VIRTUAL HERITAGE

A Guide

Edited by Erik Malcolm Champion

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Foreword

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This diverse and fascinating collection of essays on virtual heritage takes the reader on a tour of some of the most pertinent issues and challenges currently facing the domain. There is a scholarly focus on the digital technologies deployed in a virtual heritage context, what these can achieve in terms of representation, and the relationship between precision, accuracy in representation, and the characterisation of authenticity. It is refreshing also to see consideration of less technical issues such as ethics and the related question of (digital) data preservation and long-term access. While these aspects of virtual heritage may be intimately related to various technical developments they also help to situate virtual heritage within the heritage domain more broadly by drawing out the similarities, and differences, between the 'virtual' and 'non-virtual' in how the issues should be addressed. The impact of our interactions with the communities we serve and our obligations to care for and curate the content we create on their behalf are too often afterthoughts in project design.

You will also find chapters here addressing key questions around visual effects, animation, visualisation, evaluation, and the role of gaming. Each topic is handled in a way that points to the importance of remembering human experience in all aspects of heritage. Heritage, especially virtual heritage, unquestionably benefits from the advanced technologies it can now mobilise. However, at the

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heart of heritage there remains a dynamic and complex discourse around how the multiple values and diverse forms of significance attached to tangible and intangible heritage impact on communities in the present.

The tools and methods deployed today under the banner of virtual heritage serve to inform and facilitate this discourse, rather than to stifle it with a spurious authority derived solely from technical sophistication. A key task of the practitioner in virtual heritage is to recognise the active role that their work plays in informing heritage discourse and the impact that this discourse has on people, in the context of their personal and community identities, their politics, and even their livelihoods, through tourist and cultural economies.

A fundamental way in which this role can be acknowledged is to break down the barriers between the professional and academic and the communities they impact. Much of the work of virtual heritage can be done *with* communities as well as *for* communities. If the ceaseless development of hardware and software tells us anything, it is that the next version, (of whatever it is), will be easier to use, and likely cheaper and quicker too. What appears to be the sole domain of the expert one day, for example, laser scanning, becomes a ubiquitous feature of a consumer phone handset the next. Consequently, there are few meaningful technical barriers to community co-production and engagement, that last for long (see Haukaas & Hodgetts 2016). What we do in virtual heritage and who we do it with and why, are bigger questions than what are the latest technologies for recording or dissemination?

It is part of the work of the virtual heritage practitioner to find and engage with the constituencies and communities that are invested in the heritage in question or to work together with these communities to develop alternative forms of significance around heritage that may be important to them, but which often lies out with the traditional regimes of significance operating in academia and cultural heritage management (see Jeffrey et al. 2020; Jones et al. 2017).

It has been a common failing of much heritage work dealing with the distant past to assume there is no current community to engage with, and that work can be carried out as if the space in question is neutral or without stakeholders. This notion, itself now antiquated, is antithetical to the practice of heritage today and, in the virtual domain too, we must never take our eyes off the various communities with which, and for whom, we do our work.

This collection of essays, with its broad mix of topics and perspectives, avoids the pitfall of treating its topic as an adventure in a technological playground. Taken together, the chapters and topics covered here provide the reader with a valuable springboard from which to explore virtual heritage. This includes technical developments and future directions, but also many of the broader questions around what we do in virtual heritage today and why we do it.

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Virtual Heritage: From Archives to Joysticks

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While virtual heritage was initially described as a fusion of virtual reality (VR) technology with cultural heritage content (Addison 2001; Roussou 2002), as VR keeps changing, preservation of the content becomes increasingly problematic. Virtual heritage has been a (sometimes) successful communication medium but seldom has it succeeded as a preservation medium (Champion 2016).

Even the term virtual reality has been used loosely, while the terms augmented reality and mixed reality may transform into more overarching terms like XR (extended reality), or merged reality.

Stone and Takeo further emphasized the educational aspect (R. Stone & Ojika 2000):

> … 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.

I have previously suggested that the purpose and significance of virtual heritage (Champion 2006) is more clearly defined as:

> the attempt to convey not just the appearance but also the meaning and significance of cultural artefacts and the associated social agency that

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designed and used them, through the use of interactive and immersive digital media.

If we follow the above definitions, then virtual heritage is not only the bringing together of virtual reality technology with cultural heritage content, it is also an experiential medium. However, that experience is based on the recreating or reconstructing of data, measurements, and observations.

Virtual heritage is a fascinating and challenging area of practice and research, but papers seldom examine underlying assumptions and precepts or explain the complete design and testing process. Where academic work is published, it is typically behind paywalls. Where are the primers providing an overview of immersive technology applied to cultural heritage, directly and conveniently accessible to the public? And where does one learn to make the leap from measurement to user experience?

Unlike other fields, virtual heritage projects are seldom long-lived and robust, clear and significant results are hard to find, data is seldom shared or easily accessible. Because of the many fields that help develop and present virtual heritage projects and related technology, the lack of access to past projects and results, and the manic changes in related technologies, students and scholars from other fields face steep learning curves regards the technical opportunities, the interaction design challenges, and the preservation risks. Our solution was to create a guide that is more concise, applied, and accessible to students from related fields. This is a key reason why this book is available as an open access publication.

Measurement

In the first chapter, *Chapter 1: Speculating the Past: 3D Reconstruction in Archaeology*, Robert Barratt explains the relationship between virtual heritage as discipline and as argument. To be an effective scholarly medium, virtual heritage requires precision (because of its underlying computational nature), but also a way to convey the reasoning behind the measuring, the decision making informing the design of the simulations and conjectural models.

Given that measurement is important, the interesting thing about measurement is how we learn from *how* we and others measure. The next chapter, by Hafizur Rahaman, *Chapter 2: Photogrammetry: What, How, and Where*, explains the increasing importance and versatility of photogrammetry. The time-consuming process of 3D model making can be replaced by photogrammetry, leaving us time to experiment with designing better user experiences. Interestingly, photogrammetry can work on personal devices or leverage supercomputers.

From the camera arises the 3D model, but how do we give the 3D model life? Through representation and interaction, perhaps we could represent how these people understood and represented their world to each other. Animation and modellings are key elements to producing captivating virtual environments, and there is now a range of impressive but free and open source software. In *Chapter 3: Animating Past Worlds*, William Carter explains how advances in animation as technology, discipline, and art can augment and improve the field of virtual heritage.

However, there are two forms of measurement here: measurement of what has been left behind, and conveying the *contextual* measurement of what was built, created, and shared by the original peoples themselves – how did they measure and value elements of their culture? How did they map what they measured and why it was worth measuring? How could we communicate this to people today? The authors of *Chapter 4: Mapping Ancient Heritage with Digital Tools* explain how ancient concepts of place and journey can inform current initiatives to map past worlds.

Interaction

The above chapters have touched on interaction but are fundamentally concerned with visualisation based on measurement. The next group of essays focuses on the role of interaction in virtual heritage. Despite the promise and excitement of technological showcases, this is still a problematic component of virtual heritage. For instance, Roussou and Slater (2005) decried the current state of meaningful interaction and learning in virtual reality:

> Hence, the research question that emerges is how interactivity in a virtual learning environment can influence learning.

Museums and galleries are ideal environments for interactive virtual heritage, but they seldom have the resources (Birchall & Ridge 2015) to fund full-time guided teaching and interactive-learning experiences; many may even lack space to display all of their collections (Bradley 2015). Hurt by the Coronavirus pandemic and drastic cuts in staffing and overall funding, they require robust, flexible, long-term technology.

How do we address the challenges of museums and the wider GLAM sector, but also leverage their great virtues: as meeting places and as havens for education and edification? In *Chapter 5: Hybrid Interactions in Museums: Why Materiality Still Matters*, Luigina Ciolfi explains how hybrid interaction can bridge the gap between technological showcases and the direct person-to-person virtues of the museum space.

Perhaps we can also look to related industries for collaborative funding and development. For example, the video game industry is hugely profitable; Juniper Research predicted that worldwide it would surpass 100 billion dollars in revenue in 2017 (Graham 2017). Commercial game studios can spend millions on capturing 3D digital assets and animating captivating environments. Their allure and influence on virtual heritage is considerable, but their potential collaboration is vastly more significant.

In archaeology, there have been recent investigations of 'archaeogaming', defined as 'the archaeology in and of video games' (Aycock & Reinhard 2017). Designers are moving away from the principal goal of photo-realism, towards the potential of interpretation and conceptual learning (Roussou 2005). Gaming can be highly sophisticated or designed with primitive blocks by school children (such as Minecraft). In *Chapter 6: Video Games as Concepts and Experiences of the Past*, Aris Politopoulos and Angus Mol describe their teaching and research projects on archaeogaming and how this popular entertainment medium can also be educational.

We might primarily consider virtual heritage to be only virtual reality, but mixed reality and augmented reality offer several advantages over virtual reality. Virtual reality (VR) is typically custom built and expensive for the general public, requiring specialist technology experts and facilities that are expensive, hard to source (Carrozzino & Bergamasco 2010), and difficult to maintain by specialist but cash-strapped heritage organizations such as galleries, libraries, museums (Ridge & Birchall 2015), let alone by the general public or shareholder communities.

A possible solution is to employ mixed reality, augmented reality, or consumer-level virtual reality. In recent years, there have been increasing synergies between video games and virtual reality, thanks to increasingly powerful computers and the development of consumer-priced head-mounted displays (HMDs), see-through mixed reality HMDs, and smart-phone based augmented reality systems. In *Chapter 7: Mixed Reality: A Bridge or a Fusion between Two Worlds?* Mafkereseb Bekele explores whether mixed reality is an experience or a technology and how it can help bridge the past and the present.

Interaction requires an audience, and mixed reality in virtual heritage, arguably, has not yet fully leveraged the engagement and value of participative contexts.

