-Dos 5.0 using the DOSBox emulator on Windows Vista running on 64bit Hardware

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

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Emulation View Path
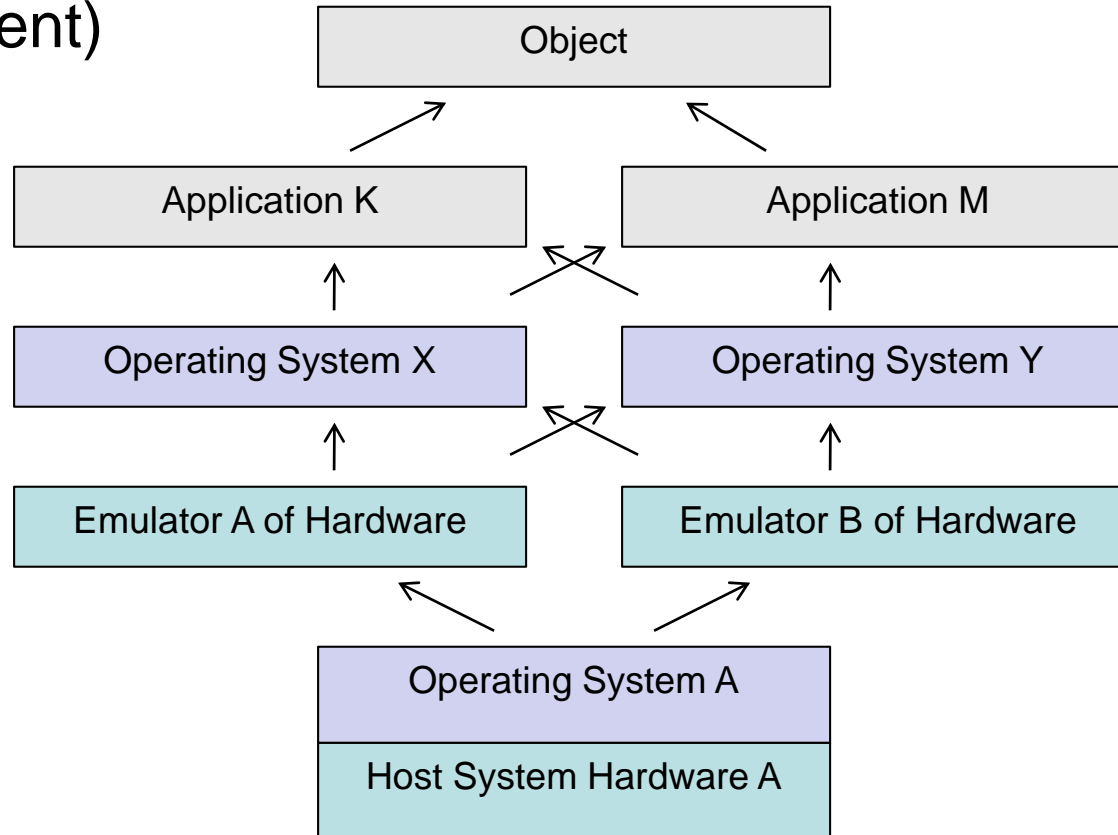
- **documentation of view path necessary**
  - objects in the view path
  - settings of the objects

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

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- **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*)

