Implementing Preservation Strategies for Complex Multimedia Objects

Jane Hunter[1], Sharmin Choudhury[2]

[1]DSTC, Brisbane Australia
jane@dstc.edu.au
[2]ITEE Dept. University of Queensland, Brisbane Australia
sharminc@dstc.edu.au

Abstract. Addressing the preservation and long-term access issues for digital resources is one of the key challenges facing informational organisations such as libraries, archives, cultural institutions and government agencies today. A number of major initiatives and projects have been established to investigate or develop strategies for preserving the burgeoning amounts of digital content being produced. To date, the alternative preservation approaches have been based on emulation, migration and metadata - or some combination of these. Most of the work has focussed on digital objects of a singular media type: text, HTML, images, video or audio and to date few usable tools have been developed to support or implement such strategies or policies. In this paper we consider the preservation of composite, mixed-media, objects, a rapidly growing class of resources. Using three exemplars of new media artwork as case studies, we describe the optimum preservation strategies that we have determined for each exemplar and the software tools that we have developed to support and implement those strategies.

1. Introduction and Objectives

A number of major initiatives have been established to tackle the problem of preservation of digital content. The US Congress recently appropriated $100 million to the Library of Congress to establish a National Digital Information Infrastructure and Preservation Program (NDIIPP) [1]. The program has begun by reviewing the current state of digital preservation. In 2002, it commissioned a series of essays by recognized experts on the preservation of: Web sites, electronic journals, electronic books, digitally recorded sound, digital moving images and digital television. [2]. Other initiatives such as the CEDARS project [3], CAMiLEON [4], the National Library of Australia's PANDORA project [5,6], Networked European Deposits Library (NEDLIB) [7] and the OCLC/RLG Working Group on Preservation Metadata [8] have all been investigating strategies for the preservation of digital content. These initiatives have been focusing on three main strategies: emulation, migration and metadata - or some amalgam of these which relies on the encapsulation of the digital object with detailed preservation metadata. In addition, these initiatives have all been focussing on digital objects of one particular media type e.g., web sites (HTML), electronic journals, electronic books, digitally recorded sound and digital moving images. The work we describe here focuses on the problem of preserving composite digital objects consisting of multiple media types.

Only recently have a couple of mixed-media preservation initiatives emerged from arts organizations and museums, wanting to preserve multimedia, new media or variable media artworks in their collections. For example, *Archiving the Avant Garde* [9] is a collaborative preservation project between the Berkeley Art Museum and Pacific Film Archive (BAM/PFA), the Solomon R. Guggenheim Museum, the Walker Art Center, Rhizome.org, the Franklin Furnace Archive, and the Cleveland Performance Art Festival and Archive. The Guggenheim Museum has also established the Variable Media Initiative [10] which is inviting media artists, curators, and museum specialists to a series of meetings to brainstorm strategies for preserving specific case study works in the Guggenheim collection.

The main outcome (to date) of the *Archiving the Avant Garde* project has been a Variable Media Questionnaire [11], a set of descriptive elements to be completed by the artist and collector, outlining the parameters for recreating the work in a new medium once the original medium is obsolete, including whether such an option is allowed or prohibited by the artist. In addition, they are investigating the development of hardware and software emulators to enable the preservation of digital artworks, originally developed on hardware and software which has become obsolete.

Rothenberg [12] argues that emulating hardware is cost effective because, once a platform has been emulated, that emulator can be used to run any software written for that platform. However he also admits there are problems with emulation: future users will need to know how to run obsolete software, so we may need use-copies for non-scholarly access to documents; we may have to emulate more than hardware; and emulation requires an emulator specification and environment per platform, which is an ambitious goal. A number of other authors have also outlined the problems associated with using emulation as a preservation strategy [13]. Problems include cost, which may be prohibitive because of issues associated with intellectual property rights. David Bearman [14] also has problems with emulation, suggesting that it would not preserve electronic records as evidence even if it could be made to work and is serious overkill for most electronic documents. He argues that Rothenberg, a major proponent of emulation, is concentrating too much on the functionality of computer systems, and not enough on the actual content of records.