Ethics and Evaluation

The last section outlines key issues in virtual heritage evaluation. However, before we set up our questionnaires and experimental designs, there are key ethical issues in cultural heritage and digital archaeology that need to be addressed but are seldom covered. In *Chapter 8: Getting It Right and Getting It Wrong in Digital Archaeological Ethics*, Meghan Dennis explains how technology is not morally neutral: there are successful projects that 'get it right', but we can also learn from failed projects that 'get it wrong'.

Inadequate interactivity or a lack of reflection on related ethical and moral issues can lead to uncertain pedagogical benefits. In virtual heritage, arguably, evaluations are usually not conducted on the intended final audience, and the experimental designs cannot be found or repeated by others. Although there are charters such as the London Charter and the Seville Charter, there are few publicly accessible models, and we lack a shared standardized evaluation dataset. In *Chapter 9: Evaluation in Virtual Heritage*, Panayiotis Koutsabasis explains the many evaluation methods available to virtual heritage, why it is a great field for user experience design, and criteria for ensuring a successful virtual heritage project.

That is not to suggest virtual heritage has many examples exhibiting exemplary usability or usefulness. Many researchers have complained about user experience issues and a scarcity of suitable pedagogical material (Karoulis, Sylaiou & White 2006) or the scarcity of data, collections and projects conveying the accuracy, authenticity and authorship of the simulated material (De Reu et al. 2012).

Neither virtual heritage software nor commercial games are currently flexible enough to quickly and simply handle various content, nor do the models have real-time capability to link to scholarly publications and crowd-sourced material; hence many are stillborn (Guidazzoli et al. 2016).

For example, (R. J. Stone, 2005) remarked:

> …VR delivered very little of use to the global IT community. A handful of organisations actually adopted VR, but most were deterred from doing so by its complexity and cost. Today's VR supply companies have either passed away or are hanging on by a thread.

There are too few successful and popular projects that people can find, access, and simply make work again (Economou & Pujol 2008). Many have simply disappeared or are only communicated via academic conference papers. For example, Thwaites (2013) recently warned that '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 are major problems encountered when preserving cultural heritage in physical museums (Michaelis, Jung & Behr 2012), and the reliability of 3D data for long-term preservation is an on-going issue. However, one way of approaching the issues of preservation – and it is not yet a mainstream one – is to approach the challenges of preservation through rethinking the challenge of authenticity. If virtual heritage is based on digital capture and digital creation, what is authentic? How are we trying to understand and preserve cultural authenticity when we employ digital technology? Why do so many projects in digital heritage avoid tackling the related issue of authenticity? And if they are not authentic (in some way), why do they deserve to be preserved?

In the final chapter, *Chapter 10: Authenticity and Preservation*, I briefly try to explain this linked challenge and offer some potential short and long-term solutions.

Conclusion

Virtual heritage is not yet a dependable and demonstratively effective communication medium; there are still too few examples of accessible useful and engaging models that one can test, verify, experience, and learn from. The field is in serious need of more contextual and useful usability research, but the biggest issue is arguably preservation of the research data and 3D models.

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CHAPTER 1

Speculating the Past: 3D Reconstruction in Archaeology

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Abstract

This chapter introduces the main uses, methods, and issues of 3D approximations. The practical advantages of using 3D approximations over traditional presentations methods is demonstrated, with a focus on realism, interactivity, and presence. Simple 2D images and enhancement such as gaming software offer multiple output formats for diverse aims. Additional uses, such as 3D simulations are also considered, demonstrating the use of these models for the interpretation of archaeological contexts. The chapter also contains a description of standard methods of 3D approximating, using general guidelines applicable to a variety of software.

Definitions and History

In any field of scientific enquiry, presenting data in a simple and effective manner is essential for the propagation of information (Benko et al. 2004; Smith & Rosendale 1999). Especially in subjects with high public interest – such

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as archaeology – theories, data and other results must be accessible both to experienced researchers and the general public. In the past 35 years, new digital technologies broadly labelled as *visualisation* have emerged. These new methodologies enhance archaeological presentation in traditional venues such as publications and exhibitions and introduce new digital knowledge repositories (Sifniotis 2012).

The rise of visualisation techniques can be traced back to the mid-1980s, when the collaboration between archaeologists and computer scientists yielded the first 3D models of archaeological sites (for example Delooze & Wood 1991; Smith 1985). This movement was a result of recent developments in computing, but contemporary changes in archaeological theory and practices also contributed to the adoption of digital techniques.

Undoubtedly, visualisation's path was paved by the processual movement, which advocated scientific enquiry in archaeological practices leading to new cross-disciplinary methodologies (Binford 1962; Clarke 1968; Willey & Phillips 1958). The development of GIS software in the 1980s, for example, demonstrated that computer science could be successfully used for archaeological enquiry (Richards-Rissetto 2017).

In recent years, the advancement of computing capabilities has led to progressively more complex and diverse 3D models (Sifniotis 2012). The increased specialisation of visualisation methodologies has caused a shift from a single 3D form, originally labelled *virtual reality*, to a wide range of different modelling techniques. Visualisation can now be subdivided into a variety of methodological groups, generally separated into survey-based and reconstruction-based techniques. Survey-based techniques include photogrammetry and laser scanning, which are discussed in Chapter 3, while the present chapter focuses on reconstruction-based visualisation.

3D reconstructions[1] are user-generated virtual geometries primarily used for the presentation of real and hypothetical archaeological data (Figure 1). They are user-generated, as they require a modeller to manually input the geometry based on archaeological evidence and established theoretical elements. They are composed of a virtual geometry, created using *xyz* points, which are connected to form surfaces and solid objects. Unlike survey-based techniques, the subjects of the 3D reconstructions are both extant archaeological evidence and hypothetical elements based on established theories. 3D reconstructions are historically linked with the field of archaeological illustration and especially the work of Alan Sorrell, aiming to present an intact view of the archaeological past prior to destruction (Earl 2006; Georgopoulos 2014; Sorrell 1981).

The main distinction between survey- and reconstruction-based techniques lies in their use. Survey-based techniques help preserve material evidence by creating a permanent digital copy, especially of features uncovered during excavation (for example, Olson et al. 2013). 3D reconstructions are not faithful renders of reality, but they have the capability of synthesising theory and evidence into an accessible medium. As such, 3D reconstructions can present hypotheses

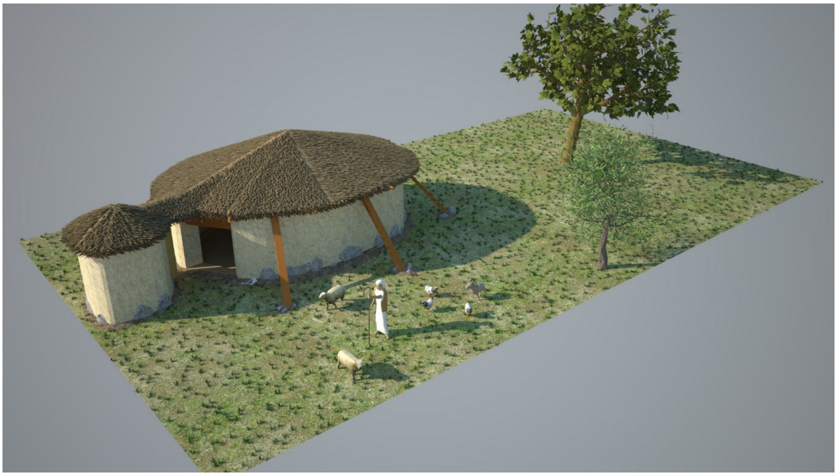

Figure 1: A 3D reconstruction of a Neolithic hut in Malta. The model has been used in publications and exhibitions to show the original form of the structure prior to destruction.

dynamically and intuitively to the public, as well as occasionally provide an environment for experimentation.

The Reconstruction Process and Uses

3D computer models are composed of a series of points in virtual space, which are connected to form textured triangular surfaces. In 3D reconstructions, these points are inputted manually by the researcher using tools provided by the 3D software. Common modelling programs such as SketchUp, Blender, and 3ds Max allow users to create simple shapes or surfaces that can be manipulated through pulling or extruding tools to generate more complex elements. More recently, procedural generation allows the creation of large-scale models such as cityscapes through a rule-based methodology (Adão et al. 2012). However, a 3D reconstruction is primarily an artistic process controlled by the modeller.

3D reconstruction starts with the archaeological data, and surviving features are recreated in the model using plans, sections, and measurements obtained during excavation. These provide a realistic basis for the model. However, archaeological data is limited, and elements that are no longer in situ must be created by the modeller based on limited sources, often by actively choosing from several plausible scenarios. Dell'Unto et al. (2003) identify a range of references that aid the reconstruction process, from photographs, literature, similarity with other parts of the site, comparison with different archaeological contexts and replication of the style of the period.

The reconstruction process is therefore an investigative methodology, similar to archaeological theory building where a variety of sources are connected to identify and support a hypothesis. The reconstruction process can itself provide new insight into archaeological interpretations (Barceló 1992). By viewing data in 3D space, relationships between individual parts are visualised, often leading to observations that were not apparent in the 2D data (Lulof et al. 2013).

3D reconstruction's ability to visualise the relationship between elements has made it a valuable tool for the presentation of archaeological contexts to the public. Archaeological remains are often partial, requiring visitors to imagine missing elements despite lacking the necessary expertise. However, 3D reconstructions provide intuitive and immediate access to complete archaeological contexts.

Until recently, 2D still images were the main form of presentation for 3D models, but in recent years the development of *serious games* – video games designed for educational purposes – has changed the way archaeological sites are showcased (Anderson et al. 2010). Serious games use gaming engines such as Unity3D or Unreal Engine to create complex virtual worlds that provide an engaging and stimulating experience to the user (Figure 2). Archaeological sites are fully recreated in 3D space that the user can explore in the first-person perspective, often directly interacting with the virtual environment.