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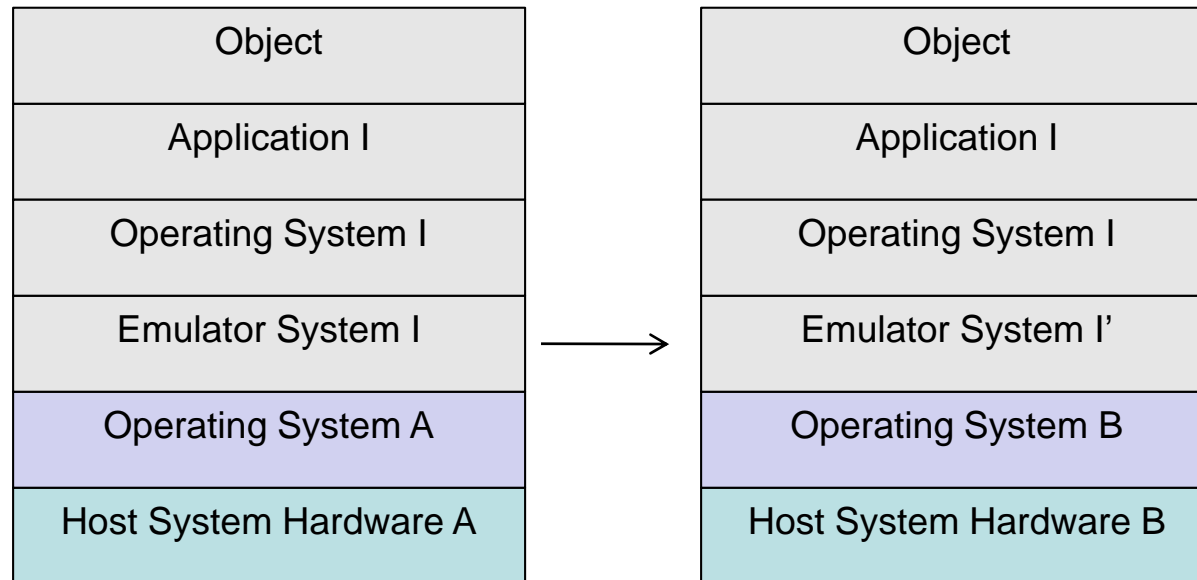
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- **needed secondary digital objects**
  - virtual machine (e.g. JVM, .net)
  - database software (e.g. MySQL)
  - software device drivers (e.g. ODBC driver)
  - memory managers (e.g. dos4gw)
  - fonts
  - codecs
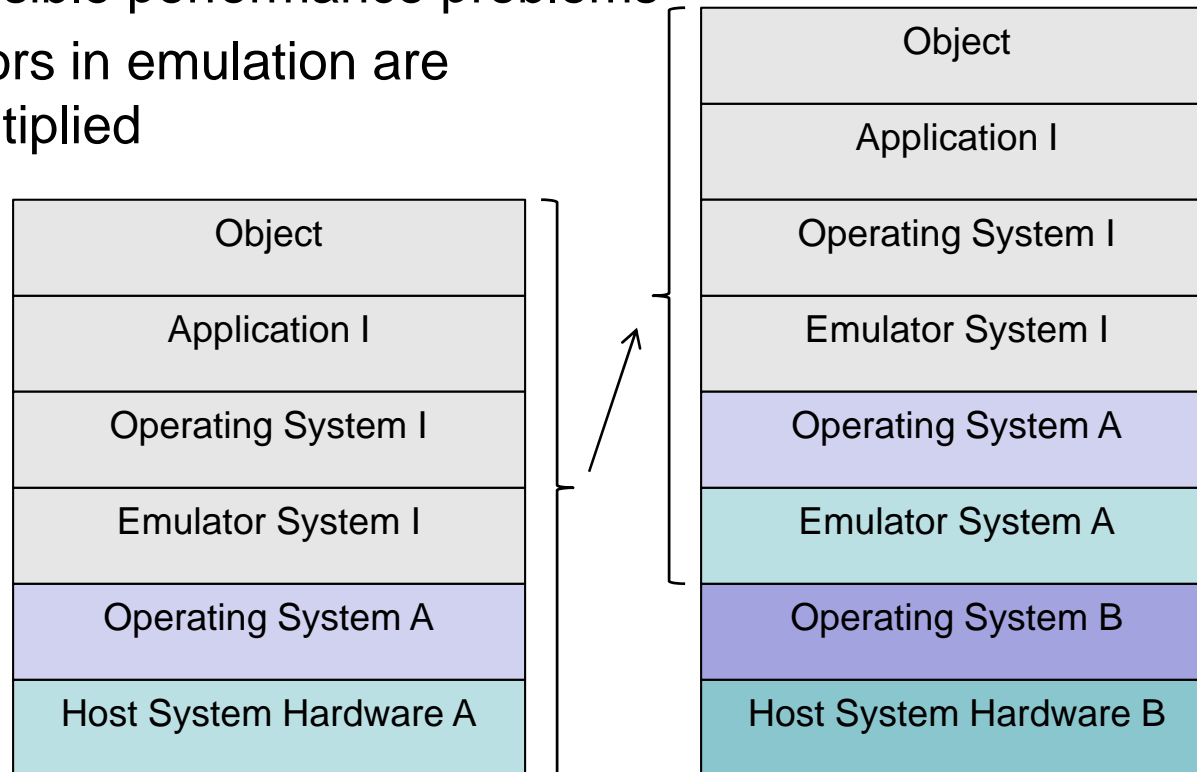 - viewer/editor application (e.g. OpenOffice, PDF-Viewer)

