Chapter 2

The Role of 3D Models in Virtual Heritage Infrastructures

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Introduction

The success of virtual heritage projects, through the careful inspection, contextualization and modification of 3D digital heritage models with virtual reality technology, is still problematic. Models are hard to find, impossible to download and edit, in unusual, unwieldy or obsolete formats. Many of the freely available models are standalone 3D meshes with no accompanying metadata or information on how the acquisition of the data. Few have information on if or how the models can be shared (and if they are editable). Fewer still quantify the accuracy of the scanning or modelling process, or make available the scholarly documents, field reports, photographs and site plans that allowed the designers to extract enough information for their models.

Where there are suitable models in standard formats that are available from repositories, such as in Europeana library portal, they are likely to be in unwieldy 3D Formats. For example, 3D models encased in the proprietary PDF format cannot be extended, altered or otherwise removed from the PDF. Part of the problem has been with the development of virtual heritage; part of the problem has been due to a lack of necessary infrastructure. In this chapter, I will suggest another way of looking at virtual heritage, and I will promote the concept of a scholarly ecosystem for virtual heritage where both the media assets involved and the communities (of scholars, shareholders and the general public) are all active participants in the development of digital heritage that is a part of *living* heritage.

Virtual Heritage

Nearly two decades ago, experts defined virtual heritage as a fusion of virtual reality technology with cultural heritage content (Addison 2000; Addison et al. 2006; Roussou 2002). Stone and Ojika (Stone and Ojika 2000) 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.

Many of the most famous and ambitious virtual heritage projects are digital simulations of UNESCO world heritage sites, yet the definitions do not explicitly address UNESCO's definition of intangible heritage. UNESCO defined intangible heritage as: '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' (UNESCO 2003). I suggest extending the definition to virtual heritage, to address the concerns of intangible heritage, because if we do not create simulations of our understanding as to how artefacts and sites (buildings and landscapes) were used, treasured and cared for, the public may not appreciate the cultural significance of the heritage site or object. Virtual Heritage Environments (VHEs), in particular, can display content in new and more experientially appropriate ways, bridging disparate collections and remote sites with the intangible heritage of the original shareholders (such as oral history, mythology and other cultural beliefs and traditions) beyond the physical constraints of the real world. Ideally, VHEs help the public to

- Create, share and discuss hypothetical or counterfactual places
- Meet virtually in these places with colleagues to discuss them
- Contextually understand limitations forced on the original inhabitants of the simulated environment.

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.

Despite recent technological advances, simulating intangible heritage with digital media is not trivial. Creating a visual and photo-realistic simulation can be misleading, people did not live in photographs, they *inhabited* space. Hence I take a wider and more inclusive view of visualization than the visual even if important virtual heritage charters like the *London Charter* (Denard 2009) define computer-based visualization as '[t]he process of representing information visually with the aid of computer technologies.' Virtual heritage is *not* simply the recreation of what used to be there, a collection of objects. Cultural objects had specific and situated meaning in terms of the cultural perceptions of the land's traditional inhabitants so digital reproducing how they may have looked as pristine artefacts is not enough, it only conveys what was left, not what was used and why it was valued. We must also convey the specific and situated importance of that cultural heritage to the public because UNESCO World Heritage awards heritage status for objects and sites of unique value.

In a book chapter written in 2008 (Champion 2008) I suggested that virtual heritage is 'the attempt to convey not just the appearance but also the meaning and significance of cultural artefacts and the associated social agency that designed and used them, through the use of interactive and immersive digital media.' I defined new media (Champion 2008) as 'the act of reshaping the user experience through the innovative use of digital media.' New media is thus a part of but not directly synonymous to digital heritage for new media is constantly changing and so the way it is used and appreciated by the end user is also constantly changing.