This new generation of 3D reconstructions exploits video games' ability to create *presence* to facilitate learning. Presence is the feeling of belonging in a digital environment without awareness of mediation (Biocca & Levy 1995). As the environment creates responses that are analogous to real-life stimuli, the user believes this digital world to be an extension of reality. The virtual environment possesses inbuilt characterises that mimic natural response (i.e., the ability to walk through water or the capacity of a wall to block movement) and creates a strong sense of belonging by allowing meaningful interactions between the user and the space (Pujol & Champion 2012). The characteristics that create natural responses are comparable to Gibson's affordances, which in turn are inspired by Heidegger's thrownness (Gibson 1979; Heidegger 1927).

The feeling of presence is unique to serious games and presents advantages to traditional methods of teaching. Presence has been closely linked with learning, as users subconsciously acquire knowledge through the engaged exploration of virtual space (Herrington et al. 2007; Lacasa et al. 2008; Rosenberg 2006). Serious games are associated with constructivism, which is

> … [the] view that learners assimilate knowledge by engaging in self-directed learning activities that are accomplished through constructive tasks (Roussou et al. 1999: 250).

By actively engaging with virtual environments the user gains an understanding of the past driven by curiosity and individual choice. Nonetheless, the learning

Figure 2: A serious game that allows exploration of a burial site in Malta. The interface provides tools for self-guided learning. [Author].

process can be guided through the use of narration, characters, and quests, thus providing an environment rich in knowledge without the constraints of traditional methods of dissemination (for example, Champion et al. 2012).

Elements such as interaction, embodiment, and realism contribute to the sensation of presence. Interaction is achieved by creating opportunities in which the user can test the world, by engaging with virtual objects and measuring the naturalness of the responses (Roussou 2004). Embodiment is the sensation that the character controlled in the serious game is an extension of the user's physical self (Biocca 1997). This feeling helps the user to experience stimuli directly, without a sense of mediation. Realism is the closeness of the virtual spaces to reality, which is created through complex geometry, textures, and shading (Gillings 2001). Additional elements such as social presence, cultural presence, immersion, stimulation of other senses, and relation to others play a role in generating presence.

The use of 3D reconstruction is not limited to presentation. The flexibility of the models and the ability of the user to manipulate the geometry allows for archaeological experimentation. 3D reconstructions can be used to test theories, by creating different scenarios and observing the relationship between elements (Barceló 2001). In such cases, the 3D reconstruction acts as a simulation – a scientific experiment conducted in a digital environment where a system replicates reality (Lake 2014).

3D reconstructions can represent digital proxies of archaeological contexts within which hypotheses are tested. Physics simulations can, for example, be used to verify the stability of structures based on the available archaeological evidence (Levy & Dawson 2006). Crowd simulations can show how architectural features affect the movement of people within the site (Maïm et al.. 2007). Astronomical studies provide new information regarding the construction and use of structures (Frischer & Fillwalk 2012, 2013). Therefore, 3D reconstructions offer the possibility of exploring queries and theories that are otherwise inaccessible with traditional archaeological practices.

Hyperrealism, Uncertainty, and Possible Solutions

Despite the advantages of using 3D reconstructions for the presentation and interpretation of archaeological data, these methodologies have encountered resistance from the wider archaeological community (McCoy & Ladefoged 2009). The main criticism raised in the literature is 3D reconstruction's tendency to mislead the end-user through highly realistic imagery (Eiteljorg 2000). Although hypothetical elements are mostly based on archaeological evidence, in most venues of publication the 3D reconstructions are stripped of archaeological sources. These 3D reconstructions often lack the required tools to identify their overall accuracy, while simultaneously carrying a sense of truth. Borrowing from the concept of hyperreality introduced by Baudrillard, the reconstructions are an intermingling of real and hypothetical without any means of distinguishing the two (Baudrillard 1983, 1988; Forte 2011). At the same time, images carry a sense of realism and legitimacy that leads users to automatically believe them to be truthful, similar to Benjamin's (1936) *aura* in art or as represented in Magritte's (1928–29) *The Treachery of Images*. As a result, 3D reconstructions carry a risk of presenting as fact a hypothesis with little supporting archaeological evidence.

Several researchers have attempted to provide visual cues within 3D reconstructions to address their inaccuracy (Dell'Unto et al. 2013; De Luca et al. 2014; Georgopoulos 2014; amongst others). Colour codes, wireframes, or point clouds are included within the 3D models to show the precision of individual parts, akin to the pink cement used when physically reconstructing archaeological sites. The non-photorealistic movement initiated by Strothotte et al. (1999; Masuch & Strothotte 1998; Masuch et al. 1999) suggests using different rendering styles to highlight uncertainty.

On the other side of the argument, researchers have argued that 3D reconstructions should not compromise realism for the sake of accuracy. Gillings (2001) suggests that the main focus of 3D reconstructions should be perceived accuracy, proposing that a model should provide a realistic experience regardless of imperfections. He quotes Dovey's (1985) claims that an artificial beach in the desert may not be a physical substitute for a real beach, but still provides the same experience.

While the issue of misrepresentation in 3D reconstructions is still under discussion, in recent years several documents such as the Seville Principles and the London Charter have been published (Denard 2012; Seville Principles 2011). These documents present a theoretical framework for 3D reconstruction, in order to legitimise the field through a formalised and standardised methodology. By ensuring 3D reconstruction follows accepted guidelines, the risk of misinterpretation can be assessed and minimised. Amongst other observations, these documents advocate for the recording of uncertainty in 3D reconstructions through the use of metadata and paradata. Metadata and paradata store necessary information regarding the reconstruction process, in the form of software data (metadata) and records of the decisions taken by the modeller (paradata) (D'Andrea & Fernie 2013; Denard 2012). By making this data accessible, it is possible to determine the overall reliability of the 3D reconstruction and identify hypothetical elements that require further consideration, allowing it to be open and replicable.

However, despite these conscientious approaches, more work is necessary. At present, metadata and paradata are not a requirement for 3D reconstruction projects, and even when these data are recorded, issues such as a lack of online repositories and non-standardised datasets impede their proliferation (Ince et al. 2012).

Conclusions: Looking to the Future

3D reconstruction is a relatively new field in archaeology and as such it has both untapped potential and unresolved issues. Serious games offer new opportunities for public engagement, by providing a learning experience driven by curiosity in an interactive medium. Further collaboration with the field of video game development could provide more powerful and focused 3D reconstructions. By fully embracing the techniques that stimulate the users in games and by creating a stronger sense of presence, archaeological information can be presented more effectively. For the interpretation of archaeological sites, the similarities between simulations and 3D environments demonstrate the possibility of using 3D reconstructions for complex experiments that can further archaeological knowledge despite limited evidence.

Yet, despite the potential, more work is needed in the development of a satisfactory theoretical background to 3D reconstruction. The issue of inaccuracy and the possibility of misleading the public through erroneous hypotheses require further consideration. The use of metadata and paradata is promising as it provides accessibility to the reconstruction process, but changes in publishing techniques are necessary to accommodate the recording of new information. Overall, 3D reconstructions can change archaeology for the better, but only by accepting their limitations and by ensuring scientific rigour is maintained.

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Notes

[1] Reconstruction-based models have been called a variety of names, including 3D reconstructions, virtual reality and 3D approximations. Although the term *3D reconstruction* has limitations, as described in Clark (2010) and Barratt (2020), it is adopted in this context as it is the most common; *3D model* is also employed in the text.

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CHAPTER 2

Photogrammetry: What, How, and Where

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Abstract

Developing 3D digital models of artefacts, monuments, excavations, and historic landscapes as part of digital documentation is becoming commonplace in the fields of heritage management, virtual tourism, immersive visualisation, and scientific research. Such 3D reconstruction or 3D data acquisition from a laser scanning process involves high costs, manual labour, and substantial expertise. On the other hand, image-based 3D modelling photogrammetry software offers a comparatively inexpensive alternative and can handle the task with ease. Besides, documenting heritage artefacts with free and open-source software (FOSS) in supporting photogrammetry is getting popular for quality data production.

Due to the present pandemic situation and social distancing restrictions, gallery, library, archive, and museum (GLAM) industries are facing an incremental burden on both their income and visitor traffic, which is affecting their survival. As a way out, we can see some GLAM institutes are trying to expand their collections on digital platforms for showcasing and promoting virtual visits. Numerous online portals and repositories are evolving for archiving, sharing,

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and trading 3D models are also evolving to support this digital 'vibe'. This chapter explains the basics of photogrammetry and its development workflow, including data acquisition (photo shooting), data processing, and a few post-processing tools.

Introduction

In areas such as heritage documentation, virtual recreation, simulation, crime scene analysis, urban project planning, augmented/virtual/mixed reality, serious games, and scientific research, 3D digital models of artefacts, buildings, archaeological excavation, and historic natural landscapes are becoming increasingly popular. Applications such as Maya, Blender, or 3D Studio Max, which follow traditional geometry-based modelling methods, involve a steep learning curve and require significant time and energy. However, advances in hardware (laser scanners, unmanned aerial vehicles, etc.) and software, have increased the opportunities for the virtual reconstruction of 3D scenes.

Lidar, also called 3D laser scanning, measures distances (ranging) by illuminating the target with laser light and measuring the reflection with a sensor. One can often refer to this pathway as the most suitable for providing the most accurate 3D models (depending on the environment and the 3D scanner). However, laser scanners and structured lighting systems are often expensive and require a high level of expertise. Furthermore, this technology has limitations regarding rendered material properties and environmental conditions, for example, dealing with strong sunlight (Nguyen et al. 2012).

There is an urgent need for tools and supports that enable non-expert users to build 3D reconstruction models comfortably and efficiently, especially for 3D digital documentation and heritage visualisation purpose. In supporting this demand, commercial software packages as well as free and open-source software (FOSS) based on image-based modelling (IBM) or photogrammetry have emerged. Regard3D, Colmap, VisualSfm, and Python Photogrammetry Toolbox are some leading examples of FOSS.

