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Abstract

This report describes the research conducted on emerging characterisation techniques. It details the most important research challenges, possible solutions investigated so far, and future directions of research.

Keyword list

Content and structure characterisation; New Media Art, Documentation; Interactivity, Interactive objects

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EXECUTIVE SUMMARY

Workpackage PC/5 deals with *Emerging Characterisation Technologies*. To this end, the work-package investigated emerging technologies from three perspectives, each of which is shortly summarised below.

Task PC/5.1 was centred on semantic technologies for content and structure characterisation, as well as metadata extraction. The focus of research was on context extraction from digital objects, along several different dimensions. The final goals are two-fold: first, to provide additional metadata, and secondly, to enable alternative, structured views for large collections of such digital objects.
Several sources of digital objects have been investigated, most prominently e-mail mailboxes and file systems. Context extraction methods along time, type, contributor and content dimensions were studied. As a direct result, three publications have been accepted to, and presented at scientific conferences related to digital libraries and context. In the course of this process, two experimental prototypes have been developed, a Java Desktop and a Web client.

The contribution in Task PC/5.2 focused exclusively on issues surrounding the documentation and preservation of new media artwork. While this challenge has been given extensive coverage within the art history and curatorial domain, the mainstream digital preservation community has made very few contributions. As a consequence, there is little evidence of the applicability or even relevance of mainstream preservation approaches, policies or tools. This appears to be a critical omission for two primary reasons. Firstly, initial exploration reveals several opportunities for deploying Planets and other mainstream tools within the new media artwork domain. Secondly, and of greater wider interest, relates to the extent to which the new media art challenges appear likely to become increasingly prevalent in much more widespread information contexts. Characteristics such as homogeneity, interactivity, temporality, variability and dialogue are typical of a great deal of new media art. However, they may soon break free of the shackles of this domain, and with examples such as social networking and the modern web indicative of future information trends, understanding how best to document and preserve such materials is a priority for future digital preservation in a very general sense.

During the work of Planets it became increasingly clear, that the separation between the properties of digital objects which reside in their persistently stored form and the properties which are inherent in the rendering software is not sufficiently clear. For some types of objects most of the information about the rendering can be found stored in the object (e.g. text files, image files) and the rendering software just interprets these properties.

On the other hand e.g. 3D objects stored in the resource files of a computer game describe the object but are put into context with the game environment, the player actions, the view-point or lighting only due to the game logic (=the rendering software). In this case it is not possible to deduce the rendering properties from a stored version of the object. Having the object rendered and comparing the outcome of rendering processes from different environments (e.g. the original and an emulated environment) makes it possible to find out if the interaction properties, i.e. the reaction of a digital object to interaction, stay intact.

Task PC/5.4 thus extended the Extensible Characterization Language (XCL) by the XCL Layout Processor, which is used to compare different renderings of a digital object and can thus help in comparing significant states of interactive objects. Significant objects in a screenshot taken from the rendering environment are identified and described in XCL. A tool that captures and replays input to the environments interaction can be applied to digital objects, and the outcome can be compared by taking a screenshot at a certain point in execution time. Using this approach, we show how the effects of interaction on a digital object can be measured comparing screenshots of the environment taken from a target state of the object.

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1. Introduction

This report summarises the activities related to emerging characterisation technologies, as part of the work-package PC/5. The work-package investigates emerging technologies from three perspectives. This report is therefore structured around the three tasks in this workpackage, each addressing a specific, challenging sub-problem for characterisation tasks and techniques.

First, it evaluates the possible application of technologies to uncover relationships between preserved content objects in order to improve access and understanding of their context. Secondly, it examines challenges that arise in the area of digital arts. This includes identifying enhanced characterisation methods as well as identifying key elements of the research agenda for future preservation work in this evolving area. Finally, it explores the possibility to describe interaction properties of a digital object abstractly and include their descriptions into the logic developed within the XCL, and evaluate this approach by the means of case studies.

For each of these approaches, this report gives a short overview on the related work and state of the art, and describes research topics and questions resulting thereof. Further, results achieved in the first year of activity are presented, followed by a short outline on future steps and directions.

2. Semantic technologies for content and structure characterisation

2.1 Short Overview

In this task, we investigated semantic technologies for content and structure characterisation, as well as metadata extraction. The focus of research is on analysing semantic, organisational and other relationships, and thus context, between digital information objects, with the goal of providing alternative structured views for large collections of such digital objects, and to enhance and augment existing meta-data.
Automatically establishing the context of creation, modification, and use of digital objects is an important aspect, as this context is essential for the interpretation of information entities, for establishing their authenticity as well as ensuring appropriate use. Thus, documenting this context of creation and use is an essential task in digital library and document management settings, for digital preservation as well as for retrieval tasks. Yet, context is notoriously difficult and labour-some to establish and document, and often missing or partially incomplete or incorrect when it has to be entered manually by the creator of the digital objects.

Therefore, we investigated several approaches to (semi-)automatically determine the creation and usage context of digital objects. Various aspects of context in different dimensions are automatically detected, and different views at multiple levels of granularity allow the extraction of the most relevant connections to other digital objects.

We can support a range of tasks by extracting context that characterises objects in more detail. One example is the task of receiving donations or bequests for ingestion into the collections of libraries or archives. So far, this process relies on predominantly manual work, supported partially by collection profiling tools that analyse the various file types, and assisting in browsing data storage media. This process could greatly be enhanced by characterising objects by contextual metadata, and visualising this context.
Another area would be disaster recovery, where after a loss of data due to hardware or software errors, a user wants to recover as many documents and files as possible from external/online sources. Those files should then be structured in a semantically meaningful way, which can be achieved by grouping the digital objects according to their contextual relations.

One important aspect was to provide a suitable visualisation of the objects and their context. One promising approach investigated was using concept from the data warehouses and online analytical processing (OLAP), which allows analysing (business) data, and to filter and aggregate the data among several dimensions, such as time, location, products, etc. We apply this concept to digital information objects, and use contextual similarities as the dimensions to group them by.

2.2 Research Topics and results achieved

Context exists in several different forms, ranging from a very low-level technical context in which the object was created, via its immediate context of use (people involved, the project or activity it is related to, etc.), to a wider sociological, legal or cultural context. All levels of context are of importance for the authentic interpretation and usage of a digital object.

However, we focus predominantly on the narrower focus of context that can be determined (semi-) automatically. Thus, major research questions include

- Which kind of source could be utilised for digital objects to be retrieved
- In which dimensions could relations between digital objects be established
- Which dimensions could be automatically extracted
- How to structure the information in each dimension, e.g. into hierarchies
- How could the contextual information be visualised

- Application scenarios where the contextual information can help in specific tasks

2.2.1.1 Object sources

We investigated mainly online object sources, such as personal e-mail mailboxes, and online collaborative tools, for example Wikis, BSCW[1], and versioning systems. All those object sources contain a rich set of metadata to be extracted for context establishment. E-mails contain information about the sending date, sender, and recipients, and other information such as the program used to compose the e-mail. Attachments in e-mails normally come along with an object type, and are embedded in the context of the e-mail they are attached to, and potential other attachments from the same e-mail. Further, e-mails might be filed in (hierarchical) folder structure, which indicates relationships between e-mails.

Wikis and similar online systems contain rich authoring and versioning information, i.e. for each version, the date, person and changes to a previous version are stored. Files attached to a page may share similar characteristics as e-mail attachments. Versioning systems also have rich data about creation, modification and authoring history of their holdings. While they are often used for storing source code of software, such systems may also be employed by writers and thus contain literature. Other collaborative systems, such as BSCW may additionally contain information about users accessing the system, and reading/opening specific documents. Further, this type of repositories may comprehend less collaborative systems, such as a user's blog.

Objects stored in a file-system might provide fewer details than the above mentioned repositories, but still a lot of information can be obtained. In most cases, either the file or the folder containing the file will bear a meaningful name, containing keywords, acronyms, and the like. Also, folders are very often organised in hierarchies. Further, file-systems generally store modification times, and sometimes creation and access times for each file. Generally, for every file, may it be part of a file-system or attached to an e-mail, specific tools allow obtaining a lot of information from metadata embedded in the file itself, such as titles or authors. File-systems may cover hard disc drives, as well as external media such as CDs or DVDs or online storage.

2.2.1.2 Context dimensions

We investigated methods of extracting context along the following dimensions:

- the time of object creation and modification
- the object type
- the people involved
- the content across different sub-categories, such as
    - the topic
    - the genre
    - acronyms, for example in project names

2.2.1.3 Time Dimension

The time-dimension can be defined very much in analogy to data warehouses, and could be structured as follows: 'hour of the day', 'day of the week', 'week', 'month', 'quarter', and 'year', with 'week' forming a separate aggregation branch in the hierarchy. Extracting the time dimension from digital objects is quite straight-forward: e-mails contain a sending date field, files in a file system have creation and modification dates, online systems such as Wiki or BSCW normally store at least an upload time. Moreover, many file formats have embedded metadata for creation or modification dates.

