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The Missing Scholarship Behind Virtual Heritage Infrastructures

Erik Malcolm Champion

School of Media, Culture & Creative Arts, Curtin Institute for Computation (CIC), Australia-Asia-Pacific Institute (AAPI), Curtin University

Abstract

This theoretical position paper outlines four key issues blocking the development of effective 3D models that would be suitable for the aims and objectives of virtual heritage infrastructures. It suggests that a real-time game environment which composes levels at runtime from streaming multimédia components would offer advantages in terms of editing, customisation and personalisation. The paper concludes with three recommendations for virtual heritage infrastructures.

Categories and Subject Descriptors (according to ACM CCS): H.5.1 [Multimedia Information Systems]. Artificial, augmented, and virtual realities, Experimentation, Human Factors, Theory.

1. Introduction

In terms of either scholastic research or end-user engagement, the deployment of virtual heritage projects at community level, in schools and in the GLAM industry (Galleries Libraries Archives and Museums) is currently limited in number and restricted in potential (especially in terms of cross-platform reconfigurability, and pedagogical impact). The careful inspection, contextualization and modification of 3D digital heritage models is still problematic. Models are hard to find, impossible to download and edit, in unusual, unwieldy or obsolete formats, and many are standalone 3D meshes with no accompanying metadata or information on how the data was acquired, how the models can be shared (and if they can be edited), and how accurate the scanning or modeling process was, or the scholarly documents, field reports, photographs and site plans that allowed the designers to extract enough information for their models.

There are some exceptions to the above, we can find models that might act as exemplars, but where models exist that are standard formats and accessible in open repositories, such as in the Europeana library portal, they are encased in a proprietary format and cannot be extended, altered or otherwise removed from that format. This paper argues that only part of the problem is to do with the technical development of virtual heritage; it argues that part of the problem is also due to a scarcity of necessary infrastructure both technical and communal.

To return to a theoretical starting point that better engages with these issues, this paper will make a distinction between digital heritage and virtual heritage. It will further suggest the notion of a scholarly ecosystem for virtual heritage. In such a concept both the media assets and the communities (of scholars, shareholders and the general public) are all considered to be active participants in the development of digital heritage that is a part of *living* heritage, and virtual heritage does not attempt to fully address both preservation and communication.

2. Virtual Heritage

Virtual heritage can be viewed as a fusion of virtual reality technology with cultural heritage content [Add08] [Rou00]. Stone and Ojika [SO08] have previously defined virtual heritage as:

... the use of computer-based interactive technologies to record, preserve, or recreate artifacts, sites and actors of historic, artistic, religious, and cultural significance and to deliver the results openly to a global audience in such a way as to provide formative educational experiences through electronic manipulations of time and space.

In order to address UNESCO requirements, I will extend the definition to cover intangible heritage, 'practices, representations, expressions, knowledge, skills – as well as the instruments, objects, artefacts and cultural spaces associated therewith – that communities, groups and, in some cases, individuals recognize as part of their cultural heritage [Une03].

The *London Charter* [Den09] defined computer-based visualization as '[t]he process of representing information visually with the aid of computer technologies.' Arguably, this definition implies visualization is only visual, and that all is required is to represent (in a visual format) content to an end user. However, this definition does not explain the cultural significance of the object or process simulated, and reasons for why it should be preserved and communicated.

In a book chapter written in 2008 [Cha08] I argued that that the purpose and significance of virtual heritage is clearer if we define it as 'the attempt to convey not just the appearance but also the meaning and significance of cultural artefacts and the

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associated social agency that designed and used them, through the use of interactive and immersive digital media.' I proffer this definition not to equate virtual heritage, digital heritage and new media, but to distinguish between the three terms.

New media is constantly changing and has an emphasis on how it can potentially suggest new perceptions and behaviour for end users. Digital heritage aims to preserve heritage content. So there is an implicit conflict here. Virtual heritage typically uses the latest technology, but as it tries to bridge both new media and digital heritage, it is unlikely to satisfy the requirements of both, at least not in fixed project form. Given the above, if new heritage is the application of new media to digital heritage then by extension the purpose of new heritage is to 'examine the user experience that digital media can provide for the understanding and experiencing of tangible and intangible cultural heritage'.