The image-based 3D modelling/reconstruction method uses uncalibrated photographs from cameras and can generate a 3D point cloud via various algorithms. A certain number of quality photographs, therefore, are required to allow the software to process, match, and triangulate visual features and to further generate the 3D point-cloud data. Structure from motion (SfM) is one of the most popular techniques in the image-based modelling method that has been employed in numerous software packages. This procedure helps non-expert users to capture high-quality models rapidly and conveniently from uncalibrated images taken with an ordinary camera, without any advanced equipment or specially designed lighting conditions.

A phone camera and a personal computer with a moderate graphics card are good enough to process 3D models of small objects and artefacts from photographs. Nevertheless, digitising large-scale buildings or landscapes with thousands of photos may require significant hardware support and processing time. If the user has limited hardware, has a weaker graphics card (CUDA capable NVIDIA video card), or is working with large data sets, he/she might need to seek the help of cloud computing. Examples of commercial services supporting large data processing (including photo captured from drones/UAVs suitable for architecture, engineering, and construction [AEC] and survey industries) include:

- Autodesk ReCap Pro (https://www.autodesk.com/products/recap/)
- Get3d (www.get3d.cn)
- Pix4Dcloud (https://www.pix4d.com/product/pix4dcloud)

There is also non-commercial free cloud processing support for remote 3D reconstruction, such as ARC 3D Webservice (https://www.arc3d.be/). For cloud-based processing, users can upload photos/data set through a client tool and get informed by an email sent automatically from the server when the process is done, and the model is ready to download. An experienced user with some technical expertise can also 'rent' virtual machines (called *cloud computing instances* or *instances*) from commercial services like Amazon Web Service (AWS), Microsoft Azure, and Google Cloud for having more customised and robust performance. These virtual machines have the necessary power to process large photogrammetry projects. However, these commercial services come with various subscription model tiers.

Smartphones can be used for scanning and extrapolating a 3D model from an existing object with the aid of applications. These apps use a phone camera to scan an object and can process the data either within the phone or can send the data to an online server for remote processing. Examples of such applications include Qlone, Scandy Pro, Scann3D, Capture:3D Scan Anything, Trino, and Sony 3D Creator. Models generated from such an app may be less accurate than models derived from 3D scanners. Still, it is a great and affordable way to learn about 3D scanning without investing in high-end hardware and software.

There are some other hardware-based solutions for 3D scanning and modelling, such as Occipital Structure Sensor (https://structure.io/) connected via an iPad. A specific app allows 3D scanning, processing, and exporting (via email) the 3D model to specific formats and locations to support the device. The software is free to use.

We can also see some other emerging technologies and recent hardware development, assisting 3D scanning tasks. For example, the recent inclusion of a lidar scanner on the rear camera of the iPad Pro/iPhone 12 Pro looks promising and may help in mapping the environment and related 3D objects. Apple's lidar scanner is not yet at the level of professional lidar scanners used for outdoor surveying and scanning. However, it can still measure the distance to surrounding objects up to approximately five meters away, and it works both indoors and outdoors, at a photon level of nanoseconds. It can also track the location of people (spatial tracking) (Narain, 2020). A portable 3D laser scanner (such as

FARO Freestyle 2) can also support fast and photorealistic 3D capture. The lightweight handheld device has a high degree of flexibility, which allows its operator to scan various places with challenging accessibility and conditions.

In general, the 3D reconstruction process comprises two parts: data acquisition and data processing. Data acquisition can be made through various hardware ranging from mobile phone cameras to satellite imaging. The data processing/3D reconstruction, on the other hand, can be undertaken with a mobile device, a local PC, or with the support of cloud-based computation. However, the selection of the hardware and software largely depends on the size and location of the object, allocated budget, technical expertise, and access to the service.

Image-based 3D modelling technique can be executed either in a local computer or in a remote computer/cloud server based on the adopted software/service. Software or services such as ARC3D and Autodesk Remake use the power of cloud computing to carry out the data processing in a remote server. By contrast, software including Regard3D, Aspect3D, Metashape, 3D SOM Pro, 3DF Zephyr, and so on process the data on a local (client) machine. This chapter does not cover the cloud processing method; instead, it presents a workflow solely featuring software/applications that run on a local computer or workstation.

Photogrammetry

Photogrammetry is all about 'measurement' of the subject of the image. A photographer needs to follow a specific rule-based procedure to collect the data set (photographs) to get a high-quality photogrammetric measurement. This standard photographing procedure, therefore, guides the photographer about configuring the camera, selection of certain objects, shooting techniques (overlapping), and positioning and orientation of the camera towards the subject in such a way that the processing software can minimise the uncertainty and produce the best result. A 3D model (or point clouds) can only be achieved when the relations between photographs are appropriately established. The success of such photogrammetry-based 3D modelling largely depends on the photographic data and the underlying algorithm of the processing and measuring software.

This 3D documentation is of prime importance in the fields of historic preservation, tourism, educational, and real state (Bertocci, Arrighetti & Bigongiari 2019; Dhonjua et al. 2017). Image-based reconstruction or photogrammetry process claims to be cost-effective as compared to traditional laser scanning methods and can provide an automated system with considerable accuracy in the 3D model generation (Scianna & La Guardia 2019; Skarlatos & Kiparissi 2012). However, there are expenses to be incurred in acquiring commercial software licenses, and a certain level of technical skill and knowledge is essential.

Several articles have described the overall production of 3D models as a sequence of calibrated or uncalibrated photographs (Fuhrmann, Langguth

& Goesele 2014; Schöning & Heidemann 2015; Skarlatos & Kiparissi 2012), including details of different techniques for achieving a high degree of accuracy (Bolognesi et al. 2014; Nguyen & Dang 2017).

One can also find comprehensive studies on image-based modelling software that analyses their performance (Durand, Engberg, & Pope 2011; Grussenmeyer & Al Khalil 2008; Scianna & La Guardia 2019; Wang 2011), accuracy in 3D production (Bolognesi et al. 2014; Deseilligny, Luca & Remondino 2011; Oniga, Chirilă & Stătescu 2017), algorithms used (Knapitsch et al. 2017), and scalability (Knapitsch et al. 2017; Santagati, Inzerillo & Di Paola 2013). A few studies also address workflows as well (Hafeez et al. 2016; Koutsoudis et al. 2008). However, research on either best practice or automated workflows that can be adopted by the general public to create free and easy 3D reconstruction models are hard to find, and low-cost workflows are scarce.

Photogrammetry-Based 3D Modelling Workflow

Photography/Data Collection

Photographs can be acquired from several cameras or a single camera. Uncalibrated photographs taken from general cameras are usually used to create a *3D point cloud* by image-based 3D reconstruction software. The software determines the geometric properties of the objects based on the provided photographs and some specific properties of the camera, such as the focal length and sensor size. This process requires comparing and referencing points or matching pixels across a series of photographs. Indeed, the quality and number of photographs play a vital role in allowing the algorithm to process the surface, match points, and triangulate the visual features. A successful compilation of the previous steps can then generate the 3D point cloud.

The camera can range from a mobile phone camera to a professional DSLR camera for photo shooting. Photos must be taken with the right amount of overlap while repositioning the camera for every shot. Depth of field is recommended as deep as possible (F.8 or higher) so more objects are in focus. The photos should not be over- or underexposed, as dark shadows and washed-out lighting can mask important details when processed. Shadows on an object may be mistaken by the photogrammetry software and can produce holes in the object, which will eventually be reflected in the resulting reconstruction. For best results, diffused light is preferred to avoid overexposure.

Background also plays a vital role in the output quality of the 3D model. The reconstruction may appear wrapped if the background prevents the object from being identified or distinguished from the surfaces or objects behind the subject. Objects with a glossy surface, uniform colour or texture, and transparent or translucent material will not yield a quality reconstruction. These objects generally produce holes in the resulting meshes or extensive warping. A *mesh* is a discrete representation of a geometric model in terms of its geometry, typology, and associated attributes (Comes, Buna & Badiu 2014). Therefore, it is often recommended to avoid dark surfaces, reflective surfaces, transparent surfaces (including water), uniform textures and solid colour surfaces, moving light sources and shadows, and capturing the photographer's own shadow.

Generally, the object of interest should take up 70% of the frame or more. Photographs should overlap every 5–10 degrees while capturing an object. The rule of thumb is, 'The more your photos overlap, the better your reconstruction'. Therefore, at least 50% of a photo needs to overlap with another. The more photos are captured, the greater chance of having an accurate model. For more information about image acquisition, please see Lab (2018).

Data Processing/3D Model Development

Structure from motion (SfM) is one of the most popular methods and often been recommended by many authors for 3D reconstruction (Nikolov & Madsen 2016). Ranging from simple home-brew systems to high-end professional packages, there are a wide variety of 3D modelling programs available based on SfM in the market. Rahman and Champion (2019) present a comparison study of four popular free and open-source software (FOSS) packages that use the SfM techniques. This study, however, generalises the photogrammetric workflow as a six-step process to produce 3D reconstructions and 3D models, which includes the following:

(1) Add photos (or image acquisition),
(2) Align photos (or feature detection, matching, triangulation),
(3) Point cloud generation (or sparse reconstruction, bundle adjustment),
(4) Dense cloud generation (or dense correspondence matching),
(5) Mesh/surface generation, and
(6) Texture generation (a few software packages also offer cloud/mesh editing, such as Metashape).

Data/photo sets must be imported to the software first. Usually, users are given options to add/import the photos all at once or as a group (or chunk). The software analyses each photo through an algorithm (such as A-KAZE) and detects features (sometimes also called key points). 'Features' are points in an object that have a high chance of being found in different images of the same object, for example, edges, corners, marks, and the like.