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- **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

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

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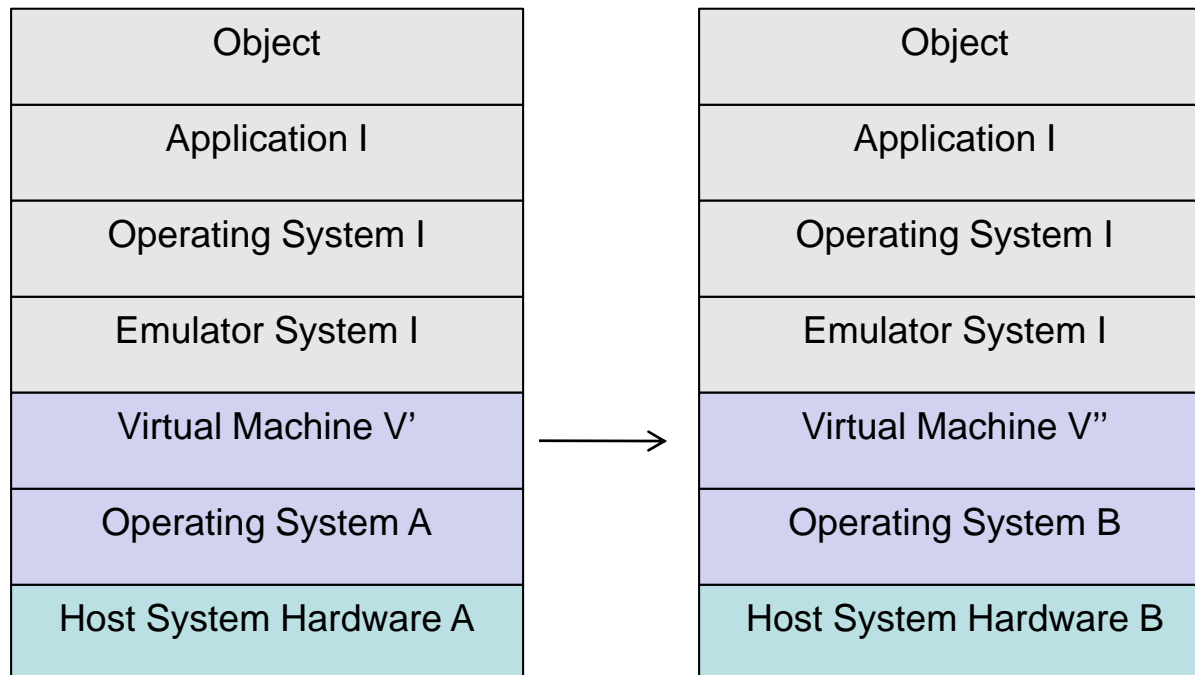 - emulation virtual machine (EVM)

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- **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

Object	Object
Application I	Application I
Operating System I	Operating System I
Emulator System I	Emulator System I'
Operating System A	Operating System B
Host System Hardware A	Host System Hardware B

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

| Object |
| Application I |
| Operating System I |
| Emulator System I |
| Operating System A |
| Host System Hardware A |

| Object |
| Application I |
| Operating System I |
| Emulator System I |
| Operating System A |
| Emulator System A |
| Operating System B |
| Host System Hardware B |

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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

Object
Application I
Operating System I
Emulator System I
Virtual Machine V'
Operating System A
Host System Hardware A

→

Object
Application I
Operating System I
Emulator System I
Virtual Machine V''
Operating System B
Host System Hardware B

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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)

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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

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Significant Properties
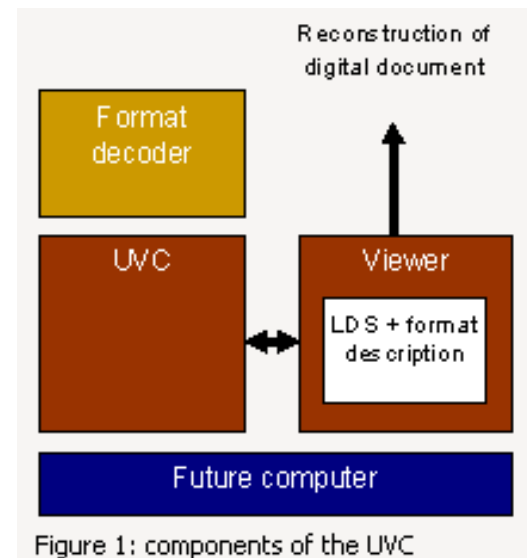
- properties of a digital object that are considered significant and as such have to be preserved

- 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

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- 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

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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?