Yet there are important reasons for virtual heritage. Galleries, libraries, archive and museums (GLAM industries) can only display a fraction of the collections that they own and have access to. Museums simply lack the space to display many of their collection [Bai15]. Scholars have outlined other problems encountered in preserving cultural heritage in physical museums [Bra15] [Car12] [Csi14] [Lep15] [Wid14] [MJB12], but the issue affects more than just museum collections, there is also the issue of how heritage collections can be maintained, disseminated, improved upon and expanded. Digital technologies hold promise for expanding the public dissemination of knowledge associated with these collections even when physical access or the physical robustness of the artefacts is limited. Interactive media can also incorporate digital models into simulations that convey the contextual ways in which they may have been used by past and distant cultures.

In terms of infrastructure, the technology also helps content experts and scholars develop experiential ways to entice a new and extended audience to both admire the content and the methods of their area of research, while providing them with feedback mechanisms and community input that does not require physical visitation.

In Australia, the Commonwealth Scientific and Industrial Research Organization of Australia (CSIRO) has released a report [Csi14] stating 'Australia's cultural institutions risk losing their relevance if they don't increase their use of digital technologies and services.' Its Digital Productivity Flagship director, Michael Brünig [Brü15] stated that the Australian GLAM industry is worth 2.5 billion Australian a year, roughly only a quarter is digitized, and there is 629km worth of archival material [MWG*14]. Despite a shift to open access models and greater collaboration with the public, Brünig cautioned that there is an ongoing need to explore new approaches to copyright management that stimulate creativity and support creators.

3. The Importance of Infrastructure

Standard definitions of virtual heritage have emphasized the criterion of preservation, but most published examples of virtual heritage appear more focused on solving issues of acquisition, accuracy, and communication. Virtual heritage projects showcase new uses and potential of technology for cultural heritage, but the funding models and composition of project teams have had minimal usability evaluations and preservation strategies.

By contrast it may be argued that while virtual heritage has had muted success in showing how digital technology can provide insight into past cultures, as *digital heritage* it has been remarkably unsuccessful at saving its own showcase projects. Lost or currently inaccessible examples include *Rome Reborn* [DFM*10], *Beyond Space and Time* [IBM08]0, or the 1996-1998 *SGI Teotihuacan VRML 2.0* model, (partially online but with missing links at http://www.kith.org/logos/things/VRML/handbook/). Hal Thwaites [Thw13] summarized key critical issues for virtual heritage infrastructure:

In the very near future some critical issues will need to be addressed; increased accessibility to (and sharing of) heritage data, consistent interface design for widespread public use and re-presentations of work, the formalization of a digital heritage database, establishment of a global infrastructure, institutionalized, archival standards for digital heritage and most importantly the on-going curation, of work forward in time as the technology evolves so that our current digital, heritage projects will not be lost to future generations. We cannot afford to have our digital heritage disappearing faster than the real heritage or the sites it seeks to 'preserve' otherwise all of our technological advances, creative interpretations, visualizations and efforts will have been in vain.

There is indeed an international need to collate and store digital heritage models of heritage sites [Rei113]. We also lack a way to provide access to the models, sites and paradata (which the London Charter [Den09] defines as 'Information about human processes of understanding and interpretation of data objects'). Despite initiatives such as the London Charter [Den09] and the Seville Charter [LG11], there are few publicly accessible models [BRF*14] and few shared resources of standardized evaluation data. Scholars have complained about user experience issues and a scarcity of suitable pedagogical material [EP08]. They are also beset with a myriad of practical and technical problems, such as how to gauge the accuracy of the recording and modeling process from a single 3D mesh, or to judge the relative authenticity of the simulated material [DPV*12] [PNT*10].