For each feature, a mathematical descriptor is calculated. This descriptor has the characteristic that can identify the same point in an object in different images (seen from different viewpoints). Techniques such as LIOP (local intensity order pattern) can be used for this purpose. The descriptors from different images are then matched and geometrically filtered. This process results in a collection of matches between each image pair.

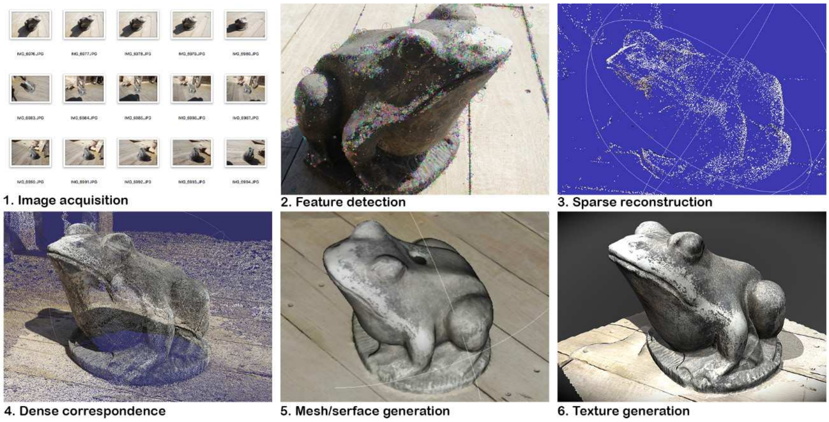

Figure 3: A typical workflow of photogrammetry data processing (3D reconstruction).

The next is the calculation of the 'tracks.' Each feature that is part of a match in an image pair is also searched for in other images. A track is then generated from features if these features satisfy certain conditions, for example, if a track is seen in at least three images. Then it goes to the 'triangulation' phase. Matches from all the image pairs are then used to calculate the 3D position and characteristic of the 'camera'. In this enormous process, the algorithm finds the location where each image was shot, including the visual characteristics of the camera, followed by calculating the 3D position of each track.

The triangulation phase produces a sparse point cloud. To obtain a more dense point cloud or 'densification', several other algorithms are used. Finally, it comes to surface generation. The point clouds are used to generate a surface, either with coloured vertices or with texture. However, not all photogrammetry software offers mesh editing, mesh optimising, cap holes, and texture generation. For a better result, additional software, with some additional steps, may need to be used.

Further Improvement/Mesh Generation and Editing

Photogrammetry software usually generates noise, outliers, and irrelevant points while developing the point clouds, and the result requires cleaning. Not all packages support editing and cleaning. The creation of a mesh from uncleaned point clouds is not recommended, as it will require more time for computation and eventually will generate unwanted surfaces. Once the mesh is developed from the point clouds, software packages such as 3D Studio Max, Maya, ZBrush, Blender, and MeshLab can be used for further processing.

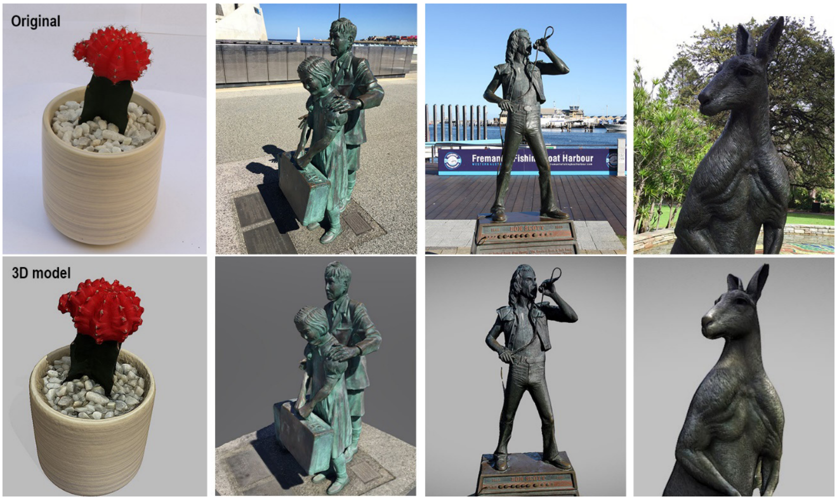

Figure 4: Original versus 3D reconstruction of objects.

The generated point clouds can be imported directly to MeshLab (http://meshlab.net), which is free and open-source software (FOSS). MeshLab provides various tools for selection and removal of points/vertexes (noise, cleaning outliers), surface reconstruction (or mesh generation), simplification of mesh, and 'cap hole' (or close holes tools closes void areas on the model substituting photogrammetric reconstruction with extrapolation data) steps that enhance the 3D model.

Mesh simplification is self-explanatory. It decreases the number of polygons while keeping the shape as close as possible to the original. Because of the reduction of the poly count, processing is faster in 3D visualisation or in a game engine. Cap holes close or cover any gap or hole where the previous mesh generation failed to generate a polygon.

'Texturing' provides visual skin/membrane coverage for the 3D models, so that the virtual objects resemble the original and look realistic. MeshLab can export a wide range of 3D file formats with supporting textures (e.g., *.x3d, *.obj), including 3D point cloud with vertex or points colour (*.ply).

Applications and Possibilities

The application of photogrammetry covers the broad areas of topographic mapping, architecture, engineering, manufacturing, quality control, police investigation, cultural heritage, geology, and the film and game industries.

Virtual heritage, digital preservation, and archiving: Archaeology and cultural heritage both use photogrammetry for digital preservation of heritage assets

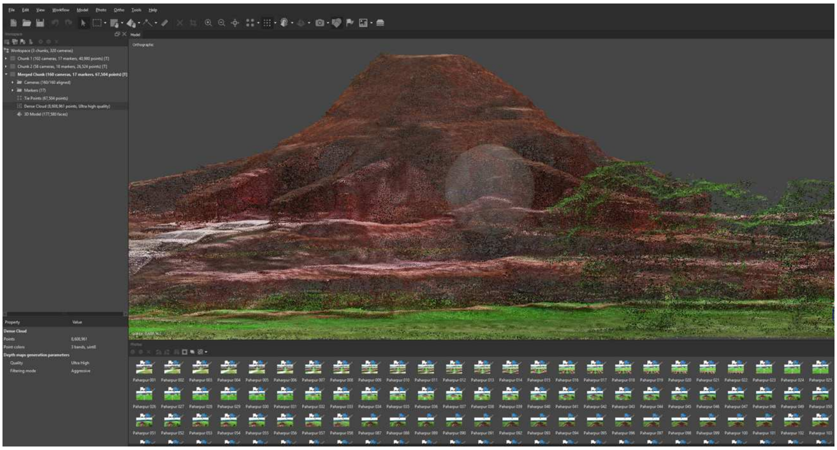

Figure 5: Dense point cloud generated from photographs (Sompur Mahavihara, Bangladesh, a world heritage site) using photogrammetry.

and sites. There is a remarkable number of public, commercial, and hobbyist 3D repositories for hosting and archiving 3D heritage models. CARARE, Europeana, Smithsonian, TurboSquid, Sketchfab, and the like support hosting and archiving 3D heritage assets. There are more than fifty commercial repositories, such as ShareCG, Turbo Squid, Blendswap, and MyMiniFactory. However, they are mostly commercial marketplaces and do not necessarily support 3D archiving.

Land surveying: Photogrammetry and land surveying have many similarities, and that is why this technique has become popular in this field. Besides satellite imagery, drones are getting popular as a cheaper alternative for obtaining images of contours and land masses. Land surveyors and building professionals can utilise photogrammetry for automated generation of 3D surface models, developing rectified and orthorectified imagery and localised mapping from photography gathered by a UAV (drone).

Forensic and accident reconstruction: Photogrammetry has been used successfully for crime scene investigation, forensics, and traffic accident reconstruction and measurement. The technology is equally applicable for both indoors and outdoors. Recording tiny details are essential in these cases, and photogrammetry can help in a court of law by documenting the precise measurements of the crime scene.

Filmmaking: Filmmakers have relied on 3D modelling and 3D animations for decades. Photogrammetry is now supporting this demand by providing a more realistic and accurate 3D environment. Close-range digital photogrammetry can be used in developing accurate 3D movie sets, while the location scouting can be done virtually using aerial photogrammetry. Photogrammetry can also be used in filmmaking for creating digital stunt doubles, texture mapping, crowd replication, and more.

3D assets and environments for games: Photogrammetry is being used in video games to create high-quality 3D assets and 3D realistic environments. The developers of "The Vanishing of Ethan Carter" first applied this technology in 2014 for creating stunning settings for the game. Since then, photogrammetry has been extensively used for 3D.

Building design and renovation: Building renovation requires drawings as a reference point for decision making for architects and associated professionals. However, construction drawings are often rarely found for historic buildings. In these cases, photogrammetry software can be used to create point cloud and 3D models, which can later be converted to CAD drawings and BIM (Building Information Modelling). Photogrammetry software is equally useful in surveying the surrounding area for further use in landscape design.

Geology and mining: Disciplines such as geology and mining use photogrammetry for various applications. Photogrammetry provides affordable solutions in generating point clouds and elevation maps, which can be used as comprehensive analytical tools to measure stockpiles and pits instantly.

3D printing and prototyping: Industries including the automobile, jewellery, and medical training industries use photogrammetry and 3D printing. Instead of creating an object manually, photogrammetry can transform images into 3D models and can cut down the required time in model production. Once the model is captured from the real-world object, it can be reproduced at any scale (Lima et al. 2019).

Photogrammetry in sports: Close-range photogrammetry is used for evaluation of players' performance and in developing virtual training systems. A photogrammetric system can track and measure the most accurate body movement of an expert player such as a javelin thrower's shooting motion. These parameters then can be used to train new players. Analysing payers' movement (biomechanical differences) also allows the scientists and athletes to minimise adverse body effects, such as an improper movement of the elbow joint during the slap-shot of ice hockey athletes (Caniberk, Sesli & Çetin 2017).