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- **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?

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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)

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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)

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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)

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where to extract properties:

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

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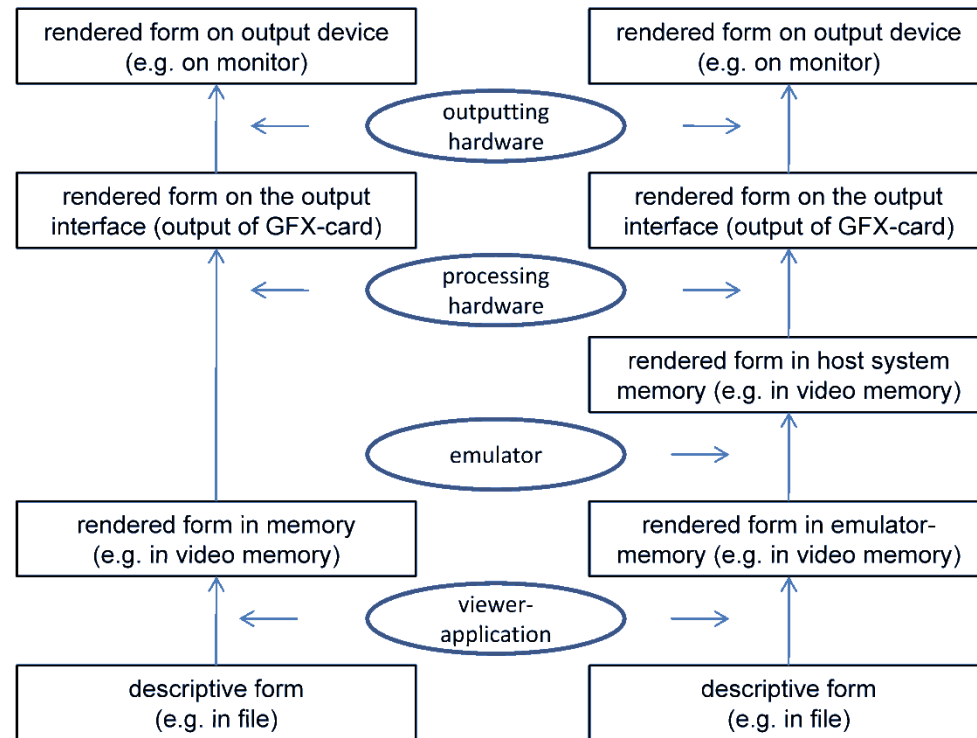
where to extract properties:

- **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)

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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

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test workflow:

- determine external events that influence the objects behaviour

- describe the original environment

- decide on what level to compare the digital object

- recreate the environment in emulation

- apply standardized input to both environments

- extract significant properties

- compare the significant properties

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- 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)

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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

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- **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)

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Digital Preservation

Preserving Interactivity

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http://www.ifs.tuwien.ac.at/dp

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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**

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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)

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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

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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)

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- **simulation**
  - software
  - interactive art
  - video games

- **reinterpretation**
  - interactive art
  - video games

- **mixed forms (e.g. reinterpretation/migration, reinterpretation/simulation)**

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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