Discussions of virtual heritage models are found in journals such as *Internet Archaeology, Journal of Computing and Cultural Heritage,* and *Digital Applications in Archaeology and Cultural Heritage,* but actual virtual heritage models are not so common. There are very few online and library-accessible depositories for virtual heritage models, and many of the academic research projects lack long-term infrastructure and preservation strategies. Yet infrastructure is critical if we are to sustain scholarly communication, enrich public involvement and consolidate the currently promised – rather than proven – *heritage* component of *virtual heritage.*

If we are serious in our aim to help the public understand and be involved in virtual heritage then the public need to understand the potential and limitations of the technologies as well. Workshops on 3D tools and software are required, which will allow communities, heritage groups and classrooms to learn from developing their own models and artefacts using free and open source game engines and 3D modeling tools. Further, the research and support of these infrastructures should be supported and rewarded by the academic community.

4. Issues in The Field

4.1 3D Models are Formatted to Disappear

Virtual heritage projects are typically composed of 3D models. Key features of the models should be that they engage the audience, are formative (allowing the audience to create test and share hypotheses), can be recycled and reconfigured, and are amenable to preservation. However, researchers have cast doubt on the ongoing reliability of 3D data for long-term preservation [Hav12] and have declared 'The possibility exists for precious and costly data sets to be lost on failed hard-drives, destroyed in floods or fires, or simply thrown out' [GB14].

A serious technical obstacle is the absence of a shared, secure, feature-rich format for 3D models [KFH09]. Although there are at least 140 file formats for 3D models [MB08] almost all have major issues in either access, reliability, longevity or range of features [KFH09]. Most research projects and publications that examine the usefulness of 3D file formats for virtual heritage appear to focus on .obj, .3ds, .u3d (which allows a 3D model to be embedded inside the .pdf file format), .o3d (a less well-known Google format which is now Open Source), .x3d (the successor to VRML), .ply and .stl for 3D printing (although Additive Manufacturing File Format (AMF) is an open standard with some advantages over .stl such as colour and textures, it is still not widely supported), or Collada's .dae format (originally a file format designed for easy transfer between different modeling applications).

There are powerful and free file format converters like MeshLab (http://meshlab.sourceforge.net/) but such projects require vigilance to ensure they are kept up-to-date with changes in file formats and there may be data loss in converting between ever-changing file formats. It may also be possible to preserve some formats by storing them in other formats and executables [Car12] but this is only a stopgap measure.

Which 3D format holds the most promise for virtual heritage projects? Choosing a format that is robust, durable, well supported, free, highly interactive, cross-platform, and easy to create or export to or export from is a serious challenge. Major 3D formats such as .unity, .dae, .3ds, .obj, .ply, .blend and .x3d all have their advantages and disadvantages, but it is risky to offer only one format.

However, we need to distinguish between a format to store models in an archive, and a format that allows people to immerse themselves in an online browser-based virtual environment. For example, .x3d (related to VRML) offers a stable environment. It is truly cross-platform, works well on the Internet and is free, but its functionality is limited and not many people are developing with it.

To make interactive 3D models available via the Internet, there are various commercial and open source game engines that have a range of features, 3D model libraries, examples and shortcuts to avoid extensive programming. Major common game engines that feature accessible editing and modding for communities include Unity, Blender, CryEngine and Unreal.

Another relatively recent option is WebGL, a JavaScript Application Programming Interface (API) that allows 3D interactive graphics (and 2D graphics) to work inside any major web browser requiring a plugin, three.js. The plugin will load .obj models into WebGL (http://threejs.org/examples/webgl_loader_obj.html) without requiring advanced programming. X3d models can run natively in HTML pages and Blender models will export directly to WebGL via Collada and three.js or via proprietary software (https://www.blend4web.com/).

Arguably, the most popular interactive game engine for virtual heritage is Unity. It is both relatively stable and very powerful and flexible, but the Pro version is considerably more expensive. Early formats might not be supported in the future by Unity. Other commercial game engine editors like CryEngine and Unreal 4-UDK have free versions but they also have cost / profit requirements based on the revenue from games sold, and they are under no obligation to ensure older versions are still being maintained.