2.2.1.4 Object Type Dimension

For the object type, several categorisations are possible. One simple approach is to 'Internet media type', also known as 'MIME-type' or 'Content-type'. It provides an, even though limited, hierarchical

[1] Basic Support for Cooperative Work, http://www.bscw.de/english/index.html

order on digital objects, in the so-called (primary) 'type' and 'subtype'. Several repositories already provide object type information – online collaborative tools and e-mails generally provide MIME type information for attached files. Moreover, several tools exist to correctly identify the types from the object if this information is missing, e.g. when considering files in a directory.

The hierarchical structure defined by MIME is not very elaborate – it provides only two levels of hierarchy, and the primary type 'application' holds a huge spectrum of very different file types. A range of other characterisation tools that provide more detailed information of the characteristics of a digital object exist. Thus, another approach is to utilise for example the Digital Record Object Identification tool 'DROID', used in combination with the registry PRONOM. Then, a more elaborate hierarchical grouping of objects by their type can be achieved.

2.2.1.5 Contributors Dimension

The persons involved in creating, modifying or using digital objects indicate a relation between those objects, for example when the same group of people are working together on multitude objects. These groups constitute organisational units such as companies or departments, or orthogonal project teams.

The first step is to identify the persons involved in the object creation process and usage. This can be extracted from e.g. from meta-data embedded in files, or be derived from its storage system. E-mails store sender and receivers, which are subsequently also known for other digital objects attached to the messages (this information can be further utilised, as often the creator of a document is the initial sender of an attachment). Wiki pages have a complete change history, so do versioning systems such as CVS or Subversion.

One important step is to resolve multiple identities of the same person. This can be e.g. when using different e-mail clients with different personal name settings, or specific user names in a Wiki or other collaboration system. This resolution can be done with a set of heuristic rules, and may be manually improved by the user.

When the set of persons involved in the objects use are identified, we can construct a social network graph to visualise subsets of persons collaborating with each other.

Also, we can employ hierarchical clustering algorithms to explicitly derive several distinctive groups of people, and how they are further split in subgroups.

2.2.1.6 Content Dimension

Even though the content of an information object does not constitute context per-se, other information objects that share some similarities in their content with a specific object do form a context of that object. Content relation can be detected on many aspects – the usage of similar keywords, similar style, similar chunks, the same logo images, etc.

Different representations of textual content can be considered for analysis. These range from standard bag-of-words based full term indexing, to more advanced indexing techniques developed to identify specific patterns and types of content, such as names of persons, places, or dates.

As a special case of content similarity and vital aspect of an object's content, we can identify the 'within-project' relation. Digital objects created for and within the same project share a strong contextual relation, and automatically detecting them is thus a desirable goal. Projects may be characterised by dealing with a certain topic; however, that assumption might not hold for larger projects with several independent tasks. Thus, one approach to identify projects is simply to detect project or task names in e-mail content, file or folder names, … Very frequently, these names are in the form of acronyms, thus project identification may be reduced to acronym detection. Automatic acronym detection works fine in many cases, but to improve the results, users can manually provide black-list of terms that are in fact not project acronyms, and provide undetected terms in a white-list.

As for the contributors dimension, applying a hierarchical clustering we can then create a hierarchical dimension of related projects. Besides acronyms, we can generally use keywords detected by standard natural language processing tools, and many other content-related characteristics, such as style, layout, the usage of certain logos marking official documents, etc.

2.2.1.7 Combining Dimension

Each context dimension alone can be used by itself, e.g. to create metadata, and to filter and group objects along that dimension.

However, combining the isolated dimensions opens plenty new exploration and analysis possibilities. In data warehouses, data in the OLAP cubes is often visualised by means of a pivot table, which is a summarisation tool that can automatically sort and aggregate data from a table, and display the thus condensed information in a smaller, second table. Filters can be applied, roughly an equivalent to the ‘drill down’ concept in OLAP cubes.

We apply this concept to digital information objects. With such a tool at hand, users can in an interactive process quickly change the abstraction level of the data displayed, which can be an important aid to discover more complex contextual relations between the digital information objects.

2.2.1.8 Research prototype implementations

Two prototypical implementations of the concepts above have been implemented, and used in the evaluation in the publications resulting from this work package. The first such prototype is a Desktop Java application, while the second implementation is a web-based application. Both implementations have been primarily tested on personal email inboxes as the object source.

2.3 Publications

As a result of our work, three paper submissions were accepted for publication. The first paper covers an introduction to the challenges in automated context extraction, and detail the dimensions of context tackled. The second paper details the interaction and visualisations with context, while the last paper specifically focuses on one of the application scenarios.

Rudolf Mayer and Andreas Rauber. **Establishing Context of Digital Objects' Creation, Content and Usage.** In *Proceedings of the First International Workshop on Innovation in Digital Preservation (InDP 2009)*, Austin, TX, USA, June 2009.

Rudolf Mayer and Andreas Rauber. **Interacting with (Semi-) Automatically Extracted Context of Digital Objects**. In *Proceedings of the Workshop on Context, Information And Ontologies (CIAO2009),* held in conjunction with the European Semantic Web Conference (ESWC2009), Chania, Greece, June 2009.

Rudolf Mayer, Robert Neumayer, and Andreas Rauber. **Data Recovery from Distributed Personal Repositories.** In *Proceedings of the European Conference on Research and Advanced Technology for Digital Libraries (ECDL'09)*, Corfu, Greece, September 27 - October 02 2009. Springer Verlag.

2.4 Future steps

Future steps will focus on a semantic and qualitative analysis of the context dimensions currently considered. Moreover, there are plenty of other dimensions, or facets of already described dimensions, that are worth to consider. We will investigate to what extent extraction of these dimensions is possible, and how they can be utilised for context analysis.

Further, we will concentrate on implementing a proto-typical solution for extracting context from various sources, and allowing advanced interaction with it.

Finally, we want to investigate how much the above outlined application scenarios, such as object ingest into digital libraries, or disaster recovery, are achievable with our approach.

3. Digital art characterisation

3.1 Introduction

As pointed out by Bruce Wands [2.12], art communicates simultaneously on sensory, emotional, mental and spiritual levels. For digital varieties, these levels of impact and our comprehension of value are based not just on tangible characteristics, but on many additional contextual factors that may be permanent or transitory, localised or global and either physical or conceptual. Furthermore, those qualities considered intrinsic to works may be similarly difficult to characterise. Contemporary art typically establishes, encourages and demands greater dialogue than more traditional fruits of creativity. Whereas paintings or sculptures are largely consumed in a passive manner by audiences, digitally equipped installations promote a high degree of often distributed user involvement. Meaning can be less than self evident; unlike more traditional art where the materials used are largely subservient to the implicit message, it is commonplace within contemporary works for specific component materials to have tremendous implications for the overall interpretation. These issues are consistent across the digital landscape - complexities of interpretation, consumption and application are commonplace, and can be contrasted with physical materials with implicit, unambiguous usefulness. Numerous logical and physical layers must exist to support the presentation and understanding of digital information, which can be contrasted with analogue information, which exists largely atomically. More layers introduce more complex dependencies between those layers; any preservation action (to alter the format of a digital image component for example) can have implications far in excess of the intended extent of the intervention. Rinehart expresses this in terms of the separability of the physical and the logical, which in turn creates opportunities for variations of behaviour and performance [2.9]. While this can contribute towards the value and impact of the creative expression, it introduces difficulties to those seeking to characterise and preserve that which is definitive in and around a digital work.

A further complication is the often modular nature of contemporary installations, whereby components operate based on inputs from discrete linked systems. This introduces further levels of complexity for those seeking to ensure their longer term accessibility. Lynn Hershman Leeson's *Synthia* provides a good example, whereby an animated character onscreen responds physically to stock market data arriving from a live stream. Partially contextual, partially intrinsic, the flow of data must nevertheless be made persistent in order to enable the piece's correct exhibition. We see similar phenomena within the digital context more generally; applications and file formats are increasingly networked, and are more and more reliant on decentralised services. How we deal with the preservation challenges associated with maintaining third party services or user contributions is particularly challenging. Web archiving appears trivial when dealing with simple networks of linked, static web pages. When the relationships between scripts, users, web services, databases and rights management systems become more intricate and integral, preservation becomes less akin to photocopying and more like performing organ transplant surgery, with all of the risks that digital materials will be 'rejected' within their anticipated preservation environment.

From the conservator's perspective, documentation assumes a critical role. In those cases where art relies on bespoke, deteriorating materials, externally managed and originating services or a critical mass of community involvement there may be no way to ensure its availability. Nevertheless, the maintenance of appropriate documentation can assist conservation and preservation strategies, most notably offering opportunities to characterise value and express priorities for individual works. This can then inform the selection of subsequent conservation or restoration strategies, and ensure their consistency with creative intention. Gaby Wijers, the Dutch conservator of The Netherlands Media Art Institute, describes the perspective of the 'variable media approach', which argues that "the best way to preserve artworks in ephemeral formats, from stick spirals to video installations to Web sites, is to encourage artists to describe them in a medium-independent way, so as to help translate them into new forms once their current medium becomes obsolete" [2.13].