Although we believe that emulation may be the optimum approach for certain multimedia/new media objects - particularly those objects dynamically generated by software programs - we also believe that there exists a large class of multimedia objects for which emulation is not the best strategy. In particular, for those multimedia objects composed of multiple audio and video channels, images, text and even physical objects combined in some spatio-temporal structure, we propose an approach based on a combination of metadata and migration to high quality, platform-independent, standardized formats. More specifically we propose the following preservation steps:

1. Store the multimedia object's components in formats which are as high quality, standardized and platform-independent as possible (e.g., MPEG-2, MP3, TIFF) and the complete object in a simple structural markup such as SMIL [15] or HTML+TIME [16] rather than Shockwave, Flash etc.;
2. Record sufficient descriptive, structural, administrative and technical metadata to interpret and display the canonicalized object;
3. Use METS [17] (the Library of Congress's Metadata Encoding and Transmission Standard) to encapsulate the platform-independent digital object with its

descriptive, administrative, technical and structural metadata, into a complete preservation package;
4. Update the links to the required software/technical requirements as required;
5. Only reformat on request – not automatically and only migrate those objects deemed to be of significant value and hence requiring preservation.

In the remainder of this paper we investigate the optimum preservation strategies for a number of case studies and present the results of our investigations. The remainder of the paper is structured as follows. The next section describes related initiatives and projects and outlines how the work described here differs from and builds upon these approaches. Section 3 describes three case studies. Section 4 provides details of the actual software tools which we developed to support the identified preservation strategies and Section 5 concludes with a discussion of problem issues and future work.

2. Background

Most of the literature regarding digital preservation refers to three main strategies:
1. Technical Preservation - maintaining the original software, and sometimes hardware, of the original operating environment.
2. Emulation - re-creating the original operating environment by programming future platforms and operating systems to emulate the original environment.
3. Migration - transferring digital information to new platforms before the earlier one becomes obsolete.

The first strategy is not considered to to be a realistic or viable solution. The two main contenders have been emulation and migration. However recent research [3,4] recommends an amalgam of these strategies which relies on the preservation of both the original bytestream as well as detailed metadata which will enable it to be interpreted in the future. In the next subsections we analyse each of these approaches.

2.1 Emulation

Jeff Rothenberg [18,19], is the principle proponent of the emulation method - in which one saves not just the data but also the program that was used to create/manipulate the information in the first place. Rothenberg suggests that the only way to decode the bit stream would be to run the old program, which would require the use of an emulator. Several different methods for defining how an emulator can be specified have been suggested, but the feasibility of these methods has not yet been fully demonstrated.

The emulation approach suffers from two major drawbacks:
1. Saving the original program is justifiable for re-enacting the behaviour of a program, but it is overkill for data archiving. In order to archive a collection of pictures, it is hardly necessary to save the full system that enabled the original user to create, modify, and enhance pictures when only the final result is of interest for posterity.
2. The original program generally shows the data (and more often, results derived from the data) in one particular output form. The program does not make the data

accessible; it is therefore impossible to export the original data from the old system to a new one.

Lorie [20,21] suggests an approach which relies only partially on emulation by differentiating between data archiving, which does not require full emulation, and program archiving, which does. Lorie's approach relies on a Universal Virtual Computer (UVC). For data archiving the UVC can extract the data from the bit stream and return it to the caller in an understandable way, so that it may be exported to a new system. To archive a program's behaviour, emulation cannot be avoided and the UVC will emulate the current computer when interpreted on a future one.

2.2 Migration

Migration is the most commonly applied approach for digital preservation. It involves converting a document from its original format into successive subsequent formats as each previous format becomes obsolete. The disadvantages of migration are that it is highly labour-intensive and that in some situations, it may either corrupt or alter the appearance, structure, meaning or behaviour of a digital resource. The advantage is that in the majority of cases it extends the longevity of a digital resource, at least until the new format becomes obsolete.

The CAMILEON project has developed an alternative approach, called *Migration on Request* [22]. The investigators claim that by maintaining the original bytestream along with a tool to migrate the object at the point of use, the preservation strategy can be more accurate and cost effective. However the task of actually writing the migration tool may be extremely difficult, time consuming and expensive and many different tools may need to be developed.

