Evaluating Strategies for the Preservation of Console Video Games

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Abstract

The amount of content from digital origin permanently increases. The short lifespan of digital media makes it necessary to develop strategies to preserve its content for future use. Not only electronic documents, pictures and movies have to be preserved, also interactive content like digital art or video games have to be kept "alive" for future generations. In this paper we discuss strategies for the digital preservation of console video games. We look into challenges like proprietary hardware and unavailable documentation as well as the big variety of media and non-standard controllers. Then a case study on console video game preservation is shown utilizing the Planets preservation planning approach for evaluating preservation strategies in a documented decision-making process. While previous case studies concentrated on migration, we compared emulation and migration using a requirements tree. Experiments were carried out to compare different emulators as well as other approaches first for a single console video game system, then for different console systems of the same era and finally for systems of all eras. Comparison and discussion of results show that, while emulation works in principle very well for early console video games, various problems exist for the general use as a digital preservation alternative. It also shows that the Planets preservation planning workflow can be used for both emulation and migration in the same planning process and that the selection of suitable sample records is crucial.

Introduction

Video games are part of our cultural heritage. The public interest in early video games is high, as exhibitions, regular magazines on the topic and newspaper articles show. Games considered to be classic are rereleased for new generations of gaming hardware as well. However with the rapid development of new computer systems the way games look and are played changes rapidly. As original systems cease to work because of hardware and media failures, methods to preserve obsolete video games for future generations have to be developed. When trying to preserve console video games, one has to face the challenges of classified development documentation, legal aspects and extracting the contents from original media like cartridges with special hardware. Special controllers and non-digital items are used to extend the gaming experience. This makes it difficult to preserve the look and feel of console video games.
The term "video game" can refer to different kinds of electronic games where a person ("player") plays a game primarily produced by a computer and usually presented on some kind of display unit. These games are played on systems which have not been designed primarily for gaming (e.g. personal computers, mobile phones, digital cameras, classic home computers) as well as on systems made specifically for gaming (e.g. consoles connected to a TV, hand held consoles, arcade machines).
The challenge to preserve diverse types of video games varies in many aspects such as used media for software, kinds of presentation, levels of known system architecture. This work concentrates on the preservation of console games. These are devices that are specially made for playing games where the system's output is displayed on a television screen. Example console systems are Atari 2600, Nintendo Entertainment System (NES) and Sony PlayStation.
First this paper gives an overview of related work. Then we present the challenges and discuss the different strategies for digital preservation for console video games. Next we show a case study for the long-term preservation of console video games using different digital preservation strategies. Similar preservation planning case studies concentrated on migration. We compare emulation and migration using the Planets[1] preservation planning approach to evaluate alternatives using an objective tree. Finally we present the conclusions that can be drawn from the experiments.

Related work

In the last years migration and emulation have been the main strategies used in digital preservation. Lorie differs between the archiving of data and the archiving of program behavior. While the first can be done without emulation, it cannot be avoided for the latter (Lorie 2001). While this rigorous statement may be challenged if re-compiling or porting code to a different platform are viewed as a form of migration, emulation definitely plays an important role for the preservation of program behavior.