Therefore, a proprietary 3D format is best avoided. If a game engine (a real-time rendering engine) is required, then a solution would be to have the game engine or application add the components (assets) dynamically, requiring the model to be broken up into subcomponents and then the computer would stream and connect to these subcomponents (packages) at runtime. There may also be a compromise solution that allows both a robust but limited 3D format for archived models and a more interactive format available either via a browser or as a downloadable application. An example of such a solution would be to archive models in, e.g., .x3d, but also provide an online converter or reformatter that can export from .x3d into, e.g., blender files (.blend) or text files that can be read by game engines.

4.2 Established Research Fields Use Metadata

A complementary issue to that of selecting appropriate formats and solutions for 3D models is how will we even find these models? We require metadata in the 3D models so we can find and classify them, an ontology of model components so we can find and label individual parts, a storage and retrieval system for the 3D models and a way of linking the models with external assets (other media assets as well as publications and papers).

Metadata is essential for virtual heritage to establish itself as a long-term research area, but metadata has to help the objectives of virtual heritage, which are arguably as much or more about education as they are about preservation. Earlier publications have suggested [TC11] virtual heritage projects should be based on care, accuracy, sensitivity, effective and inspirational pedagogical features, and that ideally they should be collaborative and evaluation-orientated.

4.3 Visualisation: More Than Presentation of Data

Even if we find and agree on a suitable 3D format, and even if we develop robust and open infrastructures to support these 3D models, we also need to leverage the potential of digital media to create new synergies between traditional forms of media. Many of the historic strengths of print-based publishing have now become cumbersome liabilities. Even digitized scholarly articles rarely allow interactivity, they are typically distributed in the PDF format and are plagued by its limitations (PDF files are slow, can crash the computer, take up valuable screen space, are confusing to annotate, and the only application to take full advantage of their features is expensive), and underlying data is seldom conveniently retrievable. Added to these issues is the undeniably messy reality of archaeological excavation and recording. For instance, Reinhard [Rei13] wrote:

Archaeology is messy, and it deals with three-dimensional artifacts in four-dimensional space-time. Its publications should reflect that ... Our new publications must incorporate all of these elements to create a record and interpretation of what we have discovered, leaving that data and interpretation open to criticism, dialogue, and growth over time. ...

There are two major issues that all publishers of archaeology (and of scholarship generally) must address now:

1) how to publish archaeology online, moving away from a traditional, two-dimensional, print-informed model, toward a multi-dimensional, interactive one that accepts that archaeological data is messy and continues to grow and change over time, and

2) how to publish archaeology in an open fashion that makes content easily discoverable and immediately accessible, promoting linking from external sources while linking itself to other open online resources [Rei13].

4.4 Repositories and Portals Require Inclusivity

We now have many institutional repositories for academic publications and scholarly collections. Despite recent European and North American moves to create archives and digital humanities infrastructures 3D models have not yet been fully incorporated into these new infrastructures while allowing full public access [Hug12]. For example, a major EU project, CARARE, created a common library format of 3D models but they were trapped inside the Adobe PDF format so people could not modify and develop their own content, and the model did not dynamically link to the scholarly information that made the model possible.

Commercial model repositories offer very consistent formats and protocols for disseminating downloadable models, but these models are either trapped inside a proprietary format that is designed to prevent flexible use, are expensive, prohibit modification and future commercial use, or their accuracy and quality cannot be verified before purchase. Further international efforts to remedy the above issues include work by 3D Icons (3D HOP) in CIDOC CRM, Europeana, Smithsonian Institute X3D BETA, Fraunhoefer (X3DOM ON GITHUB), Ariadne, EU EPOCH, and V-MUST.

Although there are interesting prototypes and selective web-based prototypes (such as http://vcg.isti.cnr.it/3dhop/ and http://www.3dicons.ie/3d-content) and online commercial suppliers of 3D models of varying quality and accuracy, there is no standard thematic research repository or national data service for 3D heritage models that I have been able to find in the Pacific region or relevant heritage content from overseas websites. While in Europe, ARIADNE and 3D-ICONS are developing standards and archives that may help provide some of the answers, in many other regions there are very few accessible 3D models of heritage sites that use a common, stable format.