2.3 Preservation Metadata

Most metadata initiatives (Dublin Core, MPEG-7, IMS) have focussed on facilitating resource discovery through standardized resource descriptions. Although such metadata standards are important to avoid a completely chaotic repository of information on the Web, they do not guarantee continual long-term access to digital resources. Hence a number of initiatives have been focussing on the use of metadata to support the digital preservation process. Such initiatives include: Reference Model for an Open Archival Information System (OAIS) [23], the CURL Exemplars in Digital Archives project (CEDARS) [3], the National Library of Australia’s (NLA) PANDORA project [5], the Networked European Deposit Library (NEDLIB) [7] and the Online Computer Library Centre/Research Libraries Group (OCLC/RLG) Working Group on Preservation Metadata [8]. These initiatives rely on the preservation of both the original bytestream or digital object, as well as detailed metadata which will enable it to be interpreted in the future.

The preservation metadata provides sufficient technical information about the resources to support either migration or emulation. Metadata can facilitate the long-term access of the digital resources by providing a complete description of the technical environment needed to view the work, the applications and version numbers needed, decompression schemes, other files that need to be linked to it etc.

However associating appropriate metadata with digital objects will require new workflows and metadata input tools at the points of creation, acquisition, reuse, migration etc.. This will demand effort the first time a particular class of digital resource is received into a collection. However assuming many of the same class of resource are received, economies of scale can be achieved by re-using the same metadata model and input tools.

The Library of Congress's Metadata Encoding and Transmission Standard (METS) [17] schema - provides a flexible mechanism for encoding descriptive, administrative, and structural metadata for a digital library object, and for expressing the complex links between these various forms of metadata. We believe that it may provide a good approach for encapsulating the complex preservation metadata required by multimedia digital objects, such as new media artworks, but that certain extensions to the METS schema may be required. We investigate this hypothesis and possible extensions to METS in sections 3 and 4.

2.4 Our Approach

We believe that no single approach is the right one. Each object or class of objects needs to be evaluated on a case-by-case basis and in many cases, the optimum approach will be some combination of emulation or migration together with preservation metadata and will involve the use of METS to wrap the canonicalized digital object and its metadata within a preservation package. However we do believe that optimum storage formats and metadata schemas can be determined for specific classes of objects and that the development of metadata input tools (based on these schemas) and their integration into workflows will facilitate the long term preservation and archival of complex multimedia objects. In the next section we test this hypothesis by considering the optimum preservation strategies for three different exemplars of new media artworks and the software tools which could support the determined strategies.

3. Case Studies

We decided to use new media artworks as the case studies for analysing multimedia preservation. This genre represents a significant preservation problem for the following reasons:

- They often comprise a highly heterogeneous mix of many media types: images, video, audio, text, hyperlinks, programs and physical objects;
- They are often highly proprietary - developed on all sorts of hardware platforms using old or eclectic combinations of software;
- They are often fragile and have a very high obsolescence rate;
- Standards are not employed and best practice guides for artists, curators or collectors rarely exist or not used if they do;
- They are often part of a travelling exhibition, requiring frequent deconstruction and reconstruction;
- They often include an element of randomness, chaos or dynamism due to uncontrollable real-time environmental input e.g., Ouija 2000 in which the planchette on a Ouija board is controlled by internet users;

- Art galleries and Museums of Contemporary Art are collecting them in greater numbers and they are often expensive or of significant cultural value.

In the next three sub-sections we consider the preservation of three different types of newmedia art:

1. *Verbum Interactive* - an interactive digital art magazine on CD-ROM;
2. *Eurovision* - a video artwork on VHS; and
3. *The elements* - a new media artwork by Nam June Paik comprising physical objects combined with video monitors and audio speakers in a particular layout.

3.1 Verbum Interactive

3.1.1 About Verbum

Verbum Interactive is described as a digital art and design CD ROM Magazine. In fact it is claimed to be the world's first fully integrated multimedia magazine. Verbum Interactive combines text, sound, graphics, animations, talking agents, video and music, accessible via a point and click interface. Two CDs make up the magazine: the first CD features stories with on-screen and printable text, sound, video clips and sample multimedia files. The second CD is an interactive panel discussion between six industry leaders on the state of the multimedia industry.

3.1.2 The Problem

Verbum Interactive was published in 1991. This edition was developed on a Macintosh Classic and required very specific system configuration to function. When the Macintosh Classic became obsolete so did this edition of Verbum Interactive. The contents of the two CDs became inaccessible and this historically important inaugural interactive multimedia magazine became lost despite the fact that the physical storage medium, the CDs, have not deteriorated.

