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Integration issues for tools to create interactive Cultural Heritage experiences

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Abstract

Recent years have seen substantial efforts to produce tools which address individual sub-areas of the process of building an interactive virtual experience of a Cultural Heritage (CH) site and its artefacts. Research in shape representation and modelling has developed techniques for image based modelling, multi-resolution modelling, level of detail manipulation, and optimisation of rendering techniques. All of these must fit together efficiently and seamlessly in order to allow non-IT professionals to focus on the content creation of the experience rather than on the technology. In this paper, we report on some real issues which arise with the integration of modelling, interactive graphics, knowledge representation and language technologies and discuss some alternative strategies for addressing the issues.

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1. Introduction

The application of Information Technology to Cultural Heritage (CH) poses many unique challenges. Visualisation, whether as a tool for documentation, interpretation or presentation of CH information, is an area particularly challenging as it aims to incorporate an extremely diverse and extended set of knowledge and data definitions from this discipline. Where other disciplines may use Visualisation without thought to the explicit or implicit logic or semantic behind a visualisation or how it will be perceived, CH benefits strongly from a more variable approach to the structures and techniques used during production. Moreover, CH requries levels of accountability in accuracy and providence of its visualisations that other disciplines may ignore. Virtual environments are commonly used for presentation of CH information, such as archaeological sites, historical cities or reconstructed artefacts. The production of these virtual environments may rely on data of many different types and source, such as from original site photography or sampling, previous documentation, or articially produced data, using modelling software or handmodelled according to the needs of the visualisation. It is intended that all these techniques interoperate efficiently and transparently in order to allow non-IT professionals to focus on the content creation of a CH experience rather than on the technology used; as it stands, most CH visitor experiences rely on handcrafted content [GCP04, CSA04, LB04], which usually require experienced graphic professionals to build and tune the interactive virtual environment for their target audience. Where visualisation for other disciplines don't necessarily require semantic data to be embedded into the modelling structures used during visualisation, this type of data has tremendous influence in bringing the full potential of visualisation to CH. Therein lies a great challenge to visualisation for CH. Where many CH projects are able to produce data and structures modelling their particular visualisation needs, it is the integration of projects that gives the greatest potential for visualisation in CH. It is in the interest of the discipline at large to recognise some of the fundamental issues concerning the integration of structures and techniques that allow the reuse and re-examination in the future, and give greater control over their selection and use in future projects. An example of such a project might be the virtual reconstruction and visualisation of the Royal Pavilion in Brighton. Built as a palace for the Prince of Wales between 1787-1821, the Royal Pavilion is a building with varying amounts of detail in its construction, both of its interior and exterior. There are a great many different techniques that could be used to construct a geometric structure of this nature, however, such a building would benefit strongly from many different types of model structuring and rendering techniques, both for real time rendering and pre-rendered visualisation. As a man-made structure, it contains many simple architectural premises upon which many of the details are applied, some in great number. Where no single modelling techniques would be ideal, a hybrid approach is suggested. Such an approach might make use of the best techniques for modelling particular features, for example,

1. The core geometries of the building using architectural plans, the minarets using the Geometric Modelling Language [GML],
2. unique objects such as the Dragon in the Music Room to be modelled by hand using modelling software such as Blender [BLE],
3. Photogrammetry based scanning of architectural features [VvG06].

Whilst each of these techniques produce geometry to be integrated into a CH scene, different considerations can be taken for each technique for rendering, both for pre-rendered visualisation, where the emphasis is upon realism and optimum quality, to real-time rendering, where interactive speeds are required and specialist techniques can make good use of semantic scene data for optimisation. Each representation of