3.2 A Wider Applicability

Whereas the digital preservation community has sought to align its primary objectives with the challenges faced within traditional records management, archiving and librarianship domains, comparatively little work has concentrated on its relationship with art conservation and restoration.

The creative domain is increasingly coming to terms with art works with digital characteristics, and fraught with the accompanying issues of obsolescence and potential inaccessibility. However, these are comparable to many of the problems that have been faced for some time by conservators of contemporary art in a more general sense. For several years artists have combined unstable materials comprised of bespoke components. These have had often complex meaning, dependent on the status of disproportionately tiny characteristics. We have heard many times of the seemingly arbitrary way in which minimal technological disruption or loss can have catastrophic implications for access to digital materials. Likewise, a restoration process for contemporary art that replaces a material component with a seemingly equivalent alternative may fundamentally alter or detract from its creative value.

Contemporary art conservation and digital preservation have a lot in common. Digital materials are objectively more easily destroyed, or divorced from appropriate representation mechanisms (as good as destroyed) than their physical, analogue counterparts. Similarly, 'meaning' (more or less synonymous with 'significance') is increasingly difficult to trace within the digital context, as multi-media and multi-modality are increasingly visible fixtures across the landscape of information creation and consumption. Users' perceptions of elements within Internet web pages and their respective importance have changed throughout the platform's short lifetime. The Internet, once primarily a tool for supporting publication has evolved into a much more experiential phenomenon. Interactivity, initially an ancillary part of the web browsing experience, has become core. The culture of conversation between individuals and systems, facilitated with web based resources is now commonplace. Tools are being used in diverse, often experimental ways, even within mainstream digital contexts.

Perhaps the most notable common characteristic shared by contemporary art and digital content is in terms of immediacy of risk exposure. Paintings, sculptures, published manuscripts and books each enjoy a reasonable 'grace period' following their conception, within which one can assume their survival without intervention. This period offers relevant stakeholders plenty of opportunities to determine meaning, significance or value that must be maintained. In contrast, digital materials, like much contemporary art, demand often immediate action. Considerable onus is placed on speculative anticipation of future use, with often limited evidence available to reference in one's characterisation, and subsequent preservation action decision making.

Reflecting these similarities, we present an initial approach to new media art documentation that supports the explication of scalable, variable and relatable elements, while where possible maintaining the possibility of their exposure to more mainstream preservation resources such as DRAMBORA [2.8], Plato [2.11] and the Planets Testbed [2.1]. We reflect a philosophy popular among the art conservation community, and consider the documentation process as analogous to the conception of musical scores. Documentation is not itself the work or a surrogate of it, but instead intended to be a comprehensive reference resource to enable its recreation, reexhibition or reperformance at a later date. This implies elements of "physical preservation", such as migration of intrinsic media assets to more stable formats, or emulation of legacy software environments. In addition though it demands the contextualisation of the work, the definition of creative specifications and the explication of steps taken to conceptualise and deliver the work. Furthermore, there is an implicit assumption that new media will be variable, and prone to evolve to reflect the contextual variation that inevitably accompanies the passage of time.

3.3 Notably Applicable Previous Work

As a foundation to much of this work, the National Archives of Australia's approach to preservation has focused on the performance aspects of digital information [2.4]. Rather than considering things only in terms of bits, files, objects or collections their model presupposes that for every discrete item of digital information one can distinguish between elements of source and process. Source describes that which is ostensibly the physical or logical object itself. This will often be a computer file or encapsulated collection of files. But in isolation, and unlike analogue media forms such as books, photographs and paintings, their meaning is not self evident. Analogue media do operate within the same performance model, but required interpretative or representation processes are generally unified, ingrained and well understood. Assuming basic literacy, and comprehension of a particular text's language, we expect analogue content to be accessible and understandable. In order to make informational sense of digital content, there may be numerous associated requirements, characterised as software or hardware dependencies, or as semantic or contextual interpreters that assist usability and understandability of encoded materials.

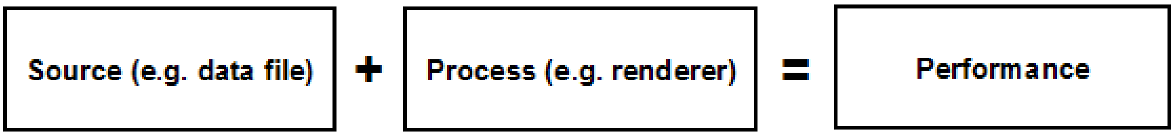

Figure 2.1: National Archives of Australia's Performance Model

With the Media Art Notation System (MANS) [2.9], Rinehart acknowledges the performance characteristics of new media art materials, and seeks to conceive implementation independent means of describing materials' value. The vocabulary is intended to be sufficient to describe objects, collections, events and activities, interrelationships, behaviours, choices, contingencies and variables. Like a musical score it is focused on supporting recreation of the work; its success depends on the avoidance of ambiguities that would prejudice the authenticity of any recreations. *Discretion* is a critical component of maintaining variable work. It equips curators to adapt works to reflect contextual changes over time, to implement appropriate preservation strategies and to determine what is and is not required to ensure the work's creative value remains consistent over time. Within MANS artists have greatest discretion to exercise choice (or sanction a default selection), with contributors and agents, hosts and owners, presenters, and finally the general public, having gradually less and less opportunity to inform the curation process.

A critical shortcoming of the MANS approach is its apparent prioritisation of *Physical* aspects of preservation, with less focus on the origins of particular information properties of value. Preservation must be focused on maintaining logical or functional elements (where function can be extended to encompass elements of creative impact, this is particularly true). Relationships between MANS' Parts and Resources should be made more explicit, in order to relate proposed preservation solutions (or, much more usefully, potential preservation risks) to both logical and physical aspects of the overall work.

It is critical that preservation planning is moored to both the tangible realities of a piece and its cumulatively realised expression, function or message. This critical dimension is best expressed in terms of significant properties. The InSPECT project [2.6] presents a workflow aimed at their identification. InSPECT adopts a terminological foundation quite traceable to that of MANS. Its FBS model (derived from Gero's Function-Behaviour-Structure Framework [2.3]) defines *Function* as broad purpose, *Behaviour* as a stakeholder's perceived outcome or consequence, and *Structure* as those elements of a given digital object that support a behaviour's realisation (significant properties). Stakeholder and object analyses demand engagement with diverse stakeholders and identification of functional facets of value. InSPECT does not prioritise the views of any individual stakeholder (unlike MANS) although it is suggested that within the artistic context the creator should enjoy greatest discretion for defining critical behaviours and properties.

3.4 Characterising New Media Art

3.4.1.1 Context

The primary purpose of recording contextual dimensions is to make explicit those external or situational influences that must persist or be recreatable to realise or perform a work and preserve original artistic intention. Context is distinct from implicit components, dependencies and stakeholder relationships, in that it may surround, influence and reflect either the global work (or in even wider terms whole collections) or just individual information facets. Many facets are represented as points on a continuum – variability and evolution of a work implies movement along this continuum, and reflects the different contextual properties that may still surround and legitimise a work. Each contextual dimension describes discrete or sliding scale characteristics and practical factors that influence them.

Context is distinct from content in terms of the extent to which it can be realistically preserved. We cannot hope to maintain every aspect of context. From even before a work's creation, at the moment an idea is first conceived by the artist, context is dynamic. In some respect one might consider context as the embodiment of much of the preservation challenge. Objects and their associated representation mechanisms may themselves change over time (for example, in the case of 'bit-rot'), but the greatest challenge for preservation professionals is keeping up with change that is wholly contextual, whether realised in financial, technological or cultural terms. This is almost always a reactive process, except in those niche cases where context is controllable. That which is beyond the control of the preserving agency is a good definition of context, and the best means of distinguishing it from content.

In this context, preservation requires the establishment (with the input of artists) of an acceptable spectrum for contextual deviation. For example, what spatial restrictions are tolerable on a particular installed piece? What opportunities are there to transfer content to new media devices? What wider contextual factors (for example a financial recession) must be documented and integrated within a work to maintain its meaning when those factors are changed and forgotten? In these respects the line between context and content (particularly objects' associated dependencies or process elements) may appear blurred; the preservation process demands the specification of that which is content, and that which is a relevant, but not integral contextual factor. Likewise, for each contributing factor, tolerable parameters and descriptions of associated documentation requirements should be made explicit.

3.4.1.2 Source

Components employed by new media artists exhibit little evidence of standardisation, and therefore the conception of a single vocabulary that is sufficient to encompass all possible component elements is difficult. We consider the component elements to resemble the source dimension of an information performance. Where objects' value is self-evident and has no explicitly defined associated process elements this can be made explicit, but such objects are rarely conceivable: even the most static object will have some kind of dependencies for its comprehension.

A problem may be that the level that components are conceived at may differ from the optimal level for addressing their preservation. A composite object like an Internet web page is a good example of something that may be created as a single whole but preserved as multiple discrete parts each with implicit preservation challenges and appropriate solutions. Documentation must support the greatest granularity of expression required to maintain the entirety of the work. For that reason, like with each dimension discussed here, the activity must be undertaken at the level of properties.