As no step-wise migration had taken place before the contents of the CD became inaccessible, migration could not be performed. Reinterpretation was also not an option since there was no information regarding the structure of the work or links to the various components of the work to enable reconstruction. This highlights the role that metadata can play in preservation. If preservation information had been recorded, including the location of the various components of text, images and other multimedia files and more importantly the information regarding the structure of the work, then it may have been possible to re-create the work on the latest platform with the original content. However the lack of metadata meant that the only strategy available to us was to attempt to play the CDs on an emulated Macintosh.

3.1.3 The Preservation Strategy

The emulator which we used was the Basilisk II, an Open Source 68k Macintosh emulator which enables you to run 68k MacOS software on any computer. However, a copy of MacOS and a Macintosh ROM image was required in order to use Basilisk II [24]. We were able to access approx. two thirds of the original content of Verbum using Basilisk II. Most of the problems that arose were in relation to the first CD. The second CD appeared to be fully accessible. The problems we encountered included:

- When the emulator was set to emulate a MAC OS with optimal setting for the two CD then the animated graphics interfered with the emulation software and the emulator froze. With less than optimal setting many of the graphics in the CD would not work.
- Certain parts of the first CD could not be accessed because the emulator is not a perfect or complete emulation of the MAC OS system.

An interesting point to note is that Verbum Interactive does contain some information that can be used to reconstruct the CDs, but because the data is stored on the CDs the information is also rendered inaccessible because the CD is inaccessible. Thus it makes sense to store the preservation metadata separate to the actual content and to link or point from the metadata to the content.

3.2 Eurovision

3.2.1 About Eurovision

Eurovision [25] is a video artwork by Linda Wallace, completed in March 2001, recorded as a PAL format video of length 19.2 minutes. Using video compositing software, Linda Wallace has combined four sequences from the Eurovision song contest with footage from Bergman and Godard films, a Russian documentary about the space race from the 50s/60s, images from the Louvre and icons of the Madonna, with a background music track and overlaid text - in a multi-framed video stream.

3.2.2 The problem

Currently there is no problem accessing this work via any VCR which supports PAL. Ancillary contextual information (metadata) is also available via the associated web site [25]. However with video cassettes fast becoming superseded by DVD players and the indifferent durability of magnetic tapes in the long run, there is a good chance that Eurovision will not be viewable in years to come unless refreshing (transfer to a better physical storage) and migration (reformatting to a high quality, standardized format e.g., Motion-JPEG or MPEG-2 (HDTV)) steps are taken.

3.2.3 The Preservation Strategy

Besser [26] and Wactlar et.al. [27] have both proposed similar approaches to the preservation of moving image materials. Both groups propose the digitisation of the film/video in a high quality standardized format (e.g., Motion JPEG or HDTV-quality MPEG-2) and storage on RAID storage systems, which are periodically refreshed. In addition, both assert that the recording of associated metadata is essential for ensuring long-term accessibility to moving image content.

MPEG-7, [28], the Multimedia Content Description Interface, is a standard developed by the Moving Pictures Expert Group (MPEG), a working group of ISO/IEC. Its goal is to provide a rich set of standardized tools to enable both humans and machines to generate and understand audiovisual descriptions which can be used to enable fast efficient retrieval from digital archives (pull applications) as well as filtering of streamed audiovisual broadcasts on the Internet (push applications).

Although MPEG-7 provides a very comprehensive set of description tools, to enable the creation of (XML) descriptions of multimedia content, it does not support the preservation needs of moving image content, which requires metadata such as:

- Contextual information provided by the artist e.g., the meaning behind the work, how it was created, how they would like it displayed etc.
- Types of reformatting, refreshing, preservation actions permitted by the artist/owner;
- Details of refreshing and migration events.

Some of this metadata may be provided in the future by MPEG-21, the Multimedia Delivery Framework [29] which aims to provide a framework to enable transparent and augmented use of multimedia resources across a wide range of networks and devices to meet the needs of all users. However until the MPEG-21 standard is final and complete, the extent to which it will satisfy the preservation metadata requirements of moving image content, will remain fuzzy. The Library of Congress Audio-Visual Prototyping Project has also developed a draft set of extension schemas to use within METS for encoding preservation metadata specific to audiovisual content [30]. The additional metadata is primarily technical metadata (specific to audio, images, video and text e.g., sampling rate, compression codec etc.) for both the current object and its source plus details of reformatting and migration events.