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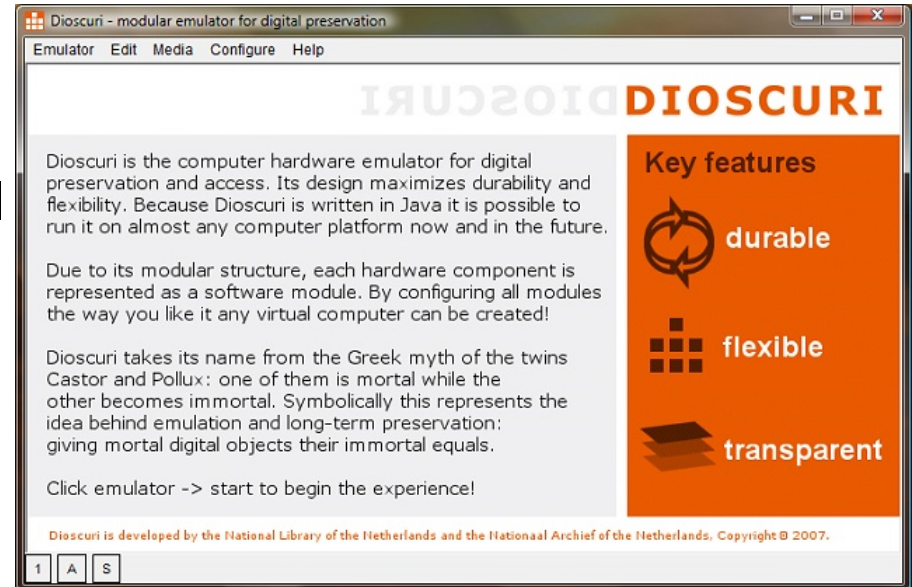
- Qemu
  http://www.nongnu.org/qemu/
  - emulation and (x86 only) virtualization
  - different target CPUs supported (ARM, SPARC, PowerPC, MIPS etc.)

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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

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Interactive Art Preservation
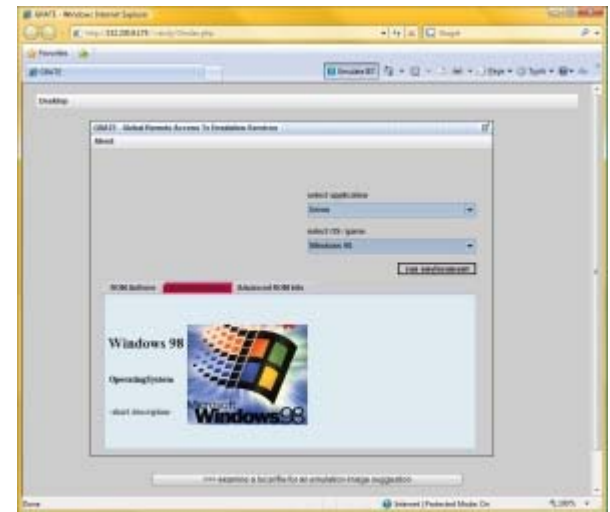
- **Archiving the Avant-Garde**
  http://www.bampfa.berkeley.edu/about/avantgarde
  - Berkley Art Museum, Guggenheim museum
  - the Variable Media Initiative (http://www.variablemedia.net/)
  - Variable Media Questionnaire: artists choose different strategies for preserving art: emulation, migration and reinterpretation

- **DOCAM (Documentation and Conservation of the Media Arts Heritage)**
  http://www.docam.ca/
  - visual and performing arts (theatre, dance, performance) and architecture
  - cataloguing structure, case studies in conservation and preservation, documentation and archival management

- **Real-time Demos**
  - Amiga Demo-Scene Archive (ADA) (http://ada.untergrund.net/)
  - Hornet Archive (PC Demos) (http://www.hornet.org/)

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Interactive Art Preservation

- "The Erl King" (1983-85) by Grahame Weinbren and Roberta Friedman
    - interactive movie, obsolete and generic hardware and software
    - original software was written by the artist -> very high priority to preserve the original code
    - emulated for Guggenheim museum
    http://www.bampfa.berkeley.edu/about/ErlKingReport.pdf
    - migrated as webpage
    http://www.grahameweinbren.net/ErlKing/Erlkoenig.html

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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
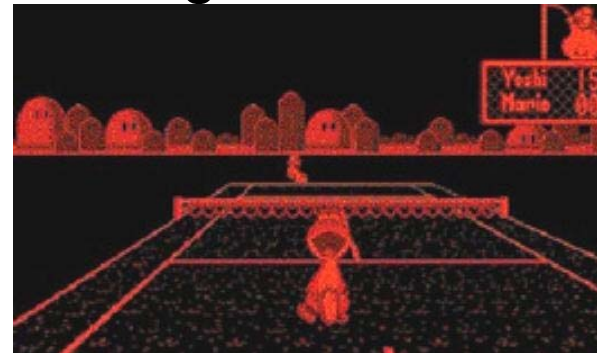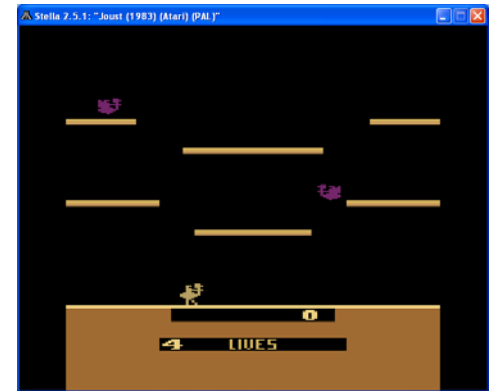 - emulates home computers & video game consoles