Conclusion

Due to the recent concerns regarding the destruction and damage inflicted on internationally recognised heritage sites in Afghanistan, Syria, Iraq, and most recently in Brazil and France, digital documentation and 3D preservation of historical and monuments have progressively entered the arena of international importance. Thanks to emerging computer technologies and the advancements in photogrammetry software, which is helping us to streamline the process of 3D documentation and digital conservation. In particular, the development of affordable techniques such as image-based photo modelling and free and open-source software (FOSS) is undeniable. The rapid adoption and application of photogrammetry in domains other than architecture and archaeology is also remarkable.

The process of image-based modelling is easy; however, photo shooting for this purpose requires specific skills and following certain rules. The software can only produce the 3D model (or part of it) if it is visible to the camera. This means any unseen section in the photograph will produce holes in the model. Not all objects are suitable for image-based photo modelling. More photos can produce better 3D models, but at the same time, more data sets require more powerful hardware and graphic card support. Free and open-source software is not always bug-free, and the developer rarely provides technical support. Regardless of these limitations, photogrammetry or image-based 3D modelling is a preferable solution for digital documentation and preservation of heritage and cultural artefacts, buildings, and sites.

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CHAPTER 3

Animating Past Worlds

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Abstract

Creating 'past worlds' is more than just creative flair or technical wizardry, it is the distillation of grounded heritage interpretation and reflection as applied to the creative (re)visualization of ancient peoples and landscapes. Be it the digital dinosaurs of Jurassic Park or the fake placement of lifelike digital actors seamlessly inserted within media, virtual heritage is increasingly caught between the praxis of the visual enchantment of feature film and television visual effects (VFX), the increasing visual and phenomenological immersive worlds of 3D, virtual games and the hyper-reality of deep fake VFX. This chapter will provide the basics of animation, while at the same time introducing the reader to the concepts of virtual archaeology and digital cultural heritage from a digital visualization perspective.

Introduction

The concept of animation has been around for centuries and archaeologically, I would argue, reaches further back into hominid evolution. The walls of

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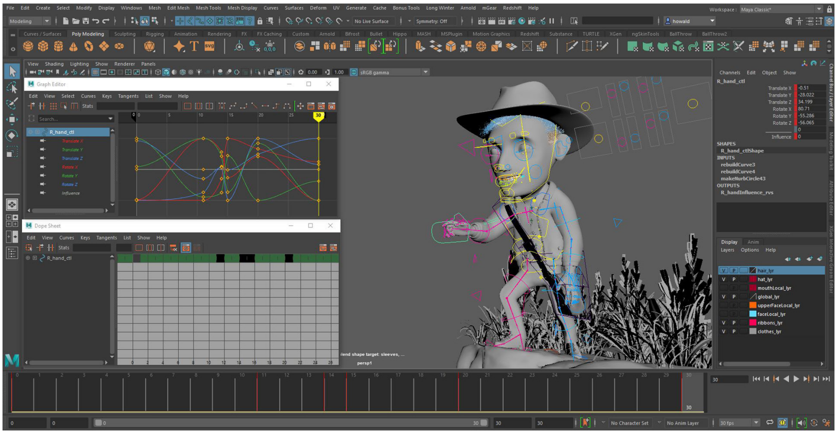

Figure 6: Adventure Man (2020) by Prof. Kris Howald, Sheridan College Computer Animation Program – Example of Animated Keyframes in Autodesk Maya.

Chauvet Caves, with their 37,000-year-old brilliantly sketched and painted depictions of hunting, prehistoric animals, and mythical creatures, dance when lit by fire or torchlight, as if animated in real time (see Azéma & Rivère 2012). Historically, the zoetrope, referred to as the 'wheel of life' is probably the most iconic tool or projector of animated images (Krasner 2013: 3). Invented by William George Horner in 1834, it included a cylinder with vertical slits on a base that allowed the cylinder to spin. When the cylinder was spun and the viewer looked through the slits to see a sequence of still images, animation could be perceived due to the rate of speed and the viewing angle.

However, it was the ground-breaking work of Victorian era photographer Eadweard Muybridge, who invented photographic technology to capture the movement of humans and animals, that formed the basis of animated film (see Baker 2007; Fresko 2013) working in Leipzig who made the next major contribution based on very simple measurements. In 1912, Windsor McCay took the concept of animated film and created one of the first animated shorts, Gertie the Dinosaur, inventing the use of keyframe animation and registration marks, which truly launched the artistic and technical process of animating images or objects (see Callahan 1988).

Today, there is an unprecedented use of animation, not only in entertainment but also in advertising, scientific visualization, and political propaganda. Animation is a convincing means to visualize imaginary characters, worlds, and concepts; combined with hyper-real image-rendering techniques, it can compel the viewer's mind to think that what is being seen could in fact be real. Although this chapter will not unpack the very real concern of how animation is now being used to promote alternative truths (see Westerlund 2019), it is important for us, as digital cultural heritage (DCH) practitioners, to reflect on how our unconscious biases influence the animated images we create and how those images also greatly influence how audiences engage with the virtual ancient cultural heritage worlds we illuminate.

We will explore the basics of 'animation' per se and how certain techniques can be used to enhance your digital cultural heritage research and potential skill-set. Given the huge range of animation techniques in various forms, such as 2D, 3D, real-time and stop-motion, I will focus on the use of 3D in film, virtual reality, and interactive gaming, which has recently exploded into the academic realm of digital cultural heritage.

What Is Animation?

The concept and word *animate* or *animato* comes from the ancient Latin meaning 'to give life' (Lewis & Short 1879). The current industry term *animation* also refers collectively to the creative and technical process in which to animate, whether it be 2D, 3D, or gaming environments. Animation comes in many forms: the traditional 2D sequenced images from Warner Bros. classics such as *Bugs Bunny*, computer-generated 3D worlds such as Pixar's *Toy Story*, or physical stop-motion such as Aardman's *Wallace & Gromit*. Visual Effects (VFX) is the seamless use of animation techniques integrated within live action film, such as *Jurassic Park* or *Lord of the Rings* franchises and in almost every TV show on air today. Animation drives 3D and 2D hand-held, console, and virtual games, now immersing the player into a new interactive experience.

In essence, to *animate* is to bring something imaginary/constructed/unreal to life. That something could be a wacky cartoon character, a loveable photorealistic Baby Yoda, or a perfect digital representation of a dead actor. All are artistic models built by creative and technical artists trained to visualize and interpret written descriptions, reference images, real objects, or environments. These models are inanimate objects that when created and animated are imbued with the style and techniques of their creators and as such, are enculturated, which is the conscious or unconscious imprinting of personal values and norms on digital data. As such, we must recognize the duty of care when bringing our vision of the past to life.

For each platform, animation takes on a different technique, however; all require objects, whether 2D, digital 3D, or physical to be moved by 'keyframes', which represents slices of motion in time. All action within the object itself, no matter how large or small, must be keyframed or 'keyed' on a per-frame basis in order for that object to be animated when sequenced together. In general, objects are animated by frames-per-second (fps). In film, the basis of all animation is 24fps. If the style of the animation is choppier, it is animated at 12fps.

For gaming, film or virtual reality (VR) that requires highly detailed or interactive movement, 48fps or higher is desirable. Why is this important? The higher the fps the more life-like or interactive the object appears to be.

Motion capture is like animation, in a sense that it attempts to record the life-like movement of real people, animals, and objects. Like Golem in the *Lord of the Rings* feature film series, the character on film was a 3D object, animated by a base layer of captured movement from a real-life actor. That motion data is recorded in real time by hundreds of sensors and cameras within a physical space when the performer is acting, then combined with a 3D character object in virtual space.

The Illusion of Life

Animation

To illuminate life is to mimic it. Several animation techniques are used to serve this process. They include primary, secondary, and tertiary movement, squash and stretch as well as over-exaggeration (see Thomas & Johnston 1995). Each technique is deployed at various intensities in order to trick the eye into believing it is a real-life character or to enhance the unbelievability of cartoon characters as they distort themselves into and out of situations.

Primary animation is the main movement of any object or character within 2D, 3D, gaming, or virtual space. It can be a simple as a walk cycle or moving from one side of the screen to another. Secondary animation is the movement that is affected by the primary movement of the object. On a virtual human that could be the sway of clothing or hair. Tertiary movement is the subtle micro-movements of the virtual humans' muscles, eyelashes or the digital hairs on the skin. In combination, it is a symphony of animated gestures that help to convince the eye that what you are seeing is believable.

Squash, stretch, and over-exaggerate are classical 2D cartoon animation techniques. If a character lands on a hard surface, they compress or squash into a pancake, then immediately stretch out into a long object, giving the impression that the character is invulnerable to any danger, but when stretched it creates tension, which preludes a burst of speed. In over-exaggeration, a character's gestures and movements are visually enhanced beyond reality to emote various forms of emotions and physical abilities.

When using motion capture, the animation is exactly as the real actor has portrayed it. When applied to a virtual human character, the mind rejects the movement as being 'too human'. As such, motion capture animators must also create artist-driven secondary and tertiary, squash, stretch, and over-exaggeration movement layered over their perfectly captured human motion capture data, so that the eye is once again tricked into believing what they are seeing is actual human movement, when in fact it isn't.

Figure 7: Adventure Man (2020) by Prof. Kris Howald, Sheridan College Computer Animation Program – Example of texturing and shading in Autodesk Maya.

Modelling, Texturing/Shading, Lighting, Rendering, Compositing, and VFX

Animation is only one element within the arsenal of tools required to animate an object. Virtual objects need to be modelled, textured, and lighted. Once the right combination of texture and lighting is achieved, the animated sequence is rendered into still images, which again are reprocessed to further enhance the final image or sequence of film by the compositing of additional 2D rendered foreground, midground or background layers, lighting, and VFX.