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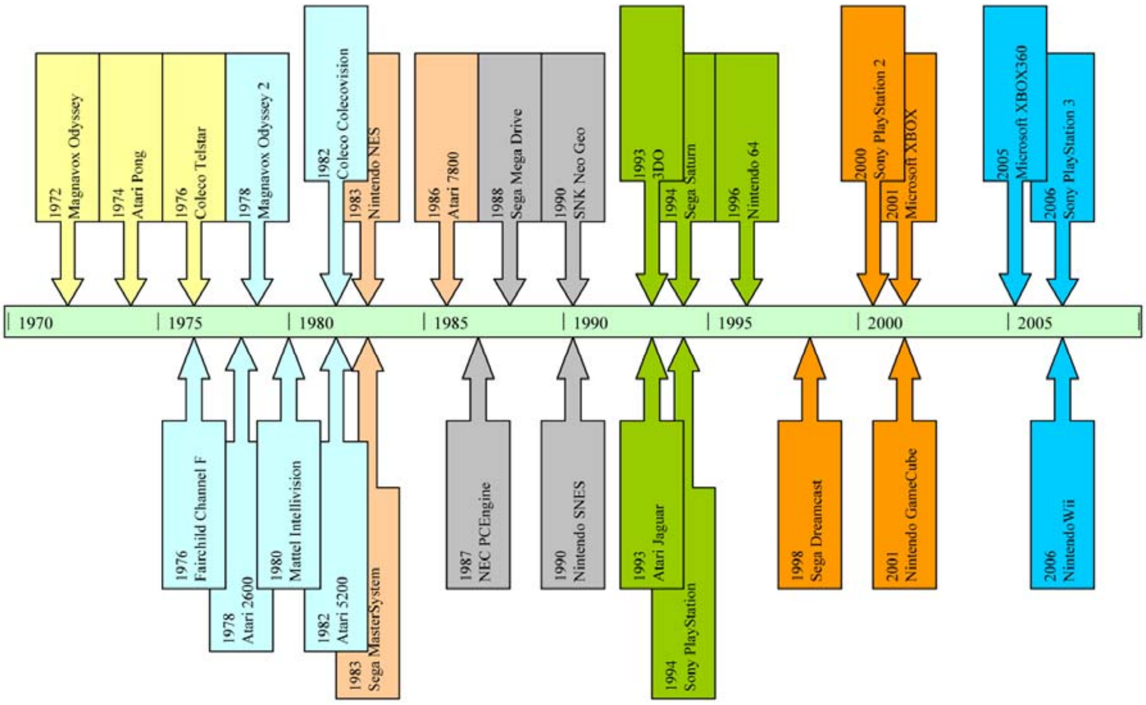

Figure 1: Timeline of release years for console video game systems. Systems of the same era are shown in the same color.

The concept of using emulation for digital preservation is to keep the data in its original, unaltered form and keep using the software originally used to display the data. This software has to be run on the operating system and the operating system on the hardware it was developed for. To keep this chain alive, an emulator for the original hardware is produced. Emulation can take place on different levels (software, operating system or hardware) as described in (Rothenberg 2000).

Several methods to establish emulation as a long term strategy for digital preservation are discussed in (Slats 2003). The concept of an Emulation Virtual Machine (EVM) was used for development of the Universal Virtual Computer (UVC) by IBM (van der Hoeven, van der Diessen, and van en Meer 2005). An approach to developing an emulator on a hardware level is discussed as a conceptual model in (van der Hoeven and van Wijngaarden 2005) as modular emulation. An emulator which uses the modular emulation approach (van der Hoeven, Lohman, and Verdegem 2007) is under development in the Planets project. Planets is a project developing services and technology to address core challenges in digital preservation co-funded by the European Union under the Sixth Framework Programme (Farquhar 2007).

A practical experiment on how to use emulation to recreate interactive art is presented in (Jones 2004).

The Planets preservation planning approach used for this case study is described in detail in (Strodl et al. 2007). Becker et. al. present case studies on sample objects of interactive multimedia art from the collection of the Ars Electronica[2] in (Becker et al. 2007).

[2] http://www.aec.at

Challenges

When preserving video games, one is faced with two different tasks: preserving the video game system and preserving the games themselves. The requirements and challenges for digitally preserving console video games are partially very different to those of preserving static documents and even video games on other systems like personal computers, home computers and arcade machines.

This case study concentrated on strategies for systems which had substantial market shares and are considered as major systems. Figure 1 shows a time-line of release years. Most of the results of this work are applicable to other console systems as well.

Numerous specific challenges have to be faced when preserving console video games. Unlike personal computers or early home computers, the exact specifications of console video game systems and development documentation for game developers are usually confidential.

Console video games have always been offered on various types of media which in most cases cannot easily be read on standard computer hardware. The most common media include ROM-cartridges which potentially also contained extra hardware besides a microchip storing the data. Optical media and on-line content are mainly used for the last generations of console systems.