Recent European trends are to create archives and digital humanities infrastructures but 3D models have not kept up with the progress achieved for other formats of cultural heritage, they are still silos. In the Europeana portal one can search by media type, in this case, 3D. As Europeana is both a portal (http://www.europeana.eu/portal/) and a platform, one is taken to an external website without knowing if the 3D model can run in the browser or requires specialist equipment (for example, please view the artefacts at http://public.cyi.ac.cy/starcRepo/explore).

There are other interesting 3D model portals for cultural heritage institutes such as the Smithsonian but they do not clearly allow for downloadable usage or explain carefully any cultural protocols that need to be associated with the ways in which the 3D models can be used (http://3d.si.edu/). On the other hand, portals can assemble disparate information conveniently and in a more useful standardized format, they attract more visitors than individual sites, and provide larger amounts of web-traffic statistics. They can also allow shareholders to retain original assets while appearing as part of a greater whole.

There are exciting new developments: such as topoi, which provides citable research data (http://repository.edition-topoi.org/); the inclusion of 3D data in the Archaeology Data Service ADS), United Kingdom (http://archaeologydataservice.ac.uk/); Sketchfab, which publishes a large range of 3D interactive models that can be viewed in different contexts including Google CardboardVR (https://sketchfab.com/); and 3Dhop, an "open-source software package for the creation of interactive Web presentations of high-resolution 3D models, oriented to the Cultural Heritage field" (http://3dhop.net/). However, we still need these portals and repositories to provide clearer examples and workflows, or demonstrate how to demarcate levels of accuracy and authenticity.

4.5 End-users

It may appear that the overall number and difficulty of technical issues is the major problem to resolve, but if there is no public involvement, understanding and appreciation, the virtual heritage project has failed *despite* any technical brilliance or infrastructure support. Indeed, infrastructure that is not used is not really infrastructure, it is merely equipment. Previous writers have written convincingly of the importance of archives [LPW*10] but there is another important step, ensuring the archive is effectively used. As Garnett and Edmond [GE14] have declared, 'Building an API is not enough!' The success of virtual heritage projects (at least as we have defined at the start) is thus dependent on community involvement, which includes scholars, students, the wider public, but also the original shareholders and owners of the cultural content simulated.

As we develop models, frameworks and infrastructure we may need to consider how to approach indigenous heritage individuals and group regarding access to the recording and dissemination of specific cultural heritage content. These considerations may require:

1. Involvement with indigenous shareholders and experts in the development of guides and protocols and the sensitive development of digital heritage knowledge
2. Exploring digitally filtered ways of creating accessible layers and levels of cultural knowledge
3. Researching and testing a method for providing on-demand 3D model formats where the level of access can determine the accuracy and resolution of the generated model to suit the copyright and ownership requirements of the owners and creators while providing a pre-determined level of public knowledge

4. Tailoring digital ontologies, indigenous record collection metadata and folksonomies to specific aspects of heritage simulations
5. Developing new forms of copyright permissions that are relevant to the cultural significance and guardianship of the heritage objects depicted.

Where tutorials, tools, and training materials are to be developed for indigenous communities or for using with indigenous content, they should be developed after consultation with relevant research conduct policies and ethical guidelines. In Australia this may mean following documents like the *Guidelines for Ethical Research in Australian Indigenous Studies* (GERAIS) and the *UN Declaration on the Rights of Indigenous Peopl*es (UNDRIP) with awareness of and commitment to free, prior and informed consent protocols that will address Intellectual Property issues, copyright requirements and other related permissions (such as for multimedia and other media content).