Until MPEG-21 is available, the optimum approach to capturing the preservation metadata for Eurovision would be to use the LoC's Audio-Visual Prototyping Project schemas for video [30] but further extended with some additional metadata specific to artworks, such as the artist's intention and perspective, technique, tools used and their views on how the artwork should be installed and screened and which preservation strategies are permissible. The Variable Media Questionnaire [11] could be used to provide this additional set of artwork-specific metadata elements. The complete set of metadata elements and links to the various digital components would be stored within a METS container.

3.3 *The elements*

3.3.1 About *The elements*

The elements by Nam June Paik (), is a typical example of a large class of new media artworks [32]. DVD players stream multiple synchronized audio and video streams to a number of television monitors and speakers arranged in some artistic juxtaposition with physical artefacts in a real gallery space. In *The elements*, Nam June Paik has set six television monitors into an oriental red lacquer cabinet and plays video footage featuring early Hollywood film stars alongside avant-garde artists and rapid sequences of images of the natural world.

3.3.2 The Problem

New media artworks such as *The elements* are notoriously difficult to install or transport. They rely on a large set of fragile physical and digital components with complex interdependencies and physical, spatial and temporal relationships which need to be satisfied in order to maintain the integrity of the artwork according to the artist's wishes. The problem is one of ensuring that all of the metadata which is required to recreate the artwork has been precisely recorded and that the various components do not degrade or alter with time or during refreshing or migration steps.

3.3.3 The Preservation Strategy

For complex mixed-media artworks such as *The elements* which are composed of multiple audio and video channels, images, text and even physical objects combined in some spatio-temporal structure, we propose an approach based on a combination of metadata and migration to high quality, platform-independent, standardized formats. More specifically we propose an approach based on the five preservation steps described at the end of Section 1. In order to ensure that all of the relevant metadata is recorded, an analysis of the workflow from content creation to acquisition to exhibition to archival to re-use and preservation was carried out. *Figure 1* illustrates the typical life cycle of a new media artwork and the kinds of metadata which are acquired/modified at each stage. Based on this analysis of the content and metadata workflows and the proposed preservation approach, we were able to determine an optimum metadata schema to support the preservation needs of new media artworks such as the Elements. This is available at: http://metadata.net/newmedia/schma.xsd.
A summary of the key extensions to METS are listed below:

- Descriptive Metadata
  - Dublin Core Metadata Initiative
  - Guggenheim Variable Media Questionnaire
- Administrative Metadata
  - Technical schemas proposed for use in the Library of Congress Audio-Visual Prototyping Project
- Structural Metadata
  - SMIL 2.0

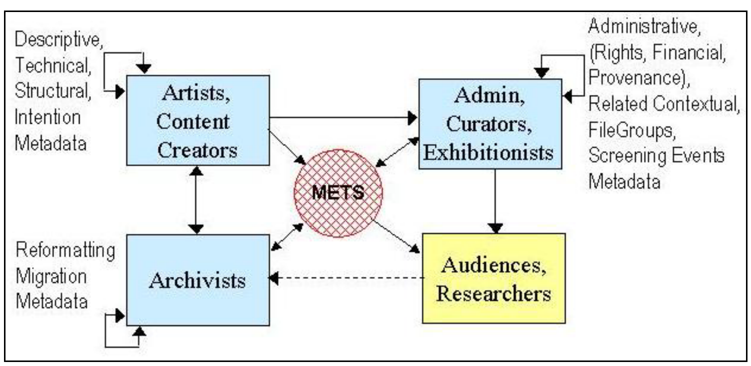

Fig. 1. Typical Metadata Workflow associated with Multimedia Artworks

Once the schema had been designed, the next step was to develop actual metadata input tools to facilitate the recording of preservation metadata, at the points of creation, acquisition, reuse, migration etc. The next section describes the metadata input tools which we've developed specifically to support the preservation of new media artworks but which can be applied more broadly to complex mixed-media objects from any domain.

4. Software Tools for Inputting Preservation Metadata

Both a stand-alone Java application and a JSP (Java Server Pages) version of the metadata input tools were developed. The application consists of a set of metadata input forms, constrained by the underlying XML Schema, which can be partitioned into four categories:

1. Descriptive and presentation metadata;
2. Purpose and intent metadata;
3. Preservation metadata; and
4. Digital Object Definition and Structural metadata.