While in many digital preservation appliances the user experience plays a minor role, it is considered the central aspect with interactive fiction like video games. To enhance the gaming experience especially for early video games, screen or controller overlays were used. These

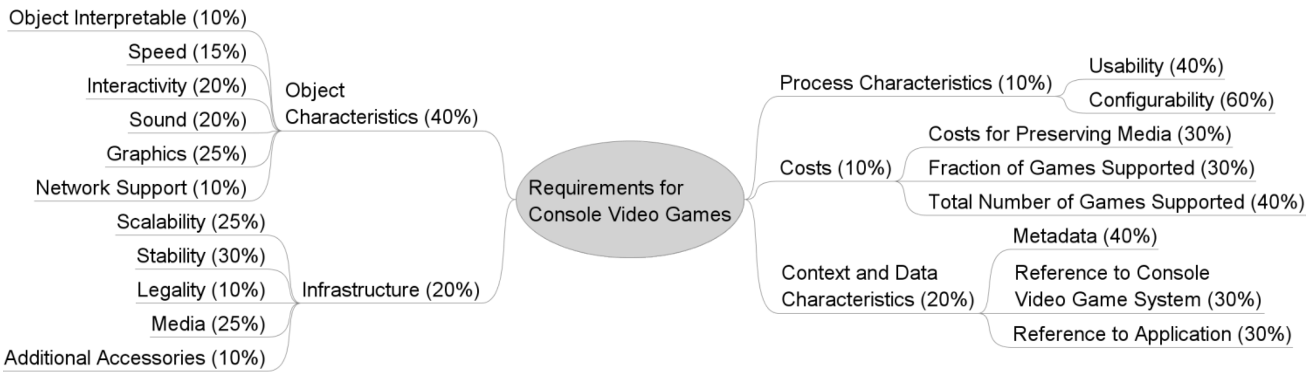

Figure 2: Requirements tree for console video games with importance factors (first two levels only).

overlays were applied to either the screen to enhance the visual impression of the image or to the controller to explain button layouts. The experience with some games lies in the use of a specially designed controller. Therefore it is necessary to find a way to recreate the game-play experiences with these games as close to the original as possible.
To preserve video games in any other way than keeping the original hardware and media, legal issues have to be addressed. It is necessary to constitute the responsibility for the preservation of digital data. Legal deposit laws should be extended to include digital data. The legal situation would have to be adjusted to carrying out the actions needed for digital preservation.

Strategies

Several strategies for preserving digital content are listed in the UNESCO Guidelines for the Preservation of the Digital Heritage (Webb 2005). Applied to the preservation of console video games, they can be summarized as follows.
The *Museum Approach* is not a long term preservation strategy as console video game systems are usually built from custom manufactured parts which cannot be replaced once broken.
Only screen shots (or non-digital videos) of video games could be preserved with the *Print-to-Paper Approach*, this does in no way preserve the dynamic look and feel of interactive content. This will for most applications not be a sufficient preservation strategy for video games.
Backwards Compatibility, the strategy to let consumers use games of earlier systems on newer generation models has been a successful commercial strategy since the third generation of video games (e.g. adapter to use Atari 2600 games on a Colecovision console (Herman 2001)). However once a manufacturer goes out of business, the games are no longer supported by a future system. As soon as the media is defective the contained video game is lost for preservation, too.
Code re-compilation for new platforms is one approach to *Migration* also known as *Source Ports*. Unavailable source code, the proprietary hardware of console video game systems and the usually very platform dependent code make it next to impossible to migrate a game to a new platform.
Another migration strategy is the approach to create a video of the game. Although all interactivity is lost, this gives a good representation of the original visual and audible characteristics of a game and can even be used as a future reference for recreating the game in an interactive way.
Simulation is another strategy that can be used for the preservation of console video games. Reprogramming a game might be possible for very early and simple games without knowing the original code. For more complex games and systems with more than just very few games this is either not possible or too costly compared to other alternatives.
For console video games *Emulation* may be the most promising solution, as most systems have to be well documented for video game software developers to write games. Only one piece of software (the emulator) has to be written to run the library of all games for a console system instead of having to deal with every piece of software for a given system.