In InSPECT a component is defined as a unit of information that forms a logical group. Components consist of identifiers, descriptive information, associated function, a preservation level, relationships, and a specification registry entry detailing a third party resource that provides additional information about the component. While components are intended to be accompanied by some kind of process in order to realise an information performance there is little within the InSPECT work that makes explicit how significant properties of those processes should be recorded.

3.4.1.3 Process

When we speak of component dependencies within digital preservation we may instinctively dwell on issues of software and hardware. What plugins must be installed in a particular web browser to ensure that embedded video plays back correctly? What kind of display hardware boasts a sufficient contrast ratio to adequately represent blacks and whites? But there are also semantic and contextual dependencies that inform the appreciation of particular art works. Within the sphere of variable media art many such dimensions are implicit within the coverage of context above. A critical requirement is the definition of not only wider, relevant and globally applicable contextual factors, but also those that play specific roles in the interpretation and usefulness of source objects.

Clearly, the determination of significant properties of software is challenging - application of the Performance model is made especially so since software performance is usually considered analogous to data process, and a contribution to data performance. It can be argued that there is little value in considering software as a performance in its own right, instead simply acknowledging its role as process counterpoint to a data source within an overall information performance.

A natural starting point for considering associated process is the OAIS Reference Model [2.2], which describes the role of representation information in the interpretation of data objects, and their realisation as information objects. Representation information is required to lend understandability to data - while not tightly aligned with the concept of process within the performance model this seems a natural association, and is workable in most situations.

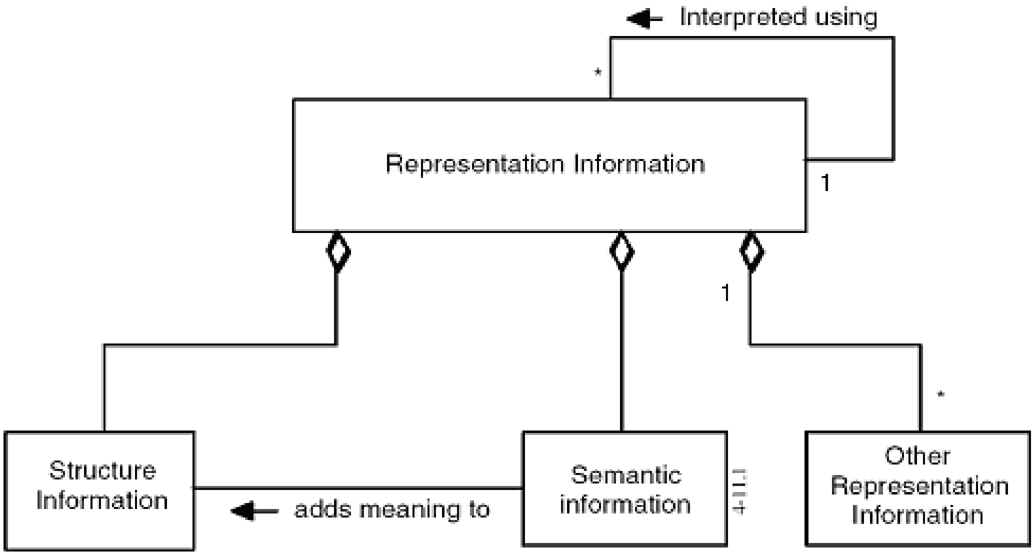

Figure 2.2: OAIS Representation Information Model

We can synonymise software performance and data's associated process. Its application to a data source yields a data performance. This is broadly akin to the role of representation information in converting a data object to an information object. The *JISC Framework for Software Preservation* [2.7], presents a four layer model for software that is roughly analogous to the Functional Requirements for Biblographic Records [2.10] model of Work, Expression, Manifestation and Items. The extent to which this approach is applicable to new media art preservation is unclear. In some respects the model is fairly applicable, and art works themselves often exhibit the same variety of layers of realisation. At a more granular level when we look to new media art to determine means of describing required process we might find the model less helpful. New media art software is frequently bespoke – in many cases it represents the unique creative development. Sometimes it represents both data source and process (in the case of executable art for instance). At some level of the technical realisation there is a more traditional software dependency, at the level of virtual machine, compiler or operating system for example.

3.4.1.4 Temporality

Frequently, the most distinguishing characteristic of new media art (as opposed to other forms of digital information) is its quite legitimate potential for variability. The *Variable Media Questionnaire* [2.5] is a tool intended to facilitate new media art preservation, by providing a structure within which artworks can be characterised and appropriate approaches conceived and associated. By making explicit the parts of new media art that are prone to change over time, or with implicit temporal variable qualities, it aims to equip practitioners to collaboratively affect their appropriate evolution. It is quite proper that the vocabulary should be expected to evolve over time to reflect emerging requirements and opportunities. This implies not only the static definition of a work at the time of its completion or exhibition but also a sliding scale of acceptability which respondents are encouraged to present to legitimise subsequent preservation interventions.

3.5 A Vocabulary for Preserved New Media Works

The vocabulary for Preserved New Media Works collates a complex set of information that may relate to multiple individual instantiations of a work across space and time. Likewise it is sufficiently loosely defined to support additional variability within the process of preservation. Our vocabulary is positioned firmly within the domain of new media art preservation. Instead of focusing on the description of materials 'in and of themselves' we look to conceive a description of the preserved new media work as a whole. This implies that some elements of preservation infrastructure become implicit within the work itself. While perhaps not part of the piece envisaged by the creator these become nevertheless integral to its ongoing survival. Naturally, as the artist's view takes on such critical importance within this domain, additions must be satisfactorily sanctioned. Failure to obtain such sanctions (which may in some circumstances be conferred by stakeholders other than the artist) immediately detracts from a piece's authenticity. For example, the unauthorised use of emulation to recreate a software-based installation may appear to retain many characteristics of a work, but must be sanctioned in order to ensure it remains compatible with the creative value.

3.5.1.1 Preserved New Media Work

At the top-most level of our information infrastructure we have the concept of a Preserved New Media Work. This has a number of sub-dimensions, which must be related and rationalised in order to determine preservation challenges and equip ourselves to satisfy them appropriately. It is at this top level that we associate descriptive metadata information, and other registration details that describe the work as a whole. There is value in presenting this information at the level of work, although further granularisation at the level of individual components and contextual elements enables more sophisticated and finely tuned recording, and associated preservation planning.

3.5.1.2 Functional Component

MANS is an attempt to apply the concept of musical scores to a new media context. Creator Rick Rinehart's goal is to present the preservation activity as a process supporting works' recreation, acknowledging its finite lifetime in any particular physical form. In truth, the approach has appeal in every preservation context. A critical foundation for this are means to describe both the intellectual object of preservation, and those physical material manifestations of that information. Both are sources, requiring further elucidation with the association of process, to realise an information outcome. Content within a new media art piece may be as potentially diverse as one could possibly envisage, including real world objects, digital media, and combinations of both. More critical than considering objects in tangible terms is their expression as measurable (and functional) properties, ideally in a manner that is agnostic to any transitory, non-specific implementation. MANS elects to approach preservation as an activity that practically focuses on tangible system components (*Resources*), with an expectation that their preservation will safeguard the more intellectually (or functionally) specific *Parts*. This seems short-sighted – we need not retain physical equivalence to ensure the sustainability of logical meaning. For example, it may be possible to replace multiple discrete media assets (e.g. still images, sound materials, interview transcripts) with a single subtitled video and retain every aspect of original information value. The message is the critical point at which persistence must be sought – the physical building blocks are merely means to that end.

Even where artists stipulate conditions that appear to concern only matters of physicality, we must interpret those in intellectual terms. If a particular model of display device must be used for example we must consider that in its functional terms (i.e., its creative significance), rather than interpreting it as a material requirement. We should not assume a 1:1 correspondence between material and intellectual components.

The functional component is best expressed in terms of properties, as described within the InSPECT significant properties framework. This affords a level of measurability that is required to validate preservation efforts, and to make explicit acceptable boundaries for variability which are an intrinsic part of especially these kinds of materials.

3.5.1.3 Version

New media works are dynamic and therefore may have multiple manifestations available simultaneously or along a time line. The version element provides a means to accommodate this dynamic quality, with the potential for multiple instances of a work which may vary but nevertheless represent the same conceptual piece. Although material aspects of the work may vary across versions the functional components (expressed primarily in terms of associated, and a bounded range of property values) will remain consistent.

3.5.1.4 Material Component

A complication facing the preservation community is that factors threatening our information often do not do so directly. Although the preservation goal is targeted on the sustainability of more intellectual or functional facets, it is often tangible and physical characteristics that are threatened by specific preservation risks (for example, the risk of file format obsolescence). This is not uniformly true – we also face challenges such as insufficiency of semantic representation information for example, but the disconnect demands an understanding of the interrelationships between each dimension.

We distinguish a work's functional and material character to support better preservation decision making. Material components are intended to encapsulate a physical, and, one would anticipate, transitory dimension of a work. Their availability is threatened by preservation risk, which demands our awareness of the relationship between risk and materiality. Having established such links, of greatest importance is their relationship with intellectual properties, and by extension function.