If we are examining the end user experience of virtual heritage and in particular, how the end user is affected by changing experiences predicated by evolving technology, we could call this phenomenon new heritage. 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'. However, it is not just the user experience of virtual heritage that requires constant review, the development of virtual heritage as an academic discipline and particularly as scholarly

infrastructure is seldom discussed, the aims and objectives are assumed to be shared and understood. In an article I co-authored with Laia Tost (Tost and Champion 2011), we identified six aims for the scholarly development of virtual heritage:

> Firstly, it should aim to carefully capture objects and processes of scientific, social or spiritual value. Secondly, it should present this information as accurately, authentically, and engagingly as possible. Thirdly, it should attempt to distribute the project in a sensitive, safe and durable manner to as wide and long-term an audience as possible. Fourthly, it should aim to provide an effective and inspirational learning environment that best communicates the intended pedagogical aims. Fifthly, it should allow the possibility to participate in its construction. Finally, it should attempt to carefully evaluate its effectiveness with regard to the above five aims in order to improve both the project and virtual heritage in general.

The above aims are more pedagogically focussed than the earlier definitions, because there is no educational impact gained from records and collections hidden from the public. Yet galleries, libraries, archive and museums (GLAM industries) can only display a fraction of the collections that they own and have access to. Many museums lack the space to display the majority of their collection (Bradley 2015) and there are a myriad of other problems to be faced when preserving cultural heritage in physical museums (Baio 2015; Barsanti et al. 2014; CSIRO 2014; Lepore 2015; Michaelis et al. 2012; Widdowson 2014).

There are logistic challenges with physical collections but also conceptual challenges in how heritage collections can be maintained, disseminated, improved upon and expanded in the face of changing markets, budgets and technology. Digital technologies hold obvious promise for expanding the public dissemination of knowledge associated with these collections even when physical access of the artefacts is restricted or their physical constitution is fragile, but the potential of digital media is limited when designers do not maximize the pedagogical impact of virtual heritage projects by selecting appropriate interaction. Digital models become meaningful simulations when they convey the culturally contextual ways in which they may have been used by past and distant cultures.

Why is Infrastructure Required for Virtual Heritage?

Previous definitions of virtual heritage have emphasized the criterion of preservation, but I suggest (with reluctance) that virtual heritage has been focused more on communication than on preservation; it showcases 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. Unfortunately, while virtual heritage has had muted success in showing how digital technology can provide insight into past cultures, as *digital heritage i*t has been remarkably unsuccessful at saving its own showcase projects. Lost or inaccessible examples include *Rome Reborn* (Dylla et al. 2008), *Beyond Space and Time* (IBM, 2008), 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 (Thwaites 2013) is even more damning in his assessment of the current situation:

> *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 a global imperative to collate and store digital heritage models of heritage sites (Reinhard, 2013). We also lack a way to provide access to the models, sites and paradata (which the London Charter (Denard, 2009) defines as 'Information about human processes of understanding and interpretation of data objects'). Despite initiatives such as the *London Charter* (Denard 2009) and the *Seville Charter* (Lopez-Menchero and Grande 2011) as there are few publicly accessible models (Barsanti et al. 2014) shared standardized evaluation data are hard to find. Scholars have complained about user experience issues and a scarcity of suitable pedagogical material (Economou

and Pujol 2008). There is also a myriad of practical and technical problems, such as how we are to gauge the accuracy of the recording and modelling process from a single 3D mesh, or how we are to judge the relative authenticity of the simulated material (De Reu et al. 2012; Pitzalis et al. 2010). Discussions of virtual heritage models are found in journals such as *Journal of Computing and Cultural Heritage,* but actual virtual heritage models are much more difficult to find. 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 helping the public understand and participate 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 modelling tools.

Desirable Features of Virtual Heritage Projects

3D Models

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. It might seem opportune then to digitalize everything one can afford but the reliability of 3D data for long-term preservation is an ongoing issue: ‘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’(Greenop and Barton 2014).

Formats are another issue (http://pvw.illinois.edu/pvw/) in the field of computer games researchers have even gone so far as to preserve the entire original game by wrapping it as an executable inside another programme (Carroll 2012). Sven Havemann (Havemann 2012) went so far as to complain:

> The file format problem is maybe today the most annoying obstacle for a further spread of 3D technology. Most of the aforementioned sophisticated shape representations can simply not be stored due to a lack of a common file format. The menace of file format degradation makes sustainable 3D only an illusion.

I find it difficult to disagree. A serious technical obstacle is the absence of a shared, secure, feature-rich format for 3D models (Koller et al. 2009). Although there are at least 140 file formats for 3D models (McHenry and Bajcsy 2008) almost all have major issues in either access, reliability, longevity or range of features (Koller et al. 2009). 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), or Collada's .dae format (originally a file format designed for easy transfer between different modelling applications). Luckily, there are powerful and free file format converters like MeshLab (http://meshlab.sourceforge.net/).