Evaluation of Strategies

We evaluate various different solutions for preserving console video games. For this we used the Planets Preservation planning workflow for making informed and accountable decisions on a preservation strategy. The planning tool PLATO which supports this workflow as well the detailed results of this case study are available online via the PLATO homepage[3].
The setting that was used for the case study is a future library. It is expected to have a mandate similar to a national library to collect published digital games and make them available for the public over a long term. The major goals are an authentic look and feel of the preserved games, easy accessibility, stable solutions for a long term preservation, and high compatibility with all games for the systems.
To achieve wide representation of significant properties to be preserved, we chose three games for each of the video game console systems we wanted to preserve as sample records. We selected sample records with these considerations in mind:

[3] http://www.ifs.tuwien.ac.at/dp/plato/

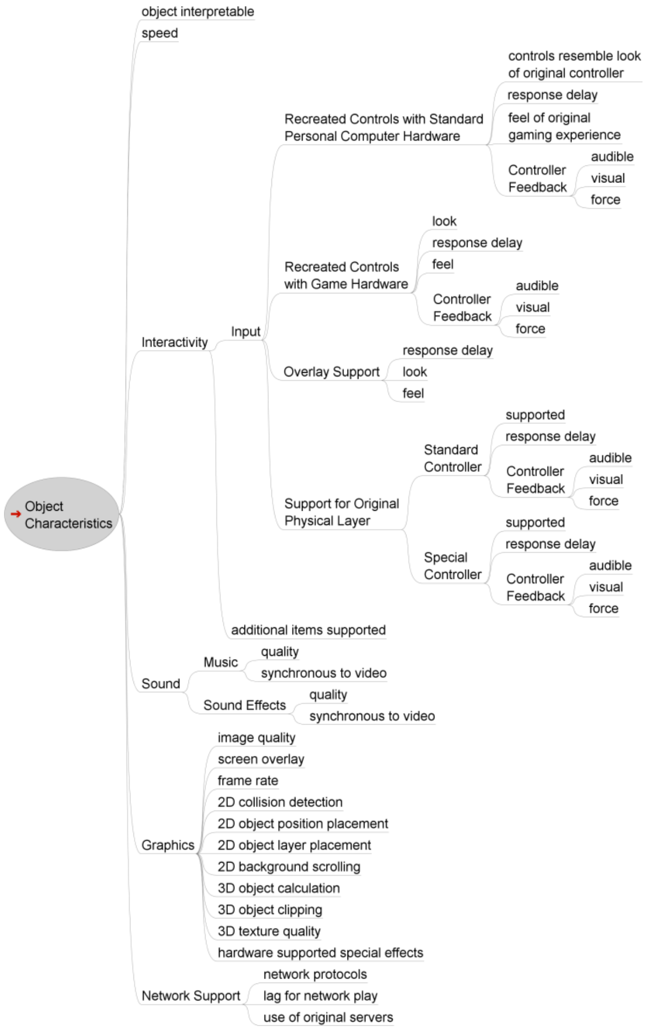

Figure 3: Object characteristics in the requirements tree.

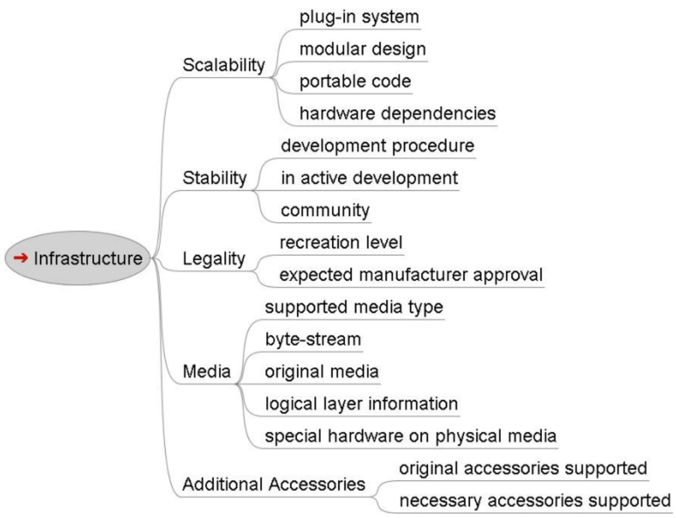

Figure 4: Infrastructure characteristics in the requirements tree.