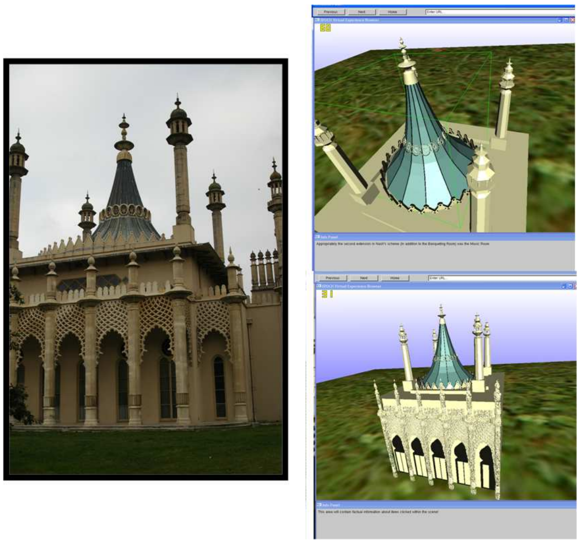

Figure 1: *Illustration of hybrid model of Brighton Royal Pavillion*

CH, whether from original source or artificially produced, will have its' own qualities such as accuracy, its' own digital and technical considerations. It is not the intention of this paper to dictate the best way to integrate multiple types of representation within a CH scene, but to raise awareness of the need to take steps to make this type of integration possible.

2. Technology Integration Framework

For present purposes we assume that a significant part of the virtual heritage content is typified by considering digital representations of architectural sites (towns and cities composed of buildings and houses with a distinctive historical style) along with digital representations of historical objects, including those discovered by archaeologists on excavations. Other digital representations, such as virtual avatars, flora and fauna could be used to add realism to the scene and portray more effectively the historical context of a place, building or object. In addition, semantic technologies allow the addition of interactivity to the environment with users interrogating the system through the use of tailored intuitive natural language interactions. The engineering processes to build such an application are roughly as follows (see figure 2):

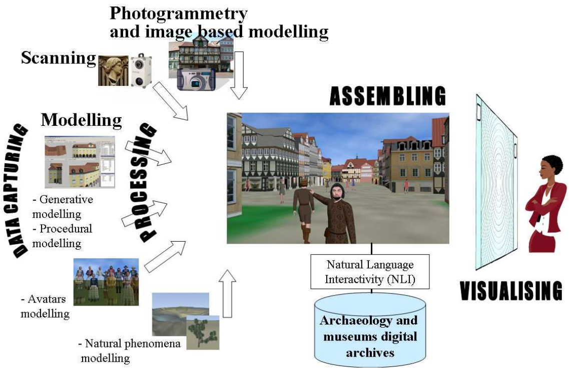

Figure 2: *Framework for the creation of a virtual CH environment*

1. The raw data is digitally captured and processed,
2. The virtual environment is assembled
3. The user interfaces, dynamic behaviours and interactivity are added and the experience scripted; and,
4. The user navigates, views and interrogates the environment

These activities are normally iterated with prototyping and usability studies. The efficient integration of the technologies used is essential for effective operations. To better understand integration issues, we selected a number of tools and used them to capture one of the sections of the Brighton Pavilion to assemble an interactive visualisation.

2.1. Capturing semantic data for 3D CH objects

In order to enhance CH environments, semantic information needs to be linked in, for example, on the style, material and history of its construction. This can be encoded using standardised ontologies so that meaningful relationships between graphical components and other data can be captured. Most CH archives have been constructed using proprietary formats, which impede interoperability without standardized concepts and structures. The International Council of Museums Conceptual Reference Model (CIDOC-CRM) [CC] is a new ontology standard developed for documenting artefacts within the museum and gallery domain. CIDOC-CRM structures can be implemented over traditional database systems, with application concepts specified precisely, using a, domain-specific vocabulary thesaurus. By standardising on conceptual structure with embedded semantics, such knowledge bases allow inference and automated reasoning, enabling intelligent interaction in an experience.