5. Addressing Infrastructure Requirements

5.1 From Aims to Objectives

Earlier publications have suggested [TC11] virtual heritage projects should be based on care, accuracy, sensitivity, effective and inspirational pedagogical features, and that ideally they should be collaborative and evaluation-orientated. Extrapolating from these aims, I suggest the following features are desirable for designing 3D virtual heritage models or for developing an infrastructure that can support virtual heritage models for the purpose of classroom teaching and public dissemination. This requires further evaluation, surveys, and discussions with educational groups and the GLAM sector, but below are suggestions to consider:

1. Data accuracy: the level of accuracy and type of data capture method should be documented and associated with the model, as well as the geographical location
2. Format limitations: any known limitations or required conditions due to the digital format or way in which the data was created, should also be associated with the model
3. Provenance: the record of ownership and scholarship and community input should be recorded and accessible (the source and the ownership rights)
4. Community protocols: social, cultural and institutional protocols that guide who accesses the sourced cultural heritage and how that should affect the transmission, distribution and dissemination of the digitally simulated model
5. Authenticity: the known, extrapolated, omitted, simplified and imagined areas and components of the model should be identified in some form of thematic (and preferably standardized) schema
6. Cultural presence: models should aim towards explaining the cultural significance of the original site, and give an impression of the situated cultural value of the place as experienced by the original inhabitants.
7. Evaluation Data: these aims should be clearly explained and any evaluation data of participants should be linked to (or otherwise associated with) the models
8. Purpose: the generic ways in which original creators and shareholders intended the models to be edited or otherwise modified could be described in accompanying text.

5.2 Useful Metadata

The first three considerations (and perhaps all of the others, especially 5: Authenticity) require the careful and appropriate use of metadata. As Wise and Miller [WM97] have noted, metadata ('data about data'), allows users to be informed without having to access the entire body of data, it helps them find information and it helps them to group and link 'bodies of information' together. However, what is still missing in this field are tools that allow people to search across projects and related data using metadata, which is also typically scattered and heterogeneous.

An example of a community-agreed standard might be the definition of CARARE Schema [DF13] [Fer13], a metadata schema inspired in part from CIDOC-CRM, (which is arguably the best-known cultural heritage ontology framework [GN13] and comparable to Addison's proposed metadata [Add08].

Although the CARARE metadata schema includes a separate Global Information element that holds additional information (record information, appellation, rights, temporal and spatial information, actors, contacts, addresses and a publication statement), I would suggest one further addition: part of the metadata should record the significant cultural heritage features noted above, and the reasons why that heritage environment or artefact deserves to be preserved, simulated and communicated. [DF09] [GM09] [HK08].

Critics may point out that many content creators do not add useful standard metadata but that is explained in part by the lack of simple tools that help content creators to access and add to existing heritage collections. However, there is a new development, Cultural Heritage Markup Language, which might bridge the gap between virtual heritage projects and metadata [MKP*15].

5.3 Scholarly Appraisal of VH Infrastructure

Bilder, Lin and Neylon [BLN15] wrote:

What should a shared infrastructure look like? Infrastructure at its best is invisible. We tend to only notice it when it fails. If successful, it is stable and sustainable. Above all, it is trusted and relied on by the broad community it serves. Trust must run strongly across each of the following areas: running the infrastructure (governance), funding it (sustainability), and preserving community ownership of it (insurance).

I distinguish between hard infrastructure (equipment) and soft infrastructure (people), as both are necessary [Got11]. A digital humanities infrastructure will not survive for long if it does not create effective synergies between equipment and people. While some scholars in the digital humanities have argued that research infrastructures are not research per se [Roc10], this appears to diverge from the *European Research Infrastructure Consortium* (ERIC) practical guidelines. The guidelines clearly state [Erc15] that 'the ERIC status is reserved for state-of-the-art research infrastructures that will create unique opportunities to carry out advanced research, attract the best researchers from across the world and train highly qualified students and engineers'.

So a successful scholarly virtual heritage infrastructure could be assessed in terms of how it supports new research and grants and how it is used to provide evidence for academic esteem and promotion.

How could a virtual heritage infrastructure help scholarly review of the projects themselves? It could provide a systematic way to show changes over time, allow for viewing on different formats for varying input mechanisms and learning mediums, allow counterfactual exploration, log user responses, track user preferences and share insights and personal feedback from distributed audiences. So, it could help content creators assess impact, usability and usefulness automatically, and allow for benchmarking against other projects.

Ideally, it would also augment *scholarly research of the content*, providing associated tools, interpretative mediums and careful references as well as usage data that could provide evidence for solid scholarly arguments.