3.5.1.5 Component Dependency

Both material and functional components exhibit dependencies, and again we must make this relationship explicit within our vocabulary. Dependencies describe those facets of process (in the language of the Performance model) that must exist to support the realisation, from a content source, of an information performance. These may assume myriad forms, including technical or other infrastructural (most obviously software), procedural or contextual dependencies. Once more, these dependencies are expressed at the level of a preserved work, meaning that there are a number of examples included primarily due to the role they perform within the preservation process.

3.5.1.6 Work Context

Context describes factors that exist beyond the control of the preservation environment, but which contribute to either its function (and associated properties) or are necessary as dependencies to realise a material component's performance. Context is a critical dimension for documentation, since it cannot be manipulated directly by the preservation professionals. There is scope to absorb evidence of contextual elements into the PNMW as documentation, and these are encapsulated as material components.

3.5.1.7 Stakeholder

The diversity of roles and priorities that contribute to the creation, documentation, preservation and consumption of art hints at the complexity of the characterisation process. Artists themselves are most naturally assumed to be the best arbiter of that which has value within a piece. Likewise, they are often relied upon to sanction preservation interventions that may potentially prejudice its value. The Variable Media Questionnaire assumes the contribution of artists, with their creativity exploited to establish baselines for a work's preservation and future recreation. This is consistent with other approaches like the Modern Art: Who Cares? [2.14] documentation model, which incorporates a section used to contain or reference interviews and general information about the responsible artist.

It is critical that relevant agents are engaged with in order to negotiate preservation challenges in a manner consistent with the work's message. The artist's perspective at the point of a work's creation is uniquely compelling (notwithstanding possible collaborations from third parties or assistants), but once free of their creative process, the work and its creator are by no means synonymous, and the exclusivity of their relationship is no more.

The view that work and maker are not interchangeable appears to be broadly adopted. A piece's meaning is established by a curator with reference to the artist's contribution, not exclusively on the basis of it. Artists can contribute more information about a piece's origins, inceptions and assembly than any other. But they cannot claim sole knowledge of what it has become since leaving their custody. Art historians and curators are responsible for such interpretation. In the event of an artist's death or non-availability, it need not be the case that the associates, kin or estate of an artist are best equipped to comment on the meaning of his or her work. Nevertheless, many argue of the criticality of artist intervention at every stage of the conservation process, and this may be realised by reference to the results of initial dialogue, or through an ongoing conversation. Sometimes artists are unavailable to assist in the ongoing interpretation of meaning and of discrepancies between condition and meaning. On other occasions, artists adopt a far more participatory role within the conservation of their work. When the Dutch *Van Abbemuseum* displayed and approached to purchase Suchan Kinshita's work *Show*, the artist willingly discussed the piece's future preservation and replacement of its parts, and proposed that she write a set of instructions that would describe the parameters for the piece's installation and performance, and what discretion was available on the part of curators. Furthermore, she suggested the appointment of named trustees that would remain available to support the work in the event of threats to its integrity [2.14]. InSPECT's stakeholder analysis appears to assume a common level of influence from those associated with a given digital object, although it makes sense in the creative context to confer primary responsibility (if welcomed) to the artist, especially when little time has passed between its conception and the commencement of the characterisation and preservation processes.

The other broad dimension of stakeholder intervention is identification of preservation risk and challenge. For bespoke, highly complex technical materials this may presuppose the input of wider constituencies than simply curators. Technological contributors for example are very well placed to comment on information dependencies implicit within any code they have implemented for a specific work. Curators must assume primary responsibility for preservation risk awareness, although as described above this assumes a close understanding of the relationships between a work's tangible assets and softer facets of message and value, expressed as properties.

3.5.1.8 Information Property

Information properties are the focus of the preservation effort, and are potentially limitlessly diverse. Each specific property has a number of individual facets. They are relatable to both functional and material components, and to stakeholders, who are at least partially responsible for their definition, and for establishing bounds of acceptability for variation of those properties over time.

3.6 Conclusion

Within this report we have summarised the principle activities undertaken in the exploration of new media art preservation approaches within the Planets project. The definition of a vocabulary for supporting new media art documentation is the most critical tangible outcome, and seeks to draw together best practice understanding from both mainstream and more domain-specific research, resulting in a novel approach intended to be quite widely applicable.

While the work has not reached anything approaching its final conclusions, there is considerable scope for future activity in this area. The definition of an initial vocabulary provides a basis for subsequent research, which should be in done in association with artists, curators and art historians, and also with those with stewardship responsibilities for an even wider range of dynamic or interactive materials. The qualities of new media art, while distinguishable from the majority of objects currently encountered by those within library and archival environments are likely to be more and more evident as information creation and publication becomes increasingly sophisticated. For it to be successful, preservation must itself be a dynamic discipline, with variability a critical consideration.

4. Describing Behaviour/Using Description Language for Interactive Properties

4.1 Short Overview

During the work of Planets it became increasingly clear, that the separation between the properties of digital objects which reside in their persistently stored form and the properties which are inherent in the rendering software is not sufficiently clear. For some types of objects most of the information about the rendering can be found stored in the object (e.g. text files, image files) and the rendering software just interprets these properties.

On the other hand e.g. 3D objects stored in the resource files of a computer game describe the object but are put into context with the game environment, the player actions, the view-point or lighting only due to the game logic (=the rendering software). In this case it is not possible to deduce the rendering properties from a stored version of the object. Having the object rendered and comparing the outcome of rendering processes from different environments (e.g. the original and an emulated environment) makes it possible to find out if the interaction properties, i.e. the reaction of a digital object to interaction, stay intact.

In this task we describe how the XCL Layout Processor as an extension to the Extensible Characterization Language (XCL) is used to compare different renderings of a digital object and can be used to compare significant states of interactive objects. We describe how significant objects in a screenshot taken from the rendering environment are identified and described in XCL. We describe how using a tool that captures and replays input to the environments interaction can be applied to digital objects and how the outcome can be compared by taking a screenshot at a certain point in execution time. Using this approach we show how the effects of interaction on a digital object can be measured comparing screenshots of the environment taken from a target state of the object.

4.2 Related Work

In previous work in Planets that was published on iPres 2008 (Guttenbrunner et.al., 2008) and will be published in the next Edition of the International Journal for Digital Curation (IJDC) we did research on significant properties of video games. It became apparent that the correct visual appearance of games is perhaps the most significant property of most games that are not directly linked to other properties (e.g. music games, special ways of interaction). In a Planets deliverable we described the levels on which significant properties can be extracted and what continuity has to be considered when extracting properties also with regards to a defined view-path and standardized interaction to expect the same results (Guttenbrunner, 2009).

A case study on characterizing a video game system used as a home computer was carried out previously in this work package. The different formats of files and the properties that had to be preserved were evaluated and the data was migrated from its stored form as a wave form on an audio tape to an appropriate non-obsolete format. Specific care was taken to preserve dynamic properties of objects, like the dynamic rendering of screens with blinking characters, showing the importance on not only file characteristics but also rendering properties. An application was created which was able to extract the data directly from the wave form without use of the original system but off-the-shelf tape players, and the data on originally unreadable tapes was successfully preserved. The results were published on iPres 2009 (Guttenbrunner et.al., 2009). A journal paper with more details about the undertaken studies will be published later this year.

In (Becker et.al., 2008) the Extensible Characterization Language (XCL) is presented with the ability to extract and compare characteristics directly from files. Thaller shows in (Thaller, 2008) that the rendering process can produce different outcomes for the same file if a different view-path for rendering a digital object is used. This makes it necessary to not only compare properties of the file but also properties of the outcome after a rendering process. In (Wieners, 2010) Wieners describes how the XCL Layout Processor was developed as an extension to the XCL tools to extract significant coordinates of areas in an image such as a screenshot of a rendered digital object.

In the approach described in this work we first reduce screenshots of rendering outcomes to a monochrome image to facilitate the edge detection. We use Otsu's global thresholding method as described in (Otsu, 1979). We then segment these monochrome images using an image segmentation algorithm described in (Felzenszwalb et.al., 2004) and record significant coordinates in the XCL of the screenshot files to allow for automatic comparison and detection of deviation between different renderings of the same object. We propose a workflow for comparing an object in different rendering environments with interaction applied and present a case study on a video game.

4.3 Identifying interaction properties

During tests with various interactive digital objects it became clear, that the some significant properties concerning interaction have to be defined for every interactive digital object. It is necessary to research to what types of input (e.g. certain keys on a keyboard, mouse pointer movement or mouse clicks, joystick input) a digital object responds but also to the timing in which this input has to occur. While the same interactive response of an action game relies very strong on the exact same timing of the input, in interactive fiction like text adventures or point-and-click adventures the timing is usually not as critical.