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, .blend and .x3d all have their advantages and disadvantages, but it is risky to offer only one format. At the time of writing, I suggest that the most promising file formats for archiving of 3D file formats and for simple web-based viewing of the 3D models would be obj, .x3d, or .dae. 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 and a successor to VRML) offers a stable environment, is truly cross-platform, works well on the

Internet and is free, but its functionality is limited and there are still relatively few exemplars and showcases.

To make interactive 3D models available via the Internet, various commercial and open source game engines have a range of features, 3D model libraries, examples and shortcuts to avoid extensive programming. Major common game engines that feature accessible editing and mudding for communities include Unity, Blender, CryEngine and Unreal. Most of these game engines can run as standalone applications, as web plugins, and across a range of devices (desktop and surround computers, specialized stereoscopic surround display screens, smartphones, and game consoles). 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 (and there are methods to export to Collada format). X3d models can run natively in HTML pages and Blender models will export directly to WebGL using Blend4web (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. Unity formats might not support such formats in the future. 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.

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. In a previous section, I mentioned six aims for virtual heritage projects: care, accuracy, sensitivity, effective and inspirational pedagogical features, and they should be collaborative and evaluation-orientated (Tost and Champion 2011). 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:

(1) Data accuracy: the level of accuracy and type of data capture method should be documented and associated with the model (and, if possible, 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 included 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 regulate 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.

The first three considerations (and possibly all of the others, especially 5: Authenticity) require the careful and appropriate use of metadata. As Wise and Miller (Wise and Miller 1997) 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. In 2008, Addison (Addison 2008) proposed the following list of virtual heritage metadata elements:

Type	#	Data Encoding/Format
What	i.	HeritageID (a superset of existing WorldHeritageID)
	ii.	Title/brief description
	iii.	Heritage Type/Classification (e.g.: cultural: archaeological …)
	iv.	Heritage Time Period (e.g.: geologic or historic time)
	v.	Heritage Time Span
Why	vi.	Purpose (reason recorded/produced)
How	vii.	Recording Device Parameters (type, sample rate, precision …)

	viii.	Secondary Device(s) (data manipulation)
	ix.	Environmental conditions
Whom	x.	Submitter and Date of Submission
	xi.	Rights given/withheld
	xii.	Author/Copyright Holder
	xiii.	Sponsor/Funder/Client
When	xiv.	Date (of recording, manipulation)
Where	xv.	Location (Latitude/Longitude + compass direction if applicable)

Although I disagree with their initial selection of 3D-PDF (.pdf) as a file format, a notable success of the CARARE consortium (D'Andrea and Fernie 2013) was the definition of CARARE Schema (Fernie 2013). This metadata schema was inspired in part from CIDOC-CRM, which is arguably the best-known cultural heritage ontology framework (Geser and Niccolucci 2013) and inspired in part by the MIDAS UK metadata standard. It is interesting to compare the list of elements in CARARE Schema (Heritage Asset Identification Set, Digital Resource, Activity, and Collection Information) with Addison's proposed metadata. 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 culturally significant cultural heritage features noted above, and the reasons why that heritage environment or artefact deserves to be preserved, simulated and communicated (Dappert and Farquhar 2009; Hockx-Yu and Knight 2008; Knight and Pennock 2009).

Connecting to Text and other Digitalized Resources

Even if we agree on a suitable 3D format supported by a robust and open infrastructure, 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 (Reinhard 2014) 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.

How can we link 3D models to library and archival systems holding scholarly literature and multimedia resources that communicate important historical and cultural aspects of the simulated heritage site? Current journals that feature scholarly papers and 3D models typically lack the capability to integrate with text resources, and have limited interactivity and immersion (Elsevier undated). 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.
Do we have feasible options to achieve this? Consider a publication system which is actually a framework dynamically drawing on various media components through assigned URIs in other words, a library of Linked Open Data). It could be a journal-publishing framework (like http://scalar.usc.edu/) or a communal blogging and publication framework (for example,

http://www.openeditions.com/), which would dynamically link to URIs of 3D projects. Archaeology also requires a way of updating and augmenting information (Dallas 2015, 2016) while heritage studies research requires a way of fostering and including community engagement. I am also convinced that scholars would appreciate a way of creating visual scholarly arguments that allows feedback from their colleagues and from the public.