- one major game for the system which most likely attracts the public's highest attention
- one game that uses special controllers to evaluate the feel aspect
- one of the games that make most intensive use of hardware-specific functions

The sample records chosen for the evaluated systems are shown in Table 1.
The requirements were collected and structured into an objective tree along the following five main categories (Figure 2):

Object Characteristics - The significant properties of video games are reflected in the visual, audible and interactive characteristics of the reproduced object. They are shown in the sub-tree in Figure 3. Visual aspects are divided into overall image impression as well as 2D and 3D features of the evaluated sample games. Sound aspects are divided into music and sound effects. Speed and the support of additional aspects like network support were tested as well. The typical scale that was used for measuring the degree to which an object requirement was met is:

- feature not applicable for this sample record
- feature not supported by the alternative
- feature supported but severe errors noticeable
- feature supported, errors noticeable but not affecting game-play
- no errors noticeable

The interactive requirements are used to measure look, feel and feedback not only for the use of standard PC components supported, but also for the support of special controllers and possible support for the original controls. Additional game items like overlays or off-screen game pieces have been considered in the requirements tree as well.

Process Characteristics - Part of this branch of the requirements tree is the configurability of a solution. It represents how easy it is to set configurations for a specific game and the system itself. Usability is the second sub-branch. It shows how straightforward and quickly games can be selected and if context specific data can be displayed with the game.

Infrastructure - This branch, depicted in Figure 4, gives the ability to measure information about how scalable and stable a solution is. The values in this part of the objective tree are used to collect data about the long term suitability of a solution. Details about the kind of development of a solution, the type of media supported and legal implications as well as expected support for a solution are considered.

Context and Data Characteristics - This branch describes the support of metadata of the game and necessary configuration options either with the solution or bundled with the game data.

Costs - This includes costs involved in retrieving data from the original media as well as costs for the preservation solution itself per supported game.

In total, the tree contains 81 leaf criteria. We set importance factors to weight these leafs (Figure 2). On the top level the highest value was assigned to the object characteristics. Infrastructure for a long-term sustainability as well as the support of metadata was also assumed to be of a high importance. Costs were considered as important as well. Process characteristics are of less importance, as it is not necessary to browse very quickly through lots of games.

Three experiments were defined: Different alternatives for one system (Super Nintendo Entertainment System, also known as Nintendo SNES) were compared to check for differences in the performance of representatives of the same strategy as well as differences between strategies. Different alternatives for systems from the same generation (Nintendo SNES, Sega Genesis, NEC PCEngine, SNK Neo Geo) were evaluated to find out if some systems are better supported than others. Finally different alternatives for systems from all generations (Coleco Telstar, Philips G7000, Sega MasterSystem, Nintendo SNES, Atari Jaguar, Sony PlayStation 2) were evaluated to compare alternatives as systems evolved, i.e. whether a single emulator can show favorable performance across a range of systems.

Depending on the systems selected for evaluation suitable alternatives were chosen (Table 1). We selected emulation and simulation (where available) strategies as alternatives as well as a migration to video for comparison. Backwards compatibility and the museum approach were ruled out because they are short term approaches only. Source ports were not considered as source code is in general not available for games on the evaluated platforms.

The experiments were developed for a defined hardware and software setting, ran and evaluated. For every leaf in the tree the measured values were recorded for the three defined experiments with the selected systems and sample records.