3. Assembling the virtual environment and adding interactivity

Once the digital content has been created, it needs to be integrated with the scene description, the dynamic behaviour of the objects and the user interaction via input devices. CH interactive environments have normally been handcrafted using device-independent graphics libraries (e.g. OpenGL) or scene graph based libraries (e.g. OpenSG, OpenScenegraph, Performer or Inventor). Although this affords a great degree of freedom, it requires experienced graphic professionals as developers. As a consequence museum curators or other CH professionals who may not have this experience, are unable to participate fully and the development focus can be diverted from creativity to technology. In the absence of tools focused on the CH application domain we suggest the open source scenegraph system OpenSG [Opec] to handcraft the experience, which requires translation of the graphic content to meshes, since application specific data types are unavailable. The first stage of integration is to translate the content from the original applications to a format that could be integrated by OpenSG. Almost all digital content creation applications rely on proprietary data formats that either cannot be reused by other applications at all or can only be reused by hand crafting modifications to the files, which can both be inefficient, inaccurate, time consuming and difficult to document changes. Although, most packages offer translators to other formats, there is still a lack of common standards for exchanging data, such as generalised scene topology, individual models and behavioural mechanisms, as well as offering flexibility for custom components. As an example, we found applications using incompatible versions of VRML, even though X3D supplanted it some years ago. This meant that everything tends to be reduced to the lowest common denominator. This data exchange problem has a direct impact on those applications that use data formats that store environmental and application specific data, such as information about the scene or the objects. The lack of integration becomes more evident as we try to take advantage of the capabilities of individual applications. The potential of GML, for example, is based on the way it encodes the geometric information. However, there is no standard way to integrate this format in an interactive experience along with objects in other formats particularly where those objects are conjoined geometrically, as interfaces are not defined to their common properties. The complexity of the integration of content and/or functionality when assembling an interactive environment is, in our opinion, due to the nature of the area (in particular the unique or rare opportunities to digitize fragile objects or environments) and partly related to the software development cycle that most projects follow. Hence, different technologies, such as data capture or image based modelling techniques, are designed and developed with the intention to be self contained applications. Only rarely are they designed to interface with other types of applications, such as applications to assemble and visualise virtual environments. In addition the opportunities to digitse CH data or artefacts are severely limited (if not "one-off") and data, once captured is expected to be preserved and re-used.

4. Visualisation of the 3D virtual CH environment

Once the CH interactive application has been assembled users can explore it, interacting with objects including buildings, artefacts and avatars. The user could explore the model and click on features of interest to obtain more information (see figure 1). The number of large meshes produced in assembling the multiple sources, proved to be an obstacle when rendering the complete scene. This highlighted the need to use application specific representations to allow efficient rendering with encoded information within the 3D object, both to identify the most efficient mechanism and to link to other domain specific information. Whilst a virtual environment can be created by integrating 3D objects from low-level capture methods to assemble the scene, low level interoperability is not a sufficient for realtime applications. Many of the content creation applications, especially research tools, rely on custom modelling, using particular techniques, geometry or pieces of a scenegraph. Whilst these can be packaged in serial representations the real benefits are only felt when the interactive manipulations of the environment can be accomplished using the special purpose data structures. There are thus two types of integration and standardisation required - serialised data exchange and runtime object manipulation. The need for standards for these two areas has been recognised for about 30 years (e.g. CGM and CGI - [AB88, AD90]). The previous section highlighted the need for common guidelines and recommendations on the use and/or adaptation of general purpose standards for *serialised data exchange* for both geometric and other knowledge about objects. *Application Specific Profiles (ASPs)* would allow a standard for categorising specific objects assembled into a CH virtual environment (e.g. museum objects, buildings in a city, avatars). The ASP approach could be applied to *runtime object exchange protocols* and *protocols for interfacing* with other functionalities, such as natural language technologies. Some of the standards that might address these needs are considered below.

4.1. General purpose standards for serialised CH data exchange

Serialised data exchange are a linear traversal of internal data structures and raw data encoded in computer-readable, and sometimes human-readable, form. Standards enable integration by allowing successful reuse of data and sub-systems. By standardising data exchange formats for 3D objects, data files from unspecified sources can be interpreted to build data structures for use applications for which the original data was not envisaged. This ability is fundamental for CH data where conservation of data well beyond the lifetime of current systems is essential. Currently, X3D (succeeding the earlier VRML) and COLLADA (COLLAborative Design Activity) are two popular standards for encoding 3D objects into common formats for sharing between applications. COLLADA is increasingly used in 3D content creation whilst X3D has particular legacy value and familiarity in the field. Both formats can encode a scene using an XML syntax. Some of their main differences are:

- X3D (Web3D Consortium 2006) is an ISO standard, while COLLADA was originally established by Sony and then adopted by other main players in the gaming industry. These will have an effect on which applications will take advantage of these formats as they being directly supported by the tool vendors.
- COLLADA is designed as an interchange format, while X3D is designed as a content deployment format, targeting web type applications.