Repositories

I think is fair to say that 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 (Huggett 2012). For example, a major EU project, CARARE (discussed earlier), 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 (discussed in the final chapter), Smithsonian Institute X3D BETA, Fraunhoefer (X3DOM ON GITHUB), Ariadne, EU EPOCH, and V-MUST.

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. 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.
For example, in Australia we simply do not have a shared data infrastructure service that is providing specialized support for 3D archaeological and heritage data. Yet the Commonwealth Scientific and Industrial Research Organization of Australia (CSIRO) has released a report (CSIRO 2014), stating 'Australia's cultural institutions risk losing their relevance if they don't increase their use of digital technologies and services.' Michael Brünig (Brünig 2014) noted that while the Australian GLAM industry is worth 2.5 billion Australian a year, roughly only a quarter has been digitized. This is why we look to Europe for inspiration.

Portals

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 (http://www.europeana.eu/portal/) one can search by media type, in this case, 3D. As Europeana is both a portal and a platform, the website visitor can be 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 websites 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/). The Smithsonian http://3d.si.edu/ website is in a sense also a platform, it provides 3D tools to edit and build with, but it is not complete platform in terms of infrastructure, it is one way. Users can play with 3D models, sometimes edit them, sometimes download them, but they cannot permanently alter what stays online in the website database and the digital 3D model does not provide full archival records or other information resource links.

Portals, unlike platforms, merely collect or link to other sites and resources, they don't provide their own tools and resources to build things with. They still have their uses, 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 (individual website owners) the ability to retain original assets while appearing as part of a greater digital collection.

Augmented Reality

Twenty years ago, Ron Azuma (Azuma 1997) published a survey on augmented reality (AR), contrasting it with Virtual Environments (VE) and virtual reality (VR). In that paper Azuma declared that unlike VR, AR supplements the real world, superimposing virtual objects on the real world, or compositing virtual objects on the real world. Today's AR phone applications do not really qualify, they do not use computer vision to merge 3D data, they simply rely on the GPS tracking of the camera. Even with this less sophisticated and less spatially immersive technology, the potential for virtual heritage is obvious (Billinghurst et al. 2015; Chung et al. 2015; tom Dieck and Jung 2015). Augmented reality does not have to create or recreate an entire scene, and it can now be carried on consumers' mobile phones because it does not require the same graphic rendering as a full virtual reality environment, and it can range in complexity from augmented avatars that appear on your phone or head-mounted display (HMD) to text labels on the screen of a phone camera, appearing to float above real-world objects (Dredge 2011). There are even research projects examining how AR can integrate with museum collections (Kraemer and Kanter 2014) and community-based projects (Speiginer et al. 2015)

In 2016 I was invited to UCLA for the second National Endowment of the Humanities (NEH) *Advanced Challenges in Theory and Practice in 3D Modeling of Cultural Heritage Sites* week-long workshop. At the first workshop, in 2015 at the University of Massachusetts Amherst, some of the participants decided to start or continue augmented reality history and heritage projects, the

technology looked fascinating. Many AR applications could be used on Android or iOS phones, some were free, some had clear and easy to use examples, and the increasing power and ease of phone-based cameras along with their increasing computational power and GPS accuracy. The recent craze of Pokémon Go (Moskowitz 2016) may have also convinced heritage professionals of a huge potential education and cultural tourism market. In terms of technological promise, the rise of software such as Layar (https://www.layar.com/), Aurasma (https://www.aurasma.com/), Vuforia (https://www.vuforia.com/), along with suitable archaeology, museum, heritage and history case studies, seems to bear this out.

Nevertheless, in terms of infrastructure, augmented reality is a quagmire. When I visited the NEH workshop in 2016 (I could only attend the 2015 workshop virtually), I was surprised by the number of educators and designers who had run into major issues with augmented reality heritage projects. In this field, we are all used to strange formats, unreliable software, bad user documentations, and the collapse of certain software. What was new to me was the scale of the augmented reality company failures. In some cases, the software would store al digital media assets on the cloud (on distant servers). However, when the software disappeared, so did the original data! As free software, the companies had not made the transfer and secondary storage of digital media projects or the digital media assets convenient, or, in some cases, even possible. Obscure formats, hidden files, incompatible version updates, these are all common when taking up new software, the hype cycle of new technology can be seductive (Gaudiosi 2016; Gilbert 2015; Mainelli 2016). But not being able to access the data created by the user? This was clearly a failure of infrastructure.