System	Alternatives	Sample Records
Nintendo SNES	ZSNES 1.51 SNES9X 1.51 MESS 0.119	Super Mario World Super Scope 6 Starfox
Nintendo SNES	video/audio grabbing with Hauppauge WinTV PVR and viewed with VLC 0.8.6c	Super Mario World
NEC PCEngine	MagicEngine 1.0.0. MESS 0.119	Bonks Revenge Gates of Thunder
Sega Mega Drive	Gens32 1.76 Kega Fusion 3.51	Sonic the Hedgehog 2 Darxide
SNK Neo Geo	NeoCD 0.3.1 Nebula 2.25b	Metal Slug Crossed Swords 2
Coleco Telstar	Pong 6.0 PEmu	Tennis
Philips G7000	O2EM 1.18 MESS 0.119	K.C. Munchin Quest for the Rings
Sega MasterSystem	Dega 1.12 Kega Fusion 3.51	Alex Kidd in Miracle World Space Harrier 3D
Atari Jaguar	Project Tempest 0.95 MESS 0.119	Doom Highlander
Sony PS2	PCSX2 0.9.2	Gran Turismo 3 Eye Toy Play

Table 1: Alternatives and sample records chosen for the experiments. All listed alternatives are emulation approaches except one migration video-taping approach for Nintendo SNES and simulation approaches for Coleco Telstar.

Evaluation Results

This section presents the results of the evaluation procedure. We start with discussing the strategies used for the three experiments and an analysis of the aggregated results. We point out strengths and weaknesses observed and compare the different approaches that were evaluated.

Analyzing the evaluation results showed that for the two dedicated emulators chosen as alternatives for Nintendo SNES the results were very similar. Both were able to produce the visual and audible characteristics very well, even for games with additional hardware on the game cartridges. No metadata for the games are supported, and the emulators are written in platform-independent code for speed reasons. The multi-system emulator tested was not able to start one game with additional hardware at all and serious flaws on the produced images were visible for other sample objects (Figure 5). Portability is high due to platform independent code. Cost characteristics are good for the multi-system emulator, as a lot more games (for other systems) are supported. With the migration video-taping approach it was possible to reproduce the look and sound perfectly, however the interactive element was lost. Metadata was supported by the file-format and the viewer that was used was open-source and platform-independent. Cost characteristics are very good for the video-taping approach as well, as it can be used for all games for all systems.

Similar results were observed for other systems of the same generation. Emulators were able to produce visuals and audible characteristics of the games well with bad infrastructure characteristics. For the multi-system emulators infrastructure characteristics were good, but not all games were playable.

The following results were observed for systems of different generations: The two simulators for Coleco Telstar were playable, but the feeling of the original paddle controllers was lost as only keyboard and mouse are supported. Infrastructure characteristics are bad, as none of the simulators is open source and development on both has been stopped. Support for Philips Videopac game pieces was not available in any of the emulators. The differences in infrastructure and costs between the multi-system and dedicated emulators are the same as observed before. Only one of the evaluated Sega MasterSystem emulators supported the 3D effect of one of the sample games. Atari Jaguar emulation was only partially working. The only available emulator able to play commercial games for the Sony PlayStation 2 was not able to produce in-game graphics for any of the sample objects. It did however support network functions

Figure 5: Screenshots of Super Mario World for the Nintendo SNES. Both pictures show the same scene. On the left is an image produced by ZSNES 1.51, on the right the same image as shown by MESS 0.119.

and provided the ability to use Sony's on-line service. Metadata was not supported in any case. Cost characteristics were better for later systems as more games were supported due to more available games per system.

According to the Planets preservation planning workflow the measured values were then transformed to a uniform scale of 0 to 5 with 0 being a value unacceptable for the use of an alternative and 5 being the best possible result. Values not applicable for a sample record or system are transformed to 5 to reflect an unchanged behavior compared to the original system.

The transformed values were then accumulated following the Planets preservation planning approach by weighted sum and weighted multiplication. This yields a ranking of the evaluated alternatives, reflecting their specific strengths and weaknesses. Three different emulators as well as the migration video-taping approach for preserving games for the Nintendo SNES video game console have been evaluated. The aggregated results can be seen in Table 2. Weighted Sum and Weighted Multiplication results for the alternatives separated into the top level branches of the requirements tree are shown in Figure 6. Minimal differences exist between the dedicated emulators. The multi-system emulator has better results in infrastructure, but lacks compatibility to certain games using special hardware on the cartridge. The video approach has very good characteristics in almost all categories, but has to be eliminated because of missing interactivity in the object characteristics. If lack of interactivity was not considered critical, this would have been the optimal solution. It can also be a suitable back-up strategy for quick access or to verify future emulators' visual and audible compliance.