Above all, it would be an *ecosystem*. All its parts would be interdependent, and it would hopefully be greater than the sum of its parts. A review community would be summoned to discuss and add to the models via publications and related links, and future publications could in turn integrate the community feedback into new research findings, improved critiques, and an enhanced research base.

5.4 Dissemination

Much of today's heritage resources are text, and two-dimensional. Heritage studies research requires a way of fostering and including community engagement and scholars may appreciate a way of creating visual scholarly arguments that allows feedback from their colleagues and from the general public.

Even if we find a good range of heritage models that are reliably stored and have provenance data and allow scholars to edit and modify them, we have a further problem. Current examples lack initial meaningful context, audience feedback, updated and maintained content. With web archives of tools and models there is simply no consistent way for the public to provide feedback.

The development of low-cost and accessible virtual heritage equipment is still around the corner, hence it makes more sense to develop digital heritage resources that will be able to be used as content and context when tomorrow's immersive technologies finally take hold in the general public.

Three major trends could prove to be of great import to the scholarly and general public here. Firstly, VR equipment is moving towards the consumer level, based on the notion of a component based system whereby your smartphone is both the stereoscopic viewer, and the computer (such as in the case of the Samsung Gear). Such consumer technology frameworks will help VR technology and related content become far more accessible.

Secondly, there are research groups now so concerned at the silo mentality of earlier virtual heritage projects that they are developing either technology solutions that allow people to create their own content using free and open source technology such as the EU CHESS project [PRP*12], or technical exemplars using free software that others can download and modify and thus learn from, for example, CINECA's APA reusable game project using Blender 3D [GLF*14].

Thirdly, journals are beginning to provide technology that allows authors to add 3D models inside or next to text-based articles. Two journals that come to mind are *Internet Archaeology*, (http://intarch.ac.uk/) and *Digital Applications in Archaeology and Cultural Heritage* (http://www.journals.elsevier.com/digital-applications-in-archaeology-and-cultural-heritage/).

Current journals that feature scholarly papers and 3D models typically lack integration with text resources, and they also have limited interactivity and immersion (for example, refer https://www.elsevier.com/books-and-journals/content-innovation/interactive-u3d-models). If on the other hand we create dynamic links between 3D models and 2D assets (text and other media), then it may be possible be to develop evaluation mechanisms to understand how the viewed and downloaded heritage models and simulations are used and critically reflected on.

Imagine a publication system which is actually a framework dynamically drawing on various media components through assigned URIs. A Linked Open Data journal-publishing framework (like http://scalar.usc.edu/ or a communal blogging and publication framework (like http://www.openeditions.com/) could dynamically link to URIs of 3D projects. Archaeology requires a way of updating and augmenting information [Dal15a] [Dal15b].

In the proceedings of the *2015 Computer Applications and Quantitative Methods in Archaeology (CAA2015)* conference, there has been an increase of papers on Linked Open Data. There is still research to be undertaken on systematic ways for Linked Open Data to connect text files with 3D models. However, we also need to develop ways of dynamically linking models and subcomponents of models to dynamic but stable documentation on the Internet [HI11]. This could be a dynamic two-way link that would link text, 3D models, other media, and community feedback (scholarly reviews, classroom projects that expand, review and comment on the material).

5.5 A Virtual Heritage Exemplar

In general, virtual heritage projects are monolithic, not traceable, not reconfigurable, not easily preserved, and do not link to external 2D material either statically or dynamically. Because of their inherent resistance to reconfiguration or to added audience feedback these projects do not have strong ongoing community reach, support and input. A cross-platform long-term robust solution that has good community support, and a flexible, richly interactive feature list does not yet appear to exist.

To address these needs, I propose the adoption of a component-based system that can load a robust file format and add links and media assets to create a dynamic and interactive online environment that can be taken apart and further modified by the public (such as CINECA's Bologna project mentioned previously). Ideally, the Web model can include specific camera angles that can be triggered by scripts or other cues in case the viewer wishes to be guided through the simulation. Both the holding page of the archived model and the Web model should provide suitable metadata and includes provenance metadata [Hug12]. The models stored in the system would also link dynamically to external scholarly repositories. If there are shareholder requirements that stipulate copyright ownership of the high-resolution model, an agreement could be negotiated so

that a lower resolution model or a model with reduced interac-interaction features is provided to the public.