These types of standard allow the transfer of text based files over http and other non-binary protocols and thus allowing easier transfer of data across networks, although there are potential versioning issues and extra processing to serialise and deserialise data structures. Also, at runtime, real time modelling and rendering techniques may require different data structures than those implied by simply reflecting the structure of the serialised data.

4.2. Application Specific Profiles (ASPs) for the CH application domain

Often efficient modelling and rendering of domain specific 3D objects have to be closely coupled. As an example, in [MVcSL05] new techniques for recording and presenting coins were developed. These techniques would be ripe for integration into a CH experience, but use specially developed modelling and rendering techniques which would not be a native part of a scenegraph such as OpenSG. An agreed set of ASPs would allow developers to go beyond the generalised standardisation and use application specific constructs. ASPs for the CH domain could consist of two parts: firstly, an abstract data layer including original source data, a unique Digital Object Identifier (DOI), and other metadata. This data corresponds to the abstract functionality of a "class" of object. A second, implementation layer would map or bind the abstract into common implementation environments such as OpenSG. The underlying implementation would allow custom algorithms for development of new techniques and experimentation whihc implemented the specification as defined. The domain knowledge embedded in ASPs can be used to optimise both at runtime and in the assembly of the virtual environment. These optimisations could include precognition of possible scenarios for user interaction, optimisation for rendering, behaviour of avatars, and other types of intelligent content delivery. ASPs also allow the specification of fallback mechanisms for system behaviour, whether due to system specifications or user requirements, such as accessibility requirements. Optimisations for particular object types could be developed and agreed to produce ASPs based on project experience and, as a natural extension, a centralised registration body for both object representation and implementation mechanisms could be developed. The organisation of these profiles will enable the standardisation of digital representation of objects in CH, which in turn will lead to the standardisation in development of content creation tools, facilitating greatly the production pipeline of CH experiences based on properly curated digital objects. In addition, format standards, such as X3D and COLLADA will facilitate the flow of data between the development tools, supporting the Application Profiles, although custom data will be required to be preserved under format conversions as part of the ASP. A further consideration may be whether to extend standards such as COLLADA to explicitly include this information, or simply use the standard user defined data fields with restrictions.

4.3. Protocols for runtime object exchange

In order to take advantage of optimisation and other modelling and rendering mechanisms at runtime, internal data structures can be traded between processes or between a process and a runtime library using data structures common to both. Examples include any Windows-based C++ application using DLLs and using a standard data currency. The requirement for this is the use of a standard library of objects and access between them, such as C++/ Windows DLLs, and an API such as OpenSG as a trade mechanism. This will provide the advantage of very fast memory transfer of objects, meaning that runtime modelling could be farmed to specific algorithms in externally developed software modules. However, the disadvantages would be that developers will be forced to conform to an interface API and that the exchange must take place within the same system environment, as well as it would not be possible to save data exchange explicitly for future reference. Figure 3 shows the use of 3^{rd} party modelling processes communicating with runtime objects. In this case, the 3^{rd} party processes will require the use of a standard API as a data currency to quickly trade data with the main User Agent or viewer at runtime. This will allow the encapsulation of algorithms within the separate process to be used for runtime modelling, such as pieces of the scenegraph itself. Both serialised and runtime objects have