For systems of the same generation as the Nintendo SNES the results were similar. Dedicated emulators were better with object characteristics whereas multi-system emulators had better results in infrastructure and costs.

Simulators for very early consoles (the Coleco Telstar) had different approaches. While one was trying to enhance the visuals, the other stayed true to the original. Dedicated and multi-system emulators for consoles prior to the Nintendo SNES were almost equally good in reproducing visual and audible characteristics with better results on infrastructure for multi-system emulators. The evaluated emulators for systems of the last three generations of video game consoles were either not able to play commercial games yet or had low compatibility.

Alternative	Sample record	WS Sample	Mult. Sample	Mult. Total	WS Total
ZSNES 1.51	Super Mario World Super Scope 6 Starfox	3,45 3,30 3,38	2,75 2,70 2,78	3,28	2,68
SNES9X 1.51	Super Mario World Super Scope 6 Starfox	3,43 3,28 3,38	2,82 2,68 2,78	3,31	2,70
MESS 0.119	Super Mario World Super Scope 6 Starfox	3,56 3,47 2,47	2,88 2,79 0,00	2,68	0,00
VLC 0.8.6c/MP4	Super Mario World	4,65	0,00	4,65	0,00

Table 2: Aggregated experiment results for preserving games for the Nintendo SNES (WS = Weighted Sum, Mult.= Multiplication). The highest values for each sample record as well as the highest ranked alternative are printed in bold.

Conclusions

In this work we used the Planets preservation planning approach to evaluate alternatives for the digital preservation of console video games. The same requirements tree was used to evaluate emulation as well as migration strategies. The case study showed that the Planets preservation planning workflow can be used to evaluate different strategies in one preservation planning process.

Furthermore it showed that the selection of sample records is especially crucial for emulation strategies and the archival of program behavior. While some sample records were reproduced flawlessly by an alternative, other sample objects could not be rendered at all by the same alternative. The results of the planning process are thus very dependent on the sample records. When doing preservation planning and considering emulation as a strategy, sample objects should be chosen with this fact in mind.

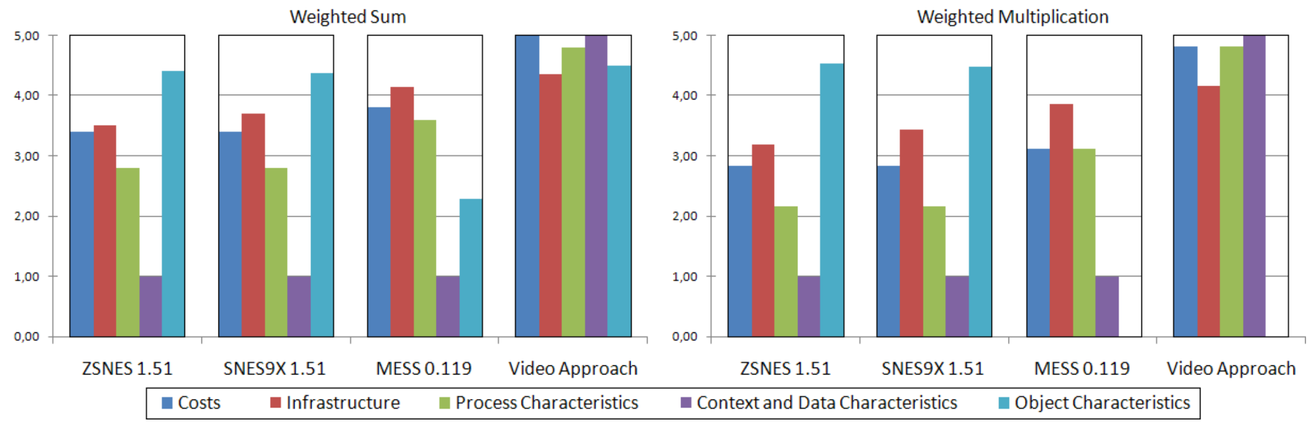

Figure 6: Aggregated results for the main categories in the requirements trees for Nintendo SNES preservation alternatives (weighted sum and weighted multiplication).