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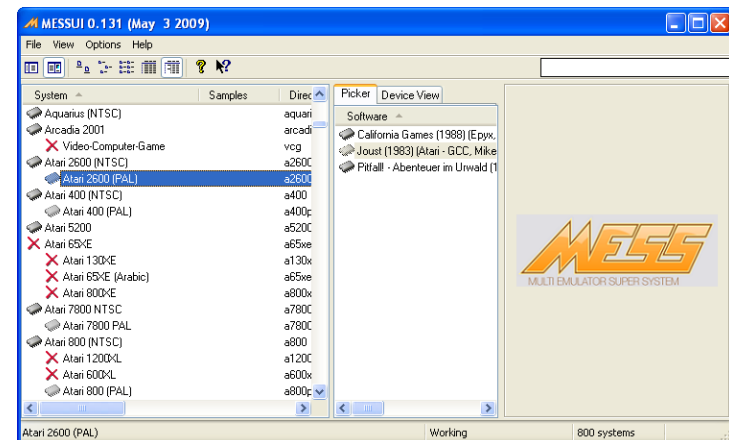
hardware emulators (single platforms)

- 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

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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/

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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

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- **cultural heritage**

- **public interest ("retro gaming")**

- **problems:**
  - broken hardware, decayed media
  - changed TV Standards

- **challenges:**
  - unavailable documentation (partially even lost forever)

  - preservation of game code from different media (optical, cartridge, online)

  - legal aspects

  - look & feel (different controllers)

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- **define basis for library scenario**
  - data collection = console video games
  - designated user community are visitors of the library
  - required goals
    - authentic look & feel, long term preservation, accessibility and metadata, high compatibility, cost to be considered

- **choosing sample records**
  - three games for every system
    - popular game
    - game with special controller / overlay
    - game using special accessory or hardware enhancement or technically complex game