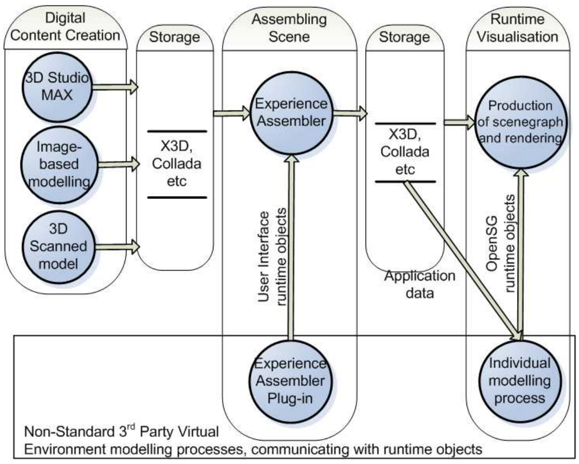

Figure 3: *Runtime object exchange*

their place within a common framework that is both flexible and data driven, in combination with Application Profiles. Use of custom components is dictated by the interface definitions made publicly available. So where individual specialists may develop unique techniques for modelling and storing different types of data, their research would not be locked into their own application framework, but instead allowed different pieces to be developed concurrently, whether the aspect be 3D geometric representation, rendering techniques, or other types of content.

5. Conclusions

The paper presents several issues with our current development cycles of interactive experiences, not only for the CH application area, but for many others. Although, some of these issues are commonly being experienced by developers, a thorough analysis is presented in order to draw useful conclusions and recommendations from them.

1. In the CH domain, access will be limited so the opportunity to create digital representations may occur rarely (due to the unwillingness of curators to make fragile objects available for digitisation) or unique (for example due to the destruction of a unique archaeological site during excavation). Since the access to create new digital representations is precious it is inevitable that data from old digitisations will need to be used where available and fully integrated into the experiences even where the potential quality of a new digitisation would be vastly preferable. This, inevitability of future reuse, applies as much to new digitisations undertaken now as to those that were done a long time ago. The implication is that new digitisations should be established such that the provenance of the digitisation process accompanies the digital artefact so that the tools, accuracy and subsequent manipulations of the data describing the digital artefact are not lost with time.
2. At the level of creating and assembling the virtual environment it is essential that the systems are capable of integrating several data formats. These will arise for a variety of reasons that are independent of the CH field - for example because different representations are most appropriate for different geometric data types and require specific manipulation techniques. However there are also compelling reasons for the inevitability of this requirement arising specifically in the context of CH.
3. At the level of visualising virtual environment, current tools are not taking advantage of rendering and modelling optimisation techniques as there is not a common framework for serialised and runtime data exchange.
4. There are two different types of requirement for additional data commonly stored in fields reserved for application data in file formats. The first applies to allow individual digital artefacts to cohabit a virtual space but be compatible to some degree. The second is required to allow the integration or linkage of non graphical metadata with the representation of the visible aspects of objects.
5. Many of the operations of assembling disparate sources of data turn out to be non-commutative and or irreversible. Thus the association with particular elements of metadata may be maintained as an object is translated from form to another for inclusion in the integrated scenes. However subsequent alterations whether in the unified environment or via additional editing of the original digital artefact will need to be propagated through the manipulations that were applied to the original artefact.

The situation might be improved through adoption of standards and protocols based on widely available technologies, both for serialised data exchange and runtime object exchange. Furthermore, the adoption of Application Profiles for the CH domain could provide a common framework for embedding metadata to individual or groups of objects via common linkage techniques - e.g. url's or Digital Object Identifiers (DOI's).

6. Further Work

In order to overcome some of the integration problems described in the paper, further research work will be conducted on the analysis and design of a common method of registering common Application Profiles, for open source implementation documentation, and simplified extension as well as maintenance as new techniques are developed. For example, the development of unique OpenSG modules to allow the representation of artefacts as best developed by experts in the field. In addition, where 3D standards exist for storing specific types of data, their usage will involve a detailed analysis of the best mechanism for adoption in order to allow the many types of representation to be referenced for use within a single environment. This includes the provenance of data, trace-ability and application-specific identifiers to account for data, ensure its reliability and track its progress through original source to storage, analysis and presentation. The design of complementary set of interfaces for the transfer of data at runtime will be based on a common set of functionality, to allow interoperability of virtual environment components, such as Natural Language Interfaces.

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