In virtual reality or interactive gaming, animation, texturing, lighting, compositing, and VFX are rendered in real time which requires substantive computing power. Unlike fully rendered 2D sequenced images, which use the computing power to render highly complex layers into photoreal animated sequences that are then viewed non-interactively, VR and interactive gaming cannot achieve a photoreal image in real time and their projected models, textures, lighting, and VFX have a less photoreal quality to them.

Modelling

The simplest object within any 3D space is a point. A point can contain X, Y, and Z coordinates, texture coordinates, normals (the front-facing direction of an object), animation channels, lighting coordinates, and a multitude of other meta- and paradata. However, a 3D point cannot be rendered unless it is given volume or mass.

If you have two 3D points occupying different X, Y, and Z coordinates, a polygonal spline can be created, which not only connects the points together into a new object but also acts like an actor-network (see Carter 2017a; Latour 2005), allowing points to share information between each other and the polygonal spline. Once three or more points are added with polygonal splines (lines) attaching to each point that is then connected in a loop back to the original point, a polygon surface or face is created in a triangular, square, or rectangular form. The more polygon faces an object has, the more the 3D model begins to have surface mass within the 3D space.

In 3D scanning, a technique now widely used in DCH, a real object is scanned by light shooting from a scanning camera, registering a point in 3D space as it hits the object being scanned (Ahmed, Carter & Ferris 2014). As such, scanned 3D objects have millions of points captured and formed into what is called a *point cloud*. Each point will have its own information created when the point is captured; however, every point within the cloud is in fact, autonomous to its neighbour. Only when polygonal splines begin to connect the points, either by hand or through an automatic software toolset, can the points share information such as texture and lighting coordinates and form actual 3D faces within the virtual environment. However, it does not capture a photographic texture.

Photogrammetry on the other hand creates a high-resolution 3D photographic envelope that represents the surface of an object. It cannot distinguish between the discreet parts of the object, so in the end what is captured is a 'blanket' of visual data information. Its 3D surfaces are approximated, meaning that it is guessed by the software system. Both photogrammetry and 3D scanning help to provide digital archives or visual representations of original objects, but due to the nature of how those objects or landscapes are brought into 3D space they themselves cannot be animated and can only be used as static 3D props or backdrops, unless broken apart, rebuilt as discreet pieces, and given the ability to be animated.

A model can have as many points and polygons as needed to create a 3D representation of the object the artist is creating; however, the more points and polygons, the slower the real-time rendering and final 2D rending of the image is, or the more power one needs from the computer's CPU and graphics card to interactively work with the model. This is why in 3D gaming the object and characters are more polygonal then in photoreal 3D objects in film, as both the point and the polygonal count has to be lower in order to achieve real-time interactive rendering.

If creating a model from scratch isn't your forte, then open-source online databases such as Sketchfab (https://sketchfab.com/museums) provide a venue for digital cultural heritage (DCH) practitioners to upload and exchange 3D heritage models for reuse.

Texturing/Shading

Texturing and shading have two different functions within 3D modelling. Textures on 3D objects are essentially 2D layered images that drape or wrap around the 3D object, or part of a 3D object. Shaders are 3D mathematical calculations that manipulate the actual surface of the polygon when rendered, thus giving textures specific properties to display.

For instance, in modelling a wooden ship, specific textures of 2D/3D images applied to the surface of the ship model would simulate the detailed look of those objects to give it the look and feel of an actual representation of rope, cloth, or wood. A texture and a shader are combined to give a dull or rough wooden surface of a ship's hull, or a shiny and reflective metal surface of the ship's cannons or the cloth-like feel of the sails. If one wants to create the illusion of ocean waves on the surface of a 3D landscape, the model itself would have an animated noise algorithm that makes the 3D surface undulate like waves. The shader assigned to that surface will also have animated noise algorithms to simulate the secondary and tertiary movement of the micro swells, ripples, eddies, and other water characteristics, but also the animated colour, lighting, and light refraction. The shader may be reflective and thus a model boat in the 3D water would be reflected on the surface of the water as well.

In many of the DCH representations and photogrammetry/3D scanning point clouds made into polygons, *grey shading* is used to give the object a sense of weight and light displacement within 3D space and to visualize the 3D object for quick editing or rendering. For many DCH examples, this half-finished look, becomes the final representation of the object, whether due to the technical or creative limitations of the DCH specialist. As such, the digital model lacks the materiality, colour, and texture, which grounds it within the context from where it came.

Lighting

Just like objects in the real world, 3D objects can be illuminated by various forms of light. Within 3D space, sunlight, moonlight, pitch blackness, or a misty haze can all be replicated by the various types of lighting. Although 3D, virtual, and gaming environments may have millions of lights within their scenes, three basic lighting techniques – fill, spot, and ambient lighting – help to generate the look and feel of the 3D objects within their environment.

Like daylight, *fill light* is omnidirectional, meaning within 3D space the light emanates all around. *Spotlights* are a concentrated unidirectional light, similar to the actual sun during daylight. Both can cast shadows by objects within the 3D space and work together to replicate the lighting in an environment. *Ambient light* casts soft rays in an omnidirectional mode, providing depth to the shaders. It casts no shadows and is used primarily for creating atmospheric lighting.

Rendering

There are two forms of rendering: pre-rendered and real time. Pre-rendered is when the 3D environment is made into a single 2D frame of film, which forms a complete animation of the character, object, or environment when combined with renders from a sequence. Pre-rendered images allow for a greater range of scene detail and photorealism. In real time, a gaming engine renders the objects or characters interactively, when in viewable range by the user. Because the 3D objects are being rendered in real time, the quality of the rendered image is solely based on the CPU and graphics card capacity to render complex scenes. As such, most game engine-driven renders tend to have lower-quality lighting, model, texture, and shader complexity. However, new hardware technologies are allowing for a smaller and portable form factor, combined with a higher CPU and graphics card capacity to eventually generate photoreal real time images. This is the goal for VR and augmented reality (AR) – to create immersive experiences of imaginary characters, objects, and environments within real-life settings.

Compositing

Compositing is a technique used to superimpose an image overtop or integrated within the broader 2D rendered scene. By rendering out in layers, artists have the ability to continue to manipulate the scene after it has been converted from 3D to 2D to tweak lighting, add VFX or new characters. In some instances, the compositing stage has been used to hand paint additional muscles on the bodies of live actors within a scene, to make them look more heroic. As in 3D animation, 2D composite layers can also be animated to enhance the secondary and tertiary motion within the overall final rendered sequence.

VFX

Visual effects, or VFX, are generally used to increase the believability of a particular scene or environment. Explosions, fire, smoke, sparks, water, wind, leaves, dust, dirt, and even crowds of background characters or spaceships fighting each other are all considered VFX. VFX is generally complex and, depending on the integration of the VFX in the scene, can be both 3D and 2D. Within gaming engines, VFX tend to be suggestive as opposed to being realistic, again because of the complex nature of the effect and the hardware rending available.

Tools and Techniques

To animate, one first needs to build an object, such as a character, in which to add motion. In 3D animation and gaming, this process starts with the modelling of the object within software applications such as Side Effects Software's Houdini, Autodesk's Maya, or Blender 3D animation software. Textures, shaders, and animation rigs are applied to the models and those animated models or static 3D objects/assets are placed within a larger 3D environment with other character and objects.

If the 3D environment is going to be user-driven, as in a 3D game, then the prebuilt 3D objects/assets are typically imported into either a Unity or Unreal game engine. At this point, the 3D objects/assets, if given the ability to be manipulated by the user using a game controller or haptic device, can then be moved, picked up, or affected interactively. If the 3D environment is part of an animated sequence and is intended as a passive 2D viewing experience, the 3D animation is rendered out to a sequence of 2D images and then into a video. If the intent is for the user to be completely immersed within the 3D environment, again a game engine is used to drive the user interactivity controls; however, the image is projected into a VR or AR headset as opposed to being rendered in real-time to a 2D screen. As such the user's physical motion is tracked and replicated within the VR/AR environment, allowing for the illusion of full immersion.

In some cases, handheld devices such as phones and tablets can be used to visualize 3D objects within physical spaces, but again the ability to see photorealistic images are limited by the CPU and graphics card capabilities.

Technical and Artistic Limitations

For most in the DCH field, the immediate technical limitations start with the laptop or desktop being used. To render and display 3D objects in real time, the computer needs a robust level of RAM, as well as a fast graphics card and CPU. Further, most animation software applications function best in a PC or Linux operating environment. In many cases, DCH funding does not allow for large-scale equipment purchases and DCH specialists. Multifunctional laptops, which tend not to be animation production-ready, are more practical in day-to-day use but not necessarily suitable for 3D animation creation.

Although almost all 3D animation software packages now offer a free student version for personal/research work, many of these applications also reduce the functionality, forcing students and researchers to eventually buy, lease, or borrow full-functioning tools to complete complex tasks or desired VFX not allowed in the free versions. Further, very few DCH academic programs teach 3D production other than a cursory introduction or not at all. As such, DCH hopefuls must hack their way through the steep learning curve to achieve basic 3D animation skills required to do their research or 3D projects.

Private DCH production companies such as LithodomosVR (www.lithodomosvr.com) have deployed traditional film, TV, and animation production techniques with consumer-level technology to create vibrant, materialized (re)visualizations of ancient worlds. These teams combine creative, technical, and subject matter experts, who work in traditional animation production pipelines, within the constraints of the software and the delivery platforms. VR and AR technologies at the consumer or prosumer level are at an effective price-point for DCH activities; however, budding developers quickly discover that functionality and features are inadequate in both ease of use and for the complexities of DCH entry-user needs.

Example

The DCH-making process is a wayfaring path (Ingold 2011). The tools, the material, the available data and knowledge, the moment in time, and one's skill all contribute to the construction of new knowledge and with that, a (re)visioning of the ancient past (Carter 2017c). Recent examples of 3D DCH production and research demonstrate a shift towards a professional theoretically and creatively grounded practice.