4.1 Descriptive and Presentation Metadata

Descriptive metadata consists of the DCMES e.g., Title, Creator, Subject, Description etc. For the “Type” of a newmedia artwork, we have used the classifications developed by the Guggenheim Museum:

1. *Installation*: this form of artwork has physical objects, such as a rocks or flowers, as part of a piece;
2. *Interactive*: artwork that requires audience interaction.
3. *Reproduced*: artwork that can be reproduced from a master.
4. *Encoded*: born-digital works of art.
5. *Networked*: digital artwork that is dynamically created using a network.

The chosen *Type* then determines the presentation and installation metadata. The descriptive metadata will be used for search and retrieval and the presentation/installation metadata will be used to set up the artwork for exhibitions. *Figure 2* illustrates the description metadata input tool.

4.2 Purpose and Intent Metadata

This type of metadata is concerned with capturing the intention of the artist when he/she created the artwork. It is important to capture this information to ensure that the key message is not lost or corrupted during the preservation process. We extended the METS schema to include specific tags to support this. *Figure 3* illustrates the metadata input form that collects this information.

4.3 Preservation metadata

The preservation metadata is designed to gauge the willingness of the artist to have their work preserved, the kinds of preservation methods permitted and the extent to which the artwork may be modified. *Figure 4* illustrates the metadata input form for *Preservation* metadata.

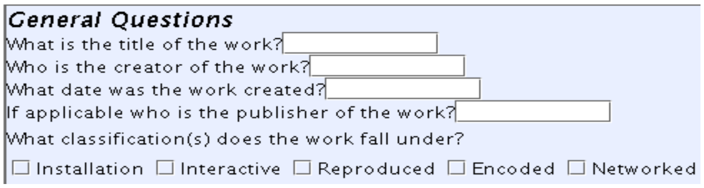

Fig. 2. Dublin Core Metadata Input Form

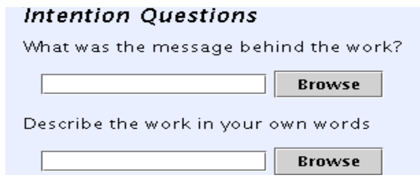

Fig. 3. Intent Metadata Input Form

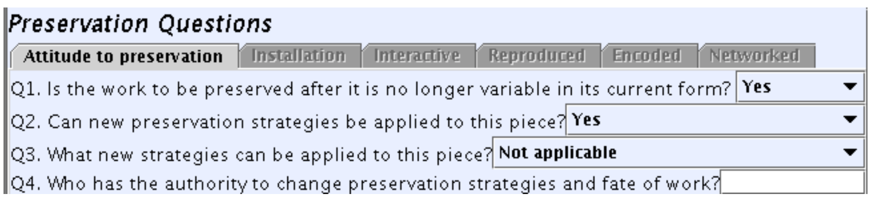

Fig. 4. Preservation Metadata Input Form

4.4 Specifying the Digital Objects Definitions and Structure

There are two components to the structural metadata: multimedia object definition metadata and overall structural metadata. The multimedia object definition metadata is required for each component of the artwork. This includes the format of the digital object, the compression characteristics and details of the software that was used to create the media object. This data will be used to migrate the multimedia objects to the current standard. The extensions to METS for encoding preservation metadata specific to audiovisual content [30] were used. *Figure 5* illustrates the input form.

We believe that SMIL 2.0 [15] is capable of providing a simple platform-independent XML-approach to specifying the structure of the artwork as a whole. Because of its simplicity, human-readability and platform-independence, it is preferable to application-dependent formats such as *Director*, *Acrobat, Shockwave* or *Flash*. Rather than build our own SMIL editing tool to specify the object's structure, we have chosen to invoke an existing SMIL authoring tool, *Fluition*, by *Confluent Technologies*, [31] from within our Java application.

Users specify the location of the digital objects and their temporal and spatial layout relative to each other by defining regions and attaching the digital objects to them. When the specification is complete, users have a choice of either saving both the structural metadata and a digital version of the object to SMIL or HTML+TIME. *Figure 6* illustrates the structural specification of *The elements*.

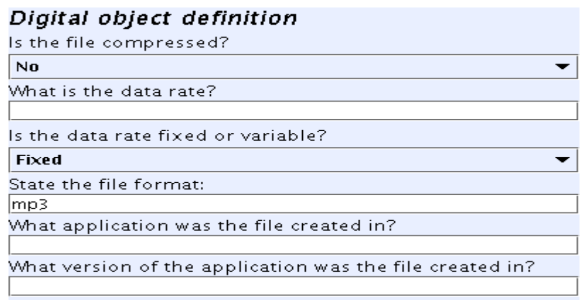

Fig. 5. Digital Object Definition metadata form for an audio object.