From the alternatives the migration to video approach showed very good results in most categories, but naturally completely failed in interactivity. The object characteristic results depended extremely on the chosen sample records with the evaluated emulators, however for the sample records with good object characteristics the interactive aspect of the games was still present.

The emulation alternatives had disadvantages in terms of infrastructure characteristics and metadata. Most emulators with high compatibility and good performance are not platform independent. Emulators supporting more than one system are usually modular and platform independent, but lack compatibility for certain games using special characteristics of the system. Metadata is not supported by the tested emulators, all expect raw binary streams of data. Compatibility and speed decreases dramatically for the emulation of modern systems. The feel aspect is only preserved well for games using standard controllers.

While all tested emulators were able to reproduce the original video or audio output to some extent, most are not usable without modification for digital preservation. Future work should focus on improving stability and metadata handling to provide a viable preservation solution for console video games. Work has also to be done in finding ways to recreating the original feel aspect of video games.

References

Becker, C.; Kolar, G.; Kueng, J.; and Rauber, A. 2007. Preserving interactive multimedia art: A case study in preservation planning. In *Asian Digital Libraries. Looking Back 10 Years and Forging New Frontiers. Proceedings of the Tenth Conference on Asian Digital Libraries (ICADL'07)*, volume 4822/2007 of *Lecture Notes in Computer Science*, 257–266. Hanoi, Vietnam: Springer Berlin / Heidelberg.

Farquhar, A., H.-Y. H. 2007. Planets: Integrated services for digital preservation. *International Journal of Digital Curation* 2(2).

Herman, L. 2001. *PHOENIX The Fall & Rise of Videogames - Third Edition*. Rolenta Press.

Jones, C. 2004. Seeing double: Emulation in theory and practice. The Erl King case study. In *Electronic Media Group, Annual Meeting of the American Institute for Conservation of Historic and Artistic Works*. Variable Media Network, Solomon R.Guggenheim Museum.

Lorie, R. 2001. A project on preservation of digital data. *RLG DigiNews* Vol. 5 (3). http://www.rlg.org/preserv/diginews/diginews5-3.html#feature2.

Rothenberg, J. 2000. *Using Emulation to Preserve Digital Documents*, Tech. Rep. Koninklijke Bibliotheek.

Slats, J. 2003. Emulation: Context and current status. Tech. Rep. http://www.digitaleduurzaamheid.nl/bibliotheek/docs/white_paper_emulatie_EN.pdf.

Strodl, S.; Becker, C.; Neumayer, R.; and Rauber, A. 2007. How to choose a digital preservation strategy: Evaluating a preservation planning procedure. In *Proceedings of the 7th ACM IEEE Joint Conference on Digital Libraries (JCDL'07)*, 29–38.

van der Hoeven, J., and van Wijngaarden, H. 2005. Modular emulation as a long-term preservation strategy for digital objects. In *5th International Web Archiving Workshop (IWAW05)*.

van der Hoeven, J.; Lohman, B.; and Verdegem, R. 2007. Emulation for digital preservation in practice: The results. *International Journal of Digital Curation* Vol. 2 (2):123– 132.

van der Hoeven, J.; van der Diessen, R.; and van en Meer, K. 2005. Development of a universal virtual computer (UVC) for long-term preservation of digital objects. *Journal of Information Science* Vol. 31 (3):196–208.

Webb, C. 2005. *Guidelines for the Preservation of the Digital Heritage*. Information Society Division United Nations Educational, Scientific and Cultural Organization (UNESCO) – National Library of Australia. http://www.unesco.nl/images/guidelines.pdf.