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- identifying requirements

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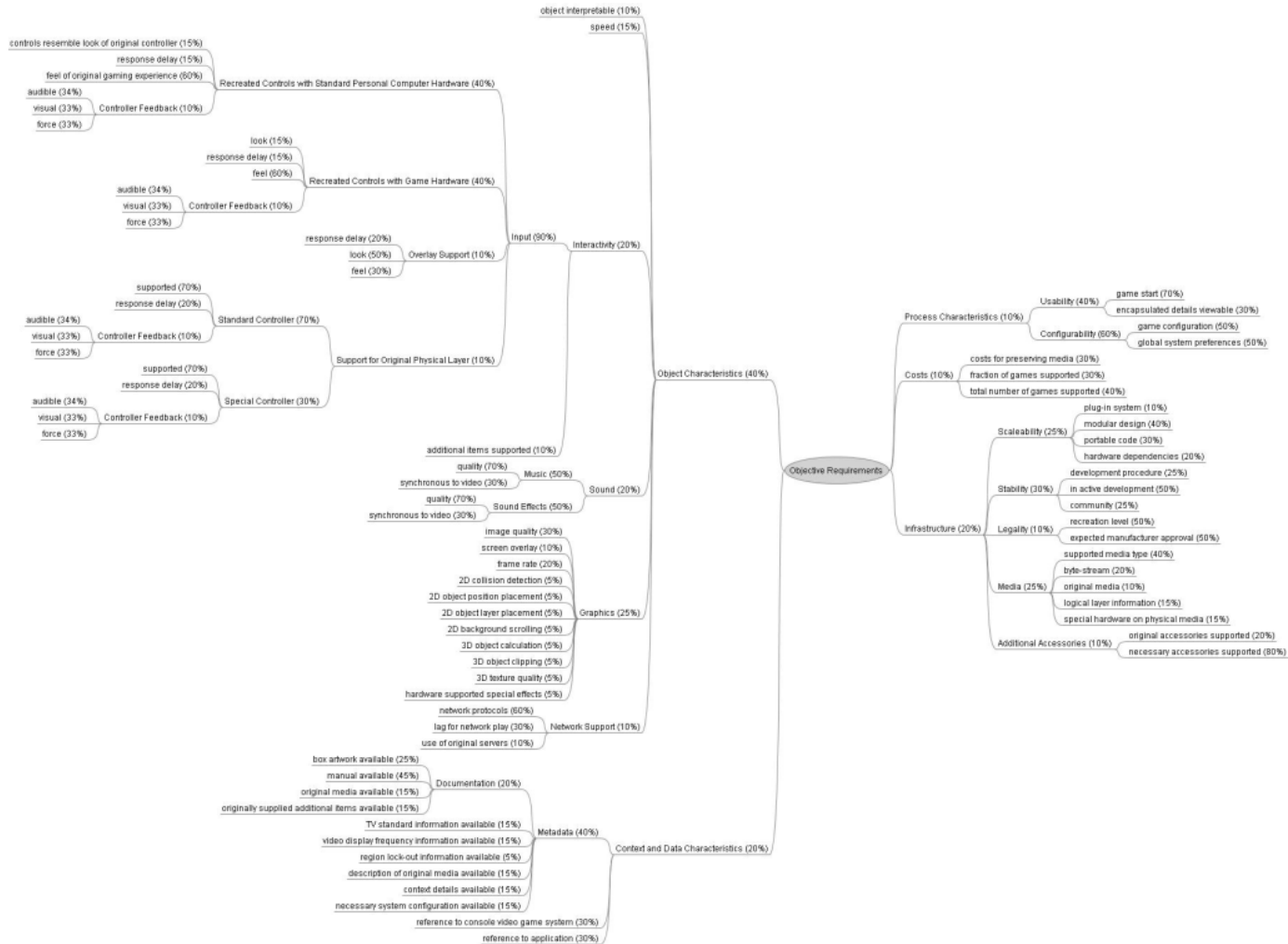
- **considered alternatives**
  - emulation
  - simulation
  - print-to-paper (video) approach

- **developing the experiments**
  - source code evaluation
  - game-play with keyboard/mouse and joystick
  - configuration of alternative

- **running the experiments**
  - alternatives for one console system
  - alternatives for different console systems from the same era
  - alternatives for one system of each era

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- **analyzing results**
  - comparison of emulators of the one system and different systems of the same generation of video game consoles
    - games emulated well
    - special hardware only supported by dedicated emulators
    - scalability and stability better for multi-system emulators
    - no metadata supported
  - comparison of emulators of one system of each generation of video game consoles
    - infrastructure, process, costs and context similar results
    - emulation better for games of earlier systems
    - no perfect emulation for systems of the last three generations

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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

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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

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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

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Video Game Preservation Projects

- **KEEP - Keeping Emulation Environments Portable (EU-project) (started 2009)**
  http://www.keep-project.eu/
  - „Emulation Access Platform" - tools for accessing and storing a wide range of digital objects
  - Disocuri, GRATE
  - Research on legal aspects of emulation

- **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...

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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)

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- **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

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Digital Preservation

Practical Tasks

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Practical Tasks

- tasks: *http://www.ifs.tuwien.ac.at/~guttenbr/teaching/dp2011/Emulation.zip*
  - *digital art*: run the "Laser Demo" demo on emulators (Altirra first, then Atari800)
  - *video games*: run "Floppy Frenzy" in DOSBox at correct speed
  - *data access*: boot Dioscuri from the provided floppy image and copy text from the file "rogue\rogue.doc" into an email-message on your host-environment – also try to run the game Rogue

- to-do:
  - set up the emulation environment(s) on your computer
  - run the application and execute the task
  - share your experience and observations with the class

- discuss these questions afterwards:
  - did you manage to set up the environment? where were the difficulties?
  - were you able to operate the system without problems?
  - can you tell if the experience was authentic? do you think it was? if not, why not?
  - what were the differences in the emulators? (if you ran more than one)

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DP Übung

- Submission of the concept papers on 2011-05-08 through TUWEL

- any question to the tasks / about the organisation of the Übung?

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Thank you for your attention.

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