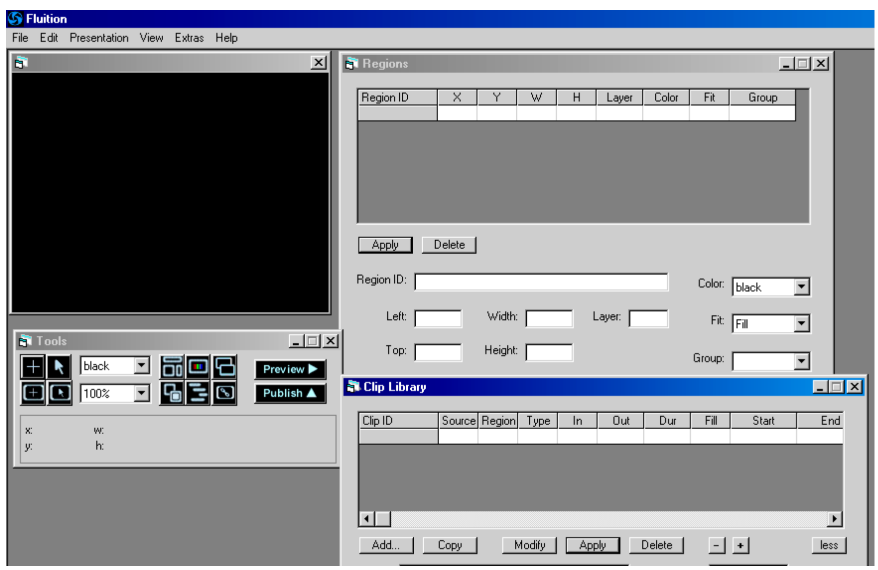

Fig. 6. Specifying Structural Metadata using *Fluition*

5. Conclusions and Future Work

In this paper we have proposed a new approach to the preservation of mixed-media objects, based on a combination of reformatting, metadata, encapsulation and migration. We evaluated the feasibility of this approach by investigating the preservation options for three case studies - exemplars of new media artworks. From the analysis of the case studies, we concluded that although our proposed approach is not the optimum for all mixed-media objects, it is the best strategy for a large subset - those objects consisting of images, video, audio, text and physical objects combined in some spatio-temporal structure or format.

We then determined the optimum metadata schema and tools which could be developed to support and implement this preservation strategy and set about building them. The tools are a combination of metadata input and structural specification tools - the outcome is an XML file which is conformant with the metadata schema based on METS, with extensions to support the audiovisual nature of the content and which uses SMIL for the structural specifications.

We believe that the preservation approach which we've described here offers the following advantages:

- Storage of the preservation metadata in XML ameliorates the potential problem of database redundancy;
- The approach is relatively simple and it works for a large class of multimedia objects;
- The metadata input tools need only be developed once but will apply to large sets of objects;
- It not only preserves the artworks but also provides an accurate digital reproduction which will provide remote visitors with access to an online version of the exhibition.

The next step is to integrate the metadata input tools into workflow design tools and then to link registries of software version releases to preservation metadata repositories in cultural institutions. It is intended that an automatic migration tool will be developed, that will use the object specific metadata to greatly streamline the migration process and hopefully extend the life of many valuable and culturally significant multimedia objects and artworks, which are currently in real danger of becoming obsolete or not viewable.

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References

[1] National Digital Information Infrastructure and Preservation Program, http://www.digitalpreservation.gov/ndiipp/

[2] Building a National Strategy for Preservation: Issues in Digital Media Archiving, commissioned for and sponsored by the National Digital Information Infrastructure and Preservation Program, Library of Congress, April 2002, copublished by the Council on Library and Information Resources (CLIR), ISBN 1-887334-91-2 http://www.clir.org/pubs/reports/pub106/contents.html

[3] CEDARS, CURL Exemplars in Digital Archives http://www.leeds.ac.uk/cedars/

[4] CAMiLEON http://www.si.umich.edu/CAMILEON/

[5] PANDORA http://pandora.nla.gov.au/

[6] National Library of Australia, Digital Archiving and Preservation at the National Library http://www.nla.gov.au/initiatives/digarch.html