While the online press predicted a future where AR made screens vanish in the real world (Chapman 2016), the AR products or even AR companies were the ones doing the vanishing (Miiler and Constine 2015). As Ogden (Ogden 2015) notes, commercial AR products are walled gardens, with little in the way of shared standards.

The lesson learnt here: compose your content online, have it stored in the cloud, and when the software changes or the company goes bankrupt or is sold to an even larger company, be prepared

not only to lose your project, but also the digital media assets that made up that project. It is always desirable to acquire software from a proven, reliable company that allows the user to store the project and assets offline, provide and accepts standard formats, can be linked to other media and other referencing systems, and has the ability to export in different formats.

A Digital Scholarly Eco-system for 3D Digital Heritage

Yet even if we find robust technology and a good range of heritage models that are reliably stored, have provenance data, and allow the community to edit and modify them, we have a further problem. Current examples lack initial meaningful context, audience feedback, updated and maintained content. Despite a plethora of web archives of digital tools and models there is simply no consistent way for the community to provide feedback. We need to develop ways of linking 3D models back to the scholarly resources that created them and inform them.

In the proceedings of the 2015 *Computer Applications and Quantitative Methods in Archaeology (CAA2015)* conference, I noticed an explosion of papers on Linked Open Data. Before too long, we should see systematic ways for Linked Open Data to connect to the text files associated 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 (Haslhofer and Isaac 2011). This should 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). Furthering the development of a digital heritage journal requires the support of a community of specialists. For example, it could necessitate incorporating the taxonomy research of CIDOC and NeDiMAH, the 3D tools directory of DiRT Bamboo, the projects and community of DHCommons and centerNet, and international networks of digital humanities centres. What would or could such a system be? Could tools, methods, projects, scholarly communities and an open access online journal-publishing system exist to communicate between and beyond digital research

infrastructures, versed in text or in 3D models? Could active communities be encouraged to adopt and extend this 'ecosystem'?

More specifically, how could it benefit research and practice into digital heritage? What are the specific needs and challenges of digital cultural heritage? Which components, user requirements, and test beds should be addressed if such a scholarly ecosystem is to benefit digital cultural heritage?

Given that I had already proposed a definition of virtual heritage, why have I returned to the concept of digital heritage here? Much of today's heritage resources are text, and two-dimensional. 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. Digital heritage can provide dynamic content to Virtual Heritage, but it should be separated in name and in practice from the latter, for the latter undergoes constant change.

A Virtual Heritage Repository

Three major thematic issues could prove to be of great import to a virtual heritage repository. 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 so concerned at the silo mentality of earlier virtual heritage projects that they are developing technology solutions that allow people to create their own content using free and open source technology such as the EU CHESS project (Pujol et al. 2012), or they are providing technical exemplars using free software that others can download, modify and learn from. 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/) discussed in this volume, and

Digital Applications in Archaeology and Cultural Heritage (http://www.journals.elsevier.com/digital-applications-in-archaeology-and-cultural-heritage/). Neylon (Neylon 2015): 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 agree with Neylon, and I would distinguish between hard infrastructure (equipment) and soft infrastructure (people), as both are necessary (Gotbaum 2011). I previously suggested (Champion 2014) that a digital humanities network 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 (Rockwell 2012), I would like to point to the *European Research Infrastructure Consortium* (ERIC) practical guidelines. The guidelines clearly state (European Research Infrastructure Consortium 2015) 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'.

Quality research infrastructure is measured by research, by the quality of the contributors, by the impact of their contribution, and by the effect of the research infrastructure on them as researchers. Following these premises, a useful research infrastructure in the new digital age is a scholarly ecology, an ongoing scholarly appraisal and reconfiguration of all media assets and outputs. It would be *digital* in order to leverage the specific benefits of digital media and digital-savvy audiences. Changes over time, different input mechanisms and learning mediums, allow counterfactual exploration, log user responses, track user preferences and share insights and personal feedback from distributed audiences. It would be *scholarly*, providing associated tools,

interpretative mediums and careful references as well as usage data that could also 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 could be summoned to discuss and add to the models via publications and related links. Future publications could in turn integrate the community feedback into new research findings, improved critiques, and an enhanced research base.