By having a user manually interact with the digital object and recording the user input to the digital object as well as the times relative to the object execution start we are able to replay the same input automatically. Using a separate tool this can be done independent of the object execution environment (e.g. a video game rendered in different emulation environments). This approach allows us the use not only on emulation environments but also on other execution environments (e.g. source ports of a game or using game engine interpreters like ScummVM[2] or Frotz[3]). By defining an “end point” where the user finishes the input actions and interactive object finishes responding to these actions we can take a screenshot of the rendering at a certain point of execution both when recording the user action but also after replaying the user action to a different (or even the same) rendering environment. Below we describe the process of analysing the image and placing the significant properties of identified segments in the image in the corresponding XCDL of the screenshot.

4.4 Image Segmentation and mapping in XCL

The central analysis task of the method described in this chapter is to identify specific regions in the rendered digital object, which can – in a final step – be compared with the rendering of the same object, using another rendering environment. Those specific regions reflect characteristic layout properties: regions with a high frequency of pixels that could refer to a significant area.

To identify and isolate such regions of interest in the prepared, cut to size and binarized image, the image is segmented by the *Efficient Graph-Based Image Segmentation* Algorithm as presented in (Felzenszwalb, 2004). For embedding the Segmentation Algorithm into the *PLANETS* context, the publicly available C++ source code[4] is used.

For each black pixel in the binarized image, the algorithm determines the affiliation of the processed pixel to a specific region by using three different parameters that influence the operation-mode of the segmentation algorithm[5]:

- σ (Sigma) indicates how strongly the image is smoothed by the Gaussian filter. The higher the σ, the more the image gets smoothed.
- *k* influences the "scale of observation"[6]: the larger the *k*, the larger the components identified by the segmentation algorithm.
- *min* determines the minimum component size: the smaller the size of min, the more objects will be identified by the segmentation algorithm.

To facilitate comparison between two images (on the one side, a screenshot of a text document, rendered with *Microsoft Word 2007*, on the other side, a screenshot of a text document, rendered with *Adobe Reader*), the proposed solution sets the upper left top pixel and the bottom rightmost pixel of a layout-screenshot in relation to the pixel dimensions of the image by dividing both pixel values by the width, respectively the height, of the processed image. Finally, these relative values

[2] ScummVM - Graphical point-and-click adventure game engine interpreter: http://www.scummvm.org/

[3] Frotz – Game Engine Interpreter for Infocom and other Z-machine games: http://frotz.sourceforge.net/

[4] Segmentation Algorithm source code: http://people.cs.uchicago.edu/~pff/segment

[5] For a detailed parameter-explanation confer (Felzenszwalb, 2004) pp14.

[6] Cf. (Felzenszwalb, 2004) p14

are embedded into XCDL files, which are connected to the screenshots, to enable a comparison of the objects through the Comparator[7].

The structure of the input XCDL is supplemented by a new property with a unique identifier: The new property with the id *p15381* is inserted into the XCDL and represents the significant points of the isolated objects in the screenshot file through different *valueSet* Tags. It is inserted after the *XML header*, the *XCDL Schema* and the *normData* part of the XCDL file, and is visualized in the following code snippet:

```
<?xml version='1.0' encoding='UTF-8'?>
<xcdl xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance" xmlns="http://www.planets-
project.eu/xcl/schemas/xcl" xsi:schemaLocation="http://www.planets-
project.eu/xcl/schemas/xcl ../xcl/xcdl/XCDLCore.xsd" id="0">
    <object id="o1">
      <normData type="text" id="nd1">Journal of Universal
      Computer Science, vol. 14, no. 18 (2008), 2936-2952
      submitted: 1/3/08, accepted: 29/9/08, appeared: 1/10/08     © J.UCS Systematic
Characterisation of Objects in      Digital Preservation: The eXtensible
Characterisation     Languages
      [...]
      </normData>
      <property id="p15381" source="raw" cat="descr">
              <name id="id9998">significantCoordinates</name>
              <valueSet id="i_i1_i2xx_s1_1">
                      <labValue>
                      <val>0.118727 0.113586 0.232558 0.335189</val>
              <type>rational</type>
              </labValue>
              </valueSet>
              <valueSet id="i_i1_i2xx_s1_2">
                      <labValue>
                      <val>0.331701 0.113586 0.403917 0.151448</val>
                      <type>rational</type>
                      </labValue>
              </valueSet>
              [...]
      </property>
      [...]
      </object>
```

The four floating point numbers in the first *valueSet* of the generated XCDL (<val>0.118727 0.113586 0.232558 0.335189</val>) represent the relative pixel position of the significant points, identified through the segmentation process. Therefore, the value 0.118727 indicates the position of the relative x coordinate of the topmost left pixel of the identified object; the second value (0.113586) indicates the relative y coordinate of the topmost left pixel of the identified object. The next two values refer to the relative x and y coordinates of the bottommost right pixel values of the identified object.

The following chapter gives a short introduction into the use and workflow of the developed application *XCL Layout Processor,* which offers an approach to the image segmentation and comparison problem.

Planets::XCL Layout Processor – overview

The *XCL Layout Processor* provides two application window areas as shown in Figure 4.1

The left-hand side (in the following explanations referred to as *source* area) takes as input a XCDL file (button “Load XCDL”) of the image that is going to be analysed (button “Load Image”). In analogy to the left-hand side, the right-hand side of the application, the *comparison* area, processes the XCDL and the screenshot through the designated buttons.

The workflow is as follows: after loading the XCDL in the left-hand side of the application window, the *XCL Layout Processor* is ready to process the input image. A click on the button *Load Image* on the left-hand side of the application window offers a dialogue to choose the image that is to be processed. After processing the source XCDL and the source image, the XCDL of the comparison image is processed through the button *Load XCDL* in the comparison area of the application. After the last step – loading the comparison screenshot into the right window area – the *XCL Layout Processor* writes a supplemented XCDL into the directory of the input images. The supplements to

[7] eXtensible Characterisation Language Suite 2.0: http://planetarium.hki.uni-koeln.de/planets_cms/deliverables/xclsuite.pdf

the XCDL are the coordinates of the identified objects, which are set up as described in the previous explanations.

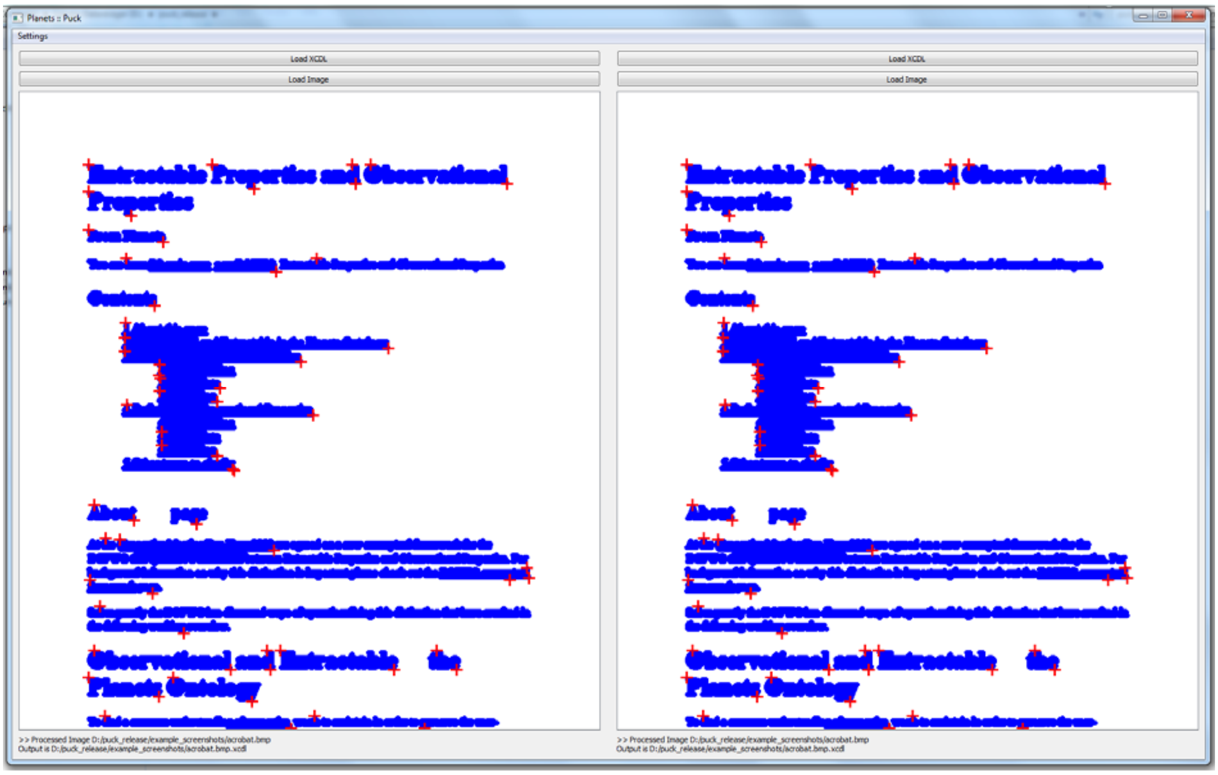

Figure 4.1. Screenshot of the XCL Layout Processor: Red crosses mark the positions of the topmost left and bottommost right pixels of identified objects. For the input screenshot with the size 1920x1200 pixels in this example, the segmentation algorithm was run with σ=1, k=2000 and min=750.