[7] Networked European Deposits Library (NEDLIB) http://www.kb.nl/coop/nedlib/

[8] OCLC/RLG Working Group on Preservation Metadata http://www.oclc.org/research/pmwg/

[9] Archiving the Avant Garde http://www.bampfa.berkeley.edu/ciao/avant_garde.html

[10] Guggenheim Museum, Variable Media Initiative
http://www.guggenheim.org/variablemedia
[11] Guggenheim Museum, Variable Media Questionnaire
http://three.org/ippolito/variablemedia/var_questionnaire_beta.html
[12] Jeff Rothenberg, Avoiding Technological Quicksand: Finding a Viable Technical Foundation for Digital Preservation, Washington, D.C.: Council on Library and Information Resources. 1999
http://www.clir.org/pubs/abstract/pub77.html
[13] Stewart Granger, "Emulation as a Digital Preservation Strategy", D-Lib Magazine, Vol 6 No. 10, October 2000 http://www.dlib.org/dlib/october00/granger/10granger.html
[14] David Bearman, "Reality and Chimeras in the Preservation of Electronic Records", D-Lib Magazine, Vol 5, No. 4, April 1999
http://www.dlib.org/dlib/april99/bearman/04bearman.html
[15] Synchronized Multimedia Integration Language SMIL 2.0, W3C Recommendation 7 August 2001 http://www.w3.org/TR/smil20/
[16] Timed Interactive Multimedia Extensions for HTML (HTML+TIME) Extending SMIL into the Web Browser http://www.w3.org/TR/NOTE-HTMLplusTIME
[17] METS Metadata Encoding and Transmission Standard http://www.loc.gov/standards/mets/
[18] Jeff Rothenberg: Ensuring the Longevity of Digital Documents. Scientific American, 272(1), January 1995.
[19] Jeff Rothenberg, An Experiment in Using Emulation to Preserve Digital Publications, RAND-Europe April 2000, published by The Koninklijke Bibliotheek, Den Haag
http://www.kb.nl/coop/nedlib/results/emulationpreservationreport.pdf
[20] Raymond Lorie, A Project on Preservation of Digital Data,
http://www.rlg.org/preserv/diginews/diginews5-3.html#feature2
[21] Raymond Lorie, The UVC: A Method for Preserving Digital Documents - proof of concept (2002) http://www.kb.nl/kb/ict/dea/ltp/reports/4-uvc.pdf
[22] Mellor, P, Wheatley, P, Sergeant, D., "Migration on Request : A practical technique for digital preservation" ECDL 2002. http://www.si.umich.edu/CAMILEON/reports/migreq.pdf
[23] OAIS Resources http://www.rlg.org/longterm/oais.html
[24] Basilisk. Basilisk II Official site. http://www.uni-mainz.de/~bauec002/B2Main.html
[25] Eurovision http://www.machinehunger.com.au/eurovision
[26] Howard Besser, "Digital Preservation of Moving Image Material", accepted for publication in: The Moving Image, Fall 2001, written March 2001
http://www.gseis.ucla.edu/~howard/Papers/amia-longevity.html
[27] Howard D. Wactlar and Michael G. Christel, "Digital Video Archives: Managing through Metadata", http://www.digitalpreservation.gov/ndiipp/repor/repor_back_archi.html
[28] MPEG-7 Overview, http://mpeg.telecomitalialab.com/standards/mpeg-7/mpeg-7.htm
[29] ISO/IEC TR 21000-1:2001(E) (MPEG-21) Part 1: Vision, Technologies and Strategy, MPEG, Document: ISO/IEC JTC1/SC29/WG11 N3939
http://www.cselt.it/mpeg/public/mpeg-21_pdtr.zip
[30] AV Prototype Project Working Documents, Extension Schemas for the Metadata Encoding and Transmission Standard, Revised February 2003.
http://lcweb.loc.gov/rr/mopic/avprot/metsmenu2.html
[31] Fluition, Confluent Technologies http://www.confluenttechnologies.com/fluition.html
[32] Queensland Art Gallery, "Nam June Paik's *The elements*" Asia-Pacific Triennial of Contemporary Art 2002.
http://www.qag.qld.gov.au/content/apt2002_standard.asp?name=APT_Artists_Nam_June_Paik