5.6 Criteria For Virtual Heritage Models

1. As a core part of a scholarly ecosystem [DPM*14], the 3D model should be traceable; it should link to previous works and to related scholarly information.
2. The model should be component-based so that parts can be directly linked and updated. Web models would be dynamically created at runtime.
3. The model should be engaging, thus extensive play-testing and evaluation will be required to ensure that it actually does engage its intended audience.
4. As part of a scholarly infrastructure, the 3D model format (and all related data formats) should be easy to find and reliable.
5. The model should not require huge files to download, or it should at least provide users with enough information to decide whether and what to download.
6. Metadata should record the completeness, measurement methodology and accuracy of the models
7. The model must provide some degree of access and feedback from the wider public or specialized interest groups and shareholders.

6. Conclusion: Scholarly Infrastructure

There are four main arguments in this paper, based on four issues concerned more with the infrastructure than the individual technological progress of virtual heritage as individual projects. This paper further contends that the majority of publications and projects in the field have not addressed these issues.

Firstly, I suggest that there is still much research and scholarly activity to be undertaken in the area of virtual heritage, but not merely to explore technological possibilities. The field lacks clear aims agreed upon by the relevant research communities, and scholarship is hindered by the lack of relevant, accessible and useful data.

Secondly, I have suggested that scholarship requires suitable infrastructure that supports such research data. I provided some potential criteria and recommended features that will hopefully generate debate and discussion.

Thirdly, I have argued that virtual heritage infrastructure is still in its infancy as it has typically been seen as individual projects rather than a framework that supports both software and hardware components.

But my fourth point is perhaps the most important of all. I have claimed that even if virtual heritage addresses the above three major issues, it will still fail as an infrastructure if it does not engage and provide feedback to communities of user that can meaningfully engage with both the modelled content and the research questions and research findings that driven the development of that modelled content. This claim may be refuted by the statement that is infrastructure is based on equipment rather than on providing skills and facilitating engagement but such a claim raises a further question: why should we fund equipment for the preservation, maintenance and scholarly research of cultural heritage if it is not effectively used?

To answer the above issues, I have made three general recommendations.

Firstly, I have outlined simple beginning criteria for the development of a framework that supports 3D heritage projects rather stipulates a single, fixed technical implementation. This framework would probably be a dynamic and distributed system that connects to, converts and uploads in real-time, and could link to various scholarly material available via the World Wide Web, and organized as Linked Open Data.

However much work is required here, not so much in terms of Linked Open Data and the Semantic Web, but in providing clear and convenient tools and examples that save content creators time and effort. And these 3D models and related paradata and other resources should also include and link dynamically to scholarly publications in a way that does not diminish the usefulness of the models and related media assets.

Secondly, to promote research and engagement in the field of virtual heritage, more of us must try to raise the level of critical review of virtual heritage projects with the aim to develop a shared understanding of the best practices and protocols to develop, support and maintain virtual heritage in terms of both preservation and communication (particularly, education).

To that end I argued that research infrastructure is itself infrastructure, however, this point is not critical to my overall argument. More importantly, however, we need to cooperate in developing criteria in order to appraise both virtual heritage infrastructure and virtual heritage projects which leverage that infrastructure but we also need to increase the quantity and quality of critique and commendation of these appraisal criteria. This may require institutional, government, and industry support for national and international awards, and the media coverage required for dissemination news of these awards and prizes and the reasons for their success. A more immediate step may be to agree on the ways in which development of 3D models is also research output, and grounds for academic promotion (and ways to do this are developing in the Digital Humanities community).

My final recommendation is that we must endeavor to improve the evaluation and feedback of virtual heritage projects, not only in terms of the immediate usability of various technical solutions, but also their usefulness in regards to the goals of UNESCO and related cultural heritage organizations.

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