Technical Obstacles and Potential Answers

We require a cross-platform long-term robust solution that has ongoing community support and a flexible, rich feature list. Unfortunately, virtual heritage projects are typically walk-around interactions only, possibly with pre-recorded text or voice-based information. There are a few instances of Kinect-based camera tracking or data-driven environment enrichment, but these projects are still relatively rare and the preservation strategy of these interactive approaches is seldom discussed.

Overall the 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. Despite a shift to open access models and greater collaboration with the public, Brünig (Brünig, 2014) cautioned that there is an ongoing need to explore new approaches to copyright management that stimulate creativity and support creators.

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. 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 (Huggett 2014). 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 interaction features is provided to the public.

Shareholders and Communities

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. Infrastructure that is not used is not really infrastructure, it is merely equipment. Previous writers have written convincingly of the importance of archives (Limp et al. 2010) but there is also another important requirement, ensuring the archive is effectively used. As Garnet and Edmond (Garnett and Edmond 2014) have declared, 'Building an API is not enough!' The success of virtual heritage projects is 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.

For example, in Australia, rock art and other heritage artefacts may have cultural taboos placed on how they are presented or viewed, whether the audience can be outside the 'mob', or even be of a certain gender. Luckily in Australia there are guidelines both at national (Australian Institute of Aboriginal and Torres Strait Islander Studies (AIATSIS) 2012) and at international level (UNESCO 2015), (United Nations 2008) and there is a great deal of scope to help communities establish how these policies and guidelines can work with the capture, augmentation and dissemination of sensitive cultural heritage data, indigenous or non-indigenous. I suggest that adherence to these guidelines be indicated in the metadata.

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).

Conclusion: A New Virtual Heritage Infrastructure

I sought to advance three major points in this chapter. Firstly, virtual heritage will not succeed as digital heritage if it cannot even preserve its own models, and it will not be effective if it cannot implement the most important advantages of digital technologies (real-time reconfiguration to suit the learner, device and task at hand, individual personalization, increased sense of agency, automatic tracking and evaluation mechanisms and filtered community feedback). My suggestion is

to implement not so much a single file format but to agree upon a shared relationship between assets. For want of a better word, I have described the overall relationship of components of virtual heritage infrastructure as a digital scholarly ecosystem.

Secondly, in this new age of digital communication the 3D model must be recognized as a key scholarly resource (Di Benedetto et al. 2014). As a core part of a scholarly ecosystem the 3D model should be traceable, it should link to previous works and to related scholarly information. I suggest that the model should be component-based so that parts can be directly linked and updated. Web models could be dynamically created at runtime. The model should be engaging, thus extensive play-testing and evaluation will be required to ensure that it actually does engage its intended audience. As part of a scholarly infrastructure, the 3D model format (and all related data formats) should be easy to find and reliable. It should not require huge files to download, or it should at least provide users with enough information to decide whether and what to download. Metadata can also help record the completeness, measurement methodology and accuracy of the models and Linked Open Data can help connect these media assets in a sensible and useful way.

Thirdly, the community of scholars, students and the wider public should be involved, and we must endeavour to incorporate their understanding, feedback and participation (in line with the fact that this is a core requirement of UNESCO World Heritage status for physical monuments). Community involvement is necessary for scholars as well, and so I suggest that virtual heritage projects dynamically link to journals and refereed conference papers, and to the list of tools and methods that were used. A robust feedback system could help continually improve the system. Other shareholder issues such as varying levels of learning skills, and varying levels of knowledge required or cultural knowledge that needs to be hidden (privacy and ownership issues) should also be incorporated into the project.

3D heritage models are here to stay but that does not mean they are addressing the aims and objectives of heritage. They are too essential and important to be locked away in proprietary, unsupported file formats. As designers, practitioners and educators, we need to provide both public

access and robust preservation infrastructures to support them. Technology is only one part of the solution; we must also develop incentives, guidelines and frameworks.

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