4.5 Applying interaction to digital objects and comparing rendering results

To evaluate if the interactive properties of a digital object are preserved properly in a different rendering environment than the one originally intended for the object it is necessary to ensure that the same kind of input is submitted to the object at the same point in time. By keeping the view-path for the object as well as external influences like user input unchanged, differences in the rendering are caused by change in the rendering environment.

A conceptual workflow for comparing the interactive properties of a digital object in different rendering environments is drafted below. It consists of 3 stages with different steps in the stages as shown in Figure 4.2.

Stage 1: Recording the original environment.

In this stage the user actions are recorded in the original environment and screenshots of the original rendering process are taken as “ground truth” against which other environments are evaluated. The following steps are followed:

1. start the rendering environment with the digital object
2. record the user actions (e.g. in a standardized XML-Format) and take screenshots at predefined intervals or one screenshot after a certain amount of time
3. shut down the rendering environment

Stage 2: Replaying

In this stage the recorded user actions are applied to the alternative rendering environment. The same settings for screenshot interval etc. are used as when recording in the original environment.

These steps in this stage are carried out for every alternative rendering environment that is evaluated:

1. start the rendering environment with the digital object (e.g. different emulation environment)
2. replay the user actions from a recorded session and take screenshots at the same predefined intervals or one screenshot after a certain amount of time as in the original recording session
3. shut down the rendering environment

Stage 3: Comparing

Finally in this step the rendering process are compared. Therefore the screenshots need to be characterized and the following steps to be taken to compare the screenshots taken during the rendering processes. The steps in this stage have to be repeated for every alternative rendering environment that is evaluated.

1. Characterization of the screenshot images
2. Extending the XCDL for the screenshots with the coordinates of the identified significant areas using the XCL Layout Processor
3. Pair wise comparison of the screenshots taken at the same object execution time using the XCL comparator to identify differences in the rendering

Using the workflow drafted above, we have a formalized way to compare the rendering results for the same digital object in different environments. The workflow can be implemented in a tool to support the automatic comparison of rendering of interactive digital objects.

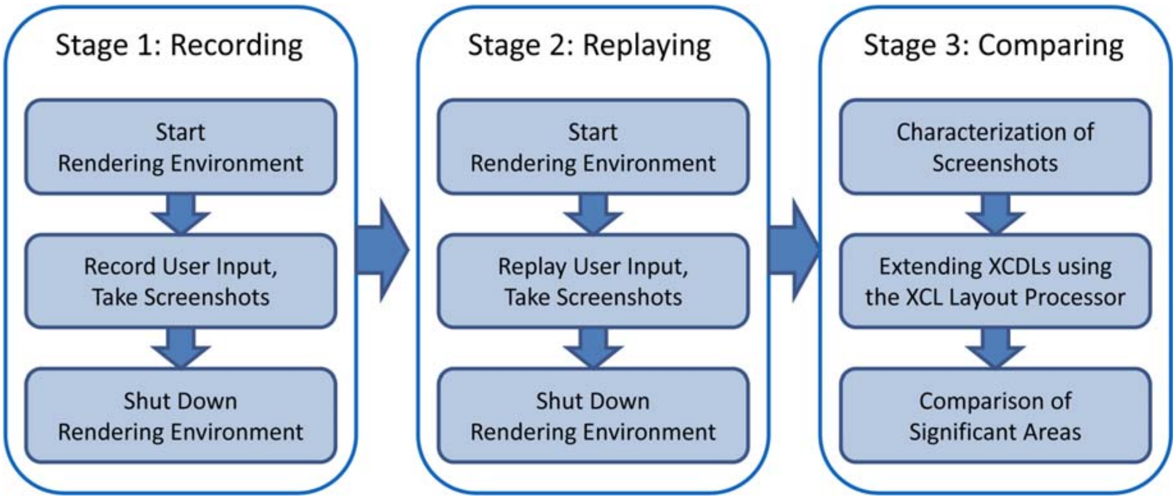

Figure 4.2. Conceptual workflow for comparing rendering results of interactive digital objects.

4.6 Case study on an interactive object

For a first case study of using the proposed workflow for testing interactive properties of digital objects by comparing rendering outputs using the XCL comparator and the XCL Layout Processor for extending the XCDL of rendering outcome screenshots we used the video game "The Secret of Monkey Island". This game was developed by Lucasfilm Games and released on various platforms from October 1990. The game is a typical point and click adventure game, thus not requiring interaction timing that is exact down to millisecond level. It was also chosen because various different rendering engines exist, that are usable for digital preservation purposes:

- ScummVM[8]: a game engine interpreter available for various non-obsolete platforms
- Emulation/Virtualization of the original hardware (e.g. DOSBox[9])

[8] ScummVM: http://www.scummvm.org/

[9] DOSBOX: http://www.dosbox.com/

Various tools for recording interaction and replaying it in the form of a macro were evaluated but failed especially in recording/applying interaction in the game running in the original environment (as a Full-Screen DOS-application). As no tool for automating the process described in the previous chapter exists yet, the steps were performed manually. First the game was executed on a workstation running Windows XP. The movements of the mouse pointer as well as the keystrokes and times of these events were manually noted and the game was played up to a point where the character in the game that is controlled by the player enters the SCUMM Bar and talks to pirates sitting on a table telling “I want to be a pirate.” At that point in the game a screenshot was taken.

Subsequently the same actions were then performed by trying to replicate the same timing by running the game under a virtualized environment using DOSBox 0.72 and using the ScummVM 1.1.148874 Engine (using also the game data files from the DOS Version of the game). For ScummVM an unscaled rendering replicating the “EGA” settings that were similar to the options of the real DOS-Version of the game were used.

The screenshots taken in the three different rendering environments were then characterized using the XCL tools. Then the XCL Layout Processor was used to binarize and segment the screenshots and extend the XCDLs of the images. Figure 4.3 shows a screenshot from the original DOS-version of the scene defined as “endpoint” for this scenario on the left. On the right the same screenshot as segmented by the XCL Layout Processor is shown. The image is binarized to black/white to identify areas. Different greyscales present in the segmented image are just a visualization of the different segments in the picture. The following values were used for the segmentation algorithm: σ=0.8, k=1000 and min=100. Figure 4.4 and Figure 4.5 show the segmentation for the screenshots of the other two rendering environments of the game. A visual comparison of the segmentations shows, that the game running in the DOSBox environment is segmented to very similar areas then the original version, whereas in the ScummVM version a lot more differences can be found.

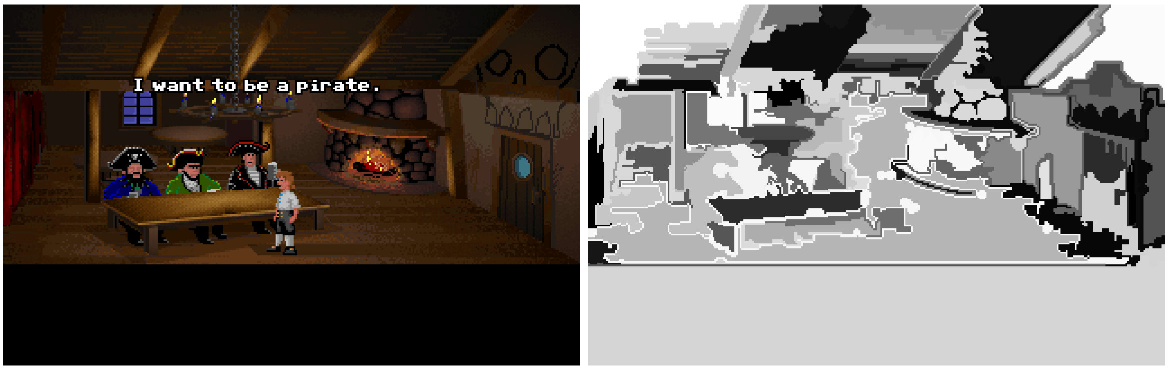

Figure 4.3. Screenshot of original DOS-Version of “The Secret of Monkey Island” (left). Significant areas in the same screenshot as a result of binarization and segmentation are shown on the right.

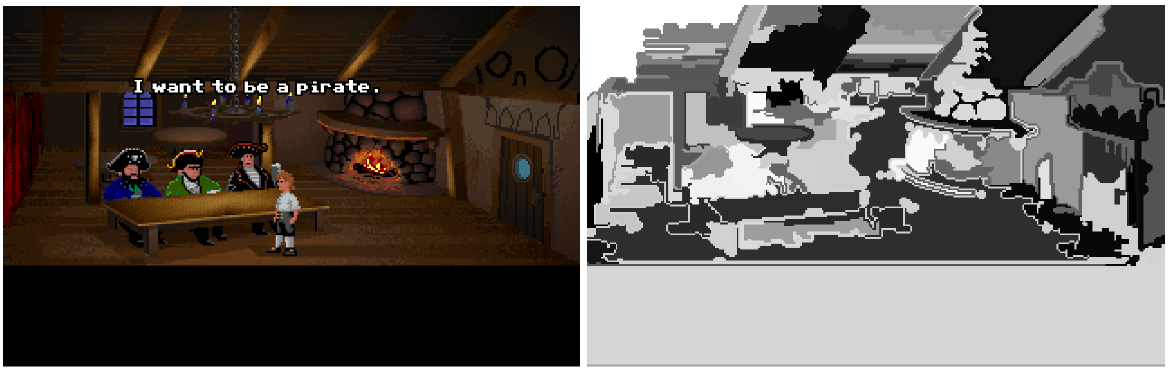

Figure 4.4. Screenshot of “The Secret of Monkey Island” running in the DOSBox Environment (left). Significant areas in the same screenshot as a result of binarization and segmentation are shown on the right.

Figure 4.5. Screenshot of “The Secret of Monkey Island” using ScummVM as a rendering engine (left). Significant areas in the same screenshot as a result of binarization and segmentation are shown on the right.

The XCL Layout Processor enhances the original XCDL which was created by using the XCL extractor on the screenshots taken in the different environments. Below is a table that shows the number of significant areas identified per screenshot:

Rendering Environment:	Original	DOSBox	ScummVM
Significant Areas in XCDL:	62	66	62

Using the XCL comparator we then compared the XCDLs of the different screenshots. The comparator reported failure for both comparisons. On closer inspection of the XCDLs of the screenshots it became apparent that:

- The original and the DOSBox version differed in significant areas that were recognized. The reason are animations in the picture which lead to slightly different images and thus to different areas that are recognized by the segmentation algorithm. Blocks not animated and without other animated blocks overlapping do have the same coordinates.
- The original and the ScummVM version differed in that the colourspaces of the screenshots were different. While the original version was rendered in an 8bit colourspace (palette mode), ScummVM rendered the image in a 24bit colourspace (truecolour mode). Even though the number of significant areas was coincidental equal, the coordinates differed throughout all areas.

Based on these differences we can draw the following conclusions:

- Timing of screenshots together with the input is important, as animations in interactive dynamic digital objects that occur continuously (e.g. a fire burning in a chimney, people moving, environment changing) changes the screenshot and thus leads to different coordinates of significant areas and also to different areas that might be recognized as significant.
- This in turn leads to the fact that the values for the segmentation algorithm have to be balanced accordingly to detect the same significant areas even when slight changes in objects occur. The algorithm has to be configured sensitive enough to recognize enough areas to compare two screenshots and detect differences, but insensitive to minor differences in an image that lead to changes in recognizing a significant area as being exactly that.

To validate the outcome of the XCL Layout Processor on a digital object which would not pose the problems of animations and need an exact timing of key presses and screenshots taken, we made a second case study on the game “Chessmaster 2100” published for the DOS platform in 1988. “Chessmaster 2100” is the second instalment in what became the best selling chess franchise so far.[10] Again the original software running in DOS was compared to the same program running in DOSBox in Windows XP. A few beginning moves in a game of chess were played with trying to keep the timing of the moves intact manually. The screenshots taken as well as the segmentations

[10] Chessmaster on Wikipedia: http://en.wikipedia.org/wiki/Chessmaster

of the screenshots can be seen in Figures 4.6 and 4.7 respectively. For all the elements on screen to be correctly visible on the segmented image (e.g. the numbers left and below the board, all the figures in the squares) the following values were used for the segmentation algorithm: σ=1.0, k=1000 and min=100.

A first inspection of the images shows that the colour depth in DOSBox was increased to 8bit compared to 4bit in the original image. This also reflects in the extracted XCDL of the images. Visually this also results in slightly different colour shades in the extracted images and is also reported when comparing the images using the XCL comparator as difference in the colour palette. Comparing the XCDL files enhanced with coordinates for significant areas by the XCL Layout Processor, we can see that the identified areas in the images are exactly the same in number (153 recognized areas) and coordinates.

Compared to the case study on “The Secret of Money Island” we can see that depending on the digital object and on the fact that no animations change the image in the evaluated chess program, the timing of screenshots and interaction is less crucial and allows us to manually evaluate the rendering results for certain interactive digital objects like “Chessmaster 2100”, thus confirming the validity of the approach of using the XCL Layout processor for comparing rendering outcomes.

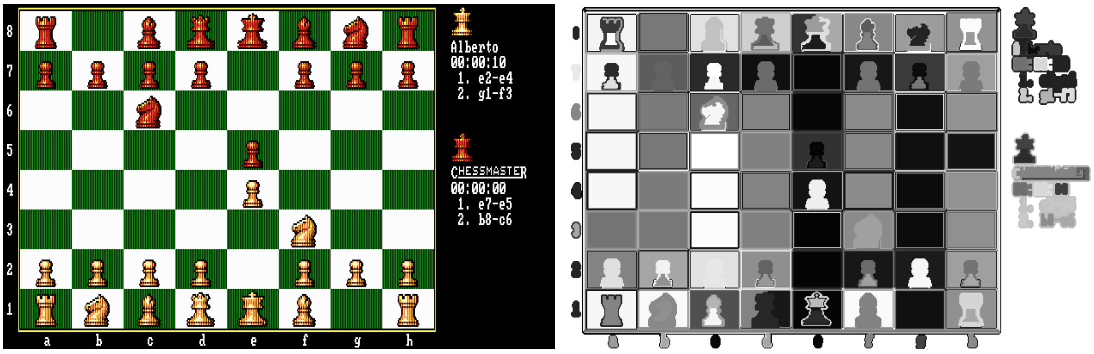

Figure 4.6. Screenshot of “Chessmaster 2100” running under DOS on the left and the segmented screenshot showing significant areas on the right.

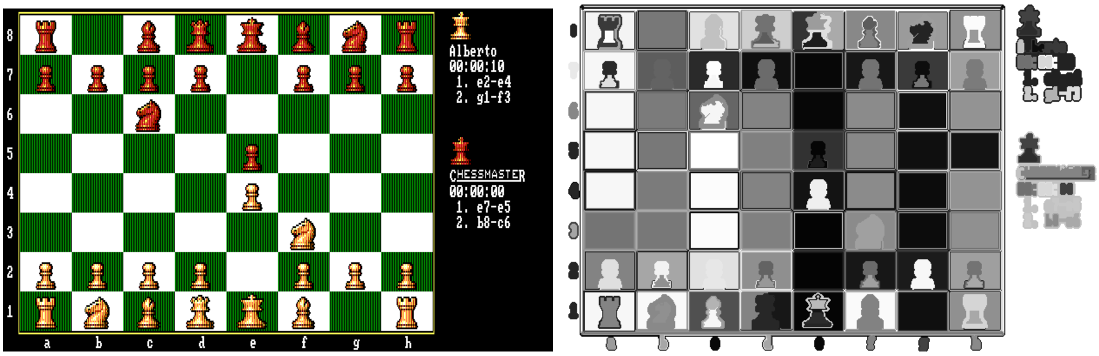

Figure 4.7. Screenshot of “Chessmaster 2100” running under DOSBox in Windows XP on the left and the segmented screenshot showing significant areas on the right.

4.7 Conclusions and Future Work

The work presented in this paper showed an approach to identify characteristic objects of rendered digital objects based on screenshots in certain stages during the lifetime of the object. Identification of significant areas in the screenshot is done using pre-processing methods like cutting and reducing the image information through binarization and, finally, the Graph-Based Image Segmentation Algorithm. By comparing the rendering results of one or more pre-determined states during the runtime of a digital object that responds to user input it is possible to evaluate, if a digital object reacts to interactive actions as expected and in the same way over various different rendering environments.

We introduced a conceptual workflow for recording user interaction in an original environment along with screenshots along the path, with applying the same interaction and taking screenshots in the same points in execution in other rendering environments. Using the extensible

Characterization Language (XCL) properties of the screenshots along with the identified significant areas in the images are compared to evaluate, if a rendering environment is creating the same result as the original rendering environment.

We carried out case studies on interactive fiction using the game “The Secret of Monkey Island” and one on the chess playing program “Chessmaster 2100”. The result of the case studies showed:

- It is important to consider exact timing both of interaction but also of the time when the screenshot is taken, to compare the same rendering results, as changes in the image that do not occur due to interaction (e.g. animations of the game environment or characters) influence the result of the segmentation algorithm. If the resulting image is constant exact timing is less crucial.
- Identifying the accurate segmentation parameters (σ, k, min) for a certain digital object is necessary to get the same number of significant areas over different screenshots, especially if the rendering environments use different colour depth or image resolution for rendering the digital object.

The case study on “Chessmaster 2100” also confirmed that comparison of different rendering environments using the XCL Layout Processor and the XCL Tools can actually be used to evaluate if interactive properties of digital objects are preserved in different rendering environments by comparing rendering outcomes after applying interaction to the digital objects.

For future work it is necessary to implement the proposed workflow in a tool, as exact timing is not possible with manual interactions. Tests with various keyboard recording and screenshot tools also showed that depending on the environment it is not always possible to record/interact from a outside the rendering environment, making it necessary to support the process inside the rendering environment (e.g. an emulator).