The *Slingsby Castle* reconstruction by University of York Master's graduate Bethany Watrous (Watrous 2018), with its highly curated and researched (re)visualization, demonstrates a new wave of academically trained 3D artist/DCH specialists who are rising to the challenge of bringing the past into the future. Watrous and a larger cohort of recent graduates in DCH represent a new form of 3D DCH production, where guidelines such as The London Charter and the use of paradata give promise to a theoretically grounded but animation-centric visualization of the past (see Denard 2012).

Professional 3D animation artists such as Bob Marshall represent a group of DCH creative practitioners who were traditionally trained in animation and

Figure 8: Warwolf – The Siege of Stirling Castle, 1304 by Bob Marshall.

then acquired their DCH knowledge through years of experience and project commissions. In *Warwolf – The Siege of Stirling Castle, 1304* (see Figure 8, above), he uses complex lighting, VFX, and character animation, combined with historical and archaeological data, to illustrate the tension and atmosphere in a slice of known history.

Beyond just visualizing within virtual space, Jonathan Westin (www.meltinghistory.org) from the Center for Digital Humanities at Gothenburg University, recently travelled in January 2020 with a team to the Antarctic to 3D scan, using a FARO system, a historic Swedish research outpost before it is lost to global warming. Apart from capturing the archaeological site digitally, the team also recorded light and specifically sound, to further incorporate within their future 3D virtual reconstruction. This process, which they called phenomenology, immerses the viewer deeper into the virtual world by adding, sound, touch, and smell (Cooper 2019; Jeffrey 2015).

Ubisoft's *Assassin's Creed* video game franchise, although not strictly DCH, represents an achievement in the application of 3D animation within a DCH-inspired virtual environments (see Ávila, Corso & Fischer 2020). The gaming company has taken a proactive community-engaged approach when conducting background research on any of their titles that deal with cultures not their own. Ubisoft actively employs a historian and a team dually trained DCH specialists to support the attempt of historical and archaeological accuracy within the franchise. They also have the budget and resources to digitally capture existing historical architecture, which is then used as 3D assets within the games. As a result of the recent loss of the structural integrity of Notre Dame due to fire in 2019, Ubisoft's 3D-scanned interiors and exteriors have played a part in the restoration planning and process to slowly rebuild the cathedral to cultural heritage standards (Ávila, Corso & Fischer 2020).

Discussion

The birth of virtual/digital archaeology can trace its roots back to 1987, when mainframe computers were required to render even the simplest grey-shaded object to screen (see Reilly & Richards 1987; Reilly 1991). Desktop computers would take almost another decade to become ubiquitous, and it would take even longer for the cultural heritage community to embrace this new technology. Many DCH examples over the last four decades are still missing the engaging and life-giving qualities of animation. We now compete with the public and institutional desire to consume high-quality digital media. Whether due to the lack of artistic or technical animation skills, access to technology, or the cost to produce, DCH continues to be overshadowed by the robust technical and creative advances and substantive budgets in the entertainment industry and as such, our own inability to fulfil those expectations.

Unlike entertainment-based animation, where the digital assets, environments, and digital people are the creation of the writers, producers, and artists who are free to mix and mingle historical or fantasy influences, DCH practitioners have a 'duty of care' in representing the cultural, historical, or archaeological unknown (see Perry & Taylor 2018; Huggett, 2015, 2017, 2018)held in Oslo. The theme of CAA2016 was 'Exploring Oceans of Data', alluding to one of the greatest challenges in this field: the use and reuse of large datasets that result both from digitalisation and digital documentation of excavations and surveys.

What does this mean? Any historical representations of past cultures, whether Roman, Mayan, or Nubian, are based on academic speculation, surviving artwork that may depict how certain objects or people looked, or colonial accounts, which are for the most part are laced with highly racist and stereotypical representations of the 'other'. As such, DCH practitioners in many cases (re)visualize the historical unknown.

When there is a gap in the knowledge, an educated guess is made and then visualized. Unlike entertainment-based artists, DCH practitioners must explain how they filled the gap in knowledge, what sources they used, and if no sources were available, how they were able to construct new knowledge and present an alternative (re)visualization. This is called 'paradata', which in effect is a recoded diary of all of the decision-making choices a DCH practitioner makes to build or construct new 3D objects, data or knowledge (Baker 2012; Bentkowska-Kafel, Denard & Baker 2012; Denard 2012). Thus, our duty of care is to not only visualize the cultural, historical, or archaeological unknown, but to also provide an explanation as to how one arrived at making that digital representation, in the most ethical, equitable, culturally considerate, and scientifically enabled way (see Dennis 2020)

Considerations

On the horizon, digital cultural heritage promises to be a scientifically and culturally valuable asset in representing the cultural, historical, or archaeological unknown. However, the potential ability to create 3D models in software packages such as Blender, or to access and reuse open access heritage 3D assets in Sketchfab, or the ability to combine assets within a real-time game engine such as Unity or Unreal then interactively engage with them in virtual space through an Oculus or HTC VR system, hasn't become easier for either novice professionals or consumers yet. Creative and technical skills acquired through being self-taught or through additional technical animation courses, combined with cultural heritage training, is still required to bring past worlds to life.

Over the last 10 years, universities such as the University of Glasgow, University of York, University of Dundee, Bournemouth University and especially Glasgow School of Art have embraced digital cultural heritage and now have actively combined programs and courses in animation and cultural heritage. As such, digital technology practice and the heritage sector have begun to converge, and this has created a new generation of digital cultural practitioners.

One of the greatest risks digital cultural heritage specialists face today, is the pervasive hyper-realism of the constructed 3D image. As software, hardware, and actual skill sets have been simplified, both professionals and consumers can, with some practice, create life-like images of ancient landscapes, peoples, artefacts, UFOs, and dinosaurs. The mundane can now be digitally replicated in uncanny realism (see Mori, MacDorman & Kageki 2012). As such, those constructed 3D environments can be misconstrued as being 'real', and there lies the danger of being able to visualize or reconstruct the 'unknown' without providing the context or research to support the (re)visualization being presented.

Conversely, should DCH specialists be the sole authority on what should and shouldn't be digitally culturally represented? What about indigenous, people of colour, or colonized voices? Does this technology allow underrepresented community stakeholders to also visualize their perceived pasts, in a manner representative of their cultural considerations? Who decides what is culturally, historically, or archaeologically accurate?

Large game companies, such as Ubisoft, now actively create new cultural-historical entertainment products that not only (re)visualize the ancient past, but retell stories and narratives in a convincing and engaging way. Ubisoft, in particular, has gone to great lengths to include community engagement when representing ancient peoples, cultures, objects, and landscapes in their historically influenced Assassin's Creed gaming franchise. But what happens in the future when this approach is too expensive or accidentally or intentionally misrepresents history in a way we know is categorically untrue? What if the consumers of these entertainment games, TV series and films begin to believe in what they are seeing is a real representation of history, only due to the fact that the digital (re)visualization of people and places is so effectively lifelike?

Lastly, what is our role in digital cultural heritage? How, as potential and active practitioners, can we engage reflexively, thoughtfully, creatively, technically, and academically within this ever-expanding field through the creative and communicative medium of animation? What is our 'duty of care' and how do we ensure community involvement and engagement when representing past histories from a culture that is not of our own?

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CHAPTER 4

Mapping Ancient Heritage Narratives with Digital Tools

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Abstract

How does 'digital' apply to ancient pasts? Digital methods, especially methods relating to identifying, visualizing, and analysing spatial data, have become increasingly important within the fields of classical literature, archaeology, and heritage. On the one hand, literary narratives offer potentially different ways of representing space and place than the usual cartographic maps to which we have become accustomed. On the other hand, by virtue of being able to locate cultural artefacts in space – where they were found, through whose hands they have passed, where they reside now, where they were produced and circulated – it becomes possible to construct biographies or even itineraries of objects that offer richer ways of understanding their use and agency.

Unique in all classical literature, Pausanias's second-century CE Periegesis Hellados presents an example of both types of spatial representation – a narrative that describes places of interest in the Greek landscape as well as the notable objects found there. This chapter discusses some of the ways in which Pausanias's narrative of Greek heritage is good to consider when attempting to use digital methods for analysing the entanglements of place, people, and objects in a textual geography.

Introduction

Digital cartography and geographic information systems (henceforth GIS) have been used for decades to connect primary sources (such as literary, archaeological, historical, and heritage evidence) to spatial data and further visualise them in cartographic interfaces. The spatial turn in humanities disciplines has been extensively applied to the study of ancient lifeworlds and has become increasingly important within the fields of classical philology, archaeology, and heritage (Barker et al. 2010; 2012: 185–200; Lundqvist & Landeschi 2015: 25–27).

GIS is a technological framework for gathering, storing, managing, presenting, and analysing data systematically, as a scientific method (Dunn 2019; Foka et al. 2020: 203–217). Exploring the spatial narratives of objects and peoples opens the possibility to a deeper and broader understanding of the past, where and when they were situated in history as space becomes place, imbued with meaning.

The Barrington Atlas became a modern GIS in 2000, covering Ancient Mediterranean geography, but literary territories are limited to the study of toponyms (place names derived from topographical features). Paladino (2016) notes how the semantic concept of space is not necessarily limited to routes; it can be seas, islands, or lakes. Other words too, may have semantic importance beyond their geographical locations. The importance of engaging with the geographies of artefacts as they transcend through histories and cultures to provide readers with a fuller analysis of provenance ought to be highlighted as object itineraries (Dunn et al. 2019: 253–271). GIS, however, may be limited to the annotation of place as static toponyms, as they do not classify other concepts or entities, such as temporal data, social networks, or movement for example.

Here we focus on the complexity of mining spatial heritage datasets by looking at mining information from languages beyond English. Our case study is Pausanias's Periegesis Hellados (Description of Greece),[1] a cultural geography of Greece written in the second century CE in Greek and composed essentially by 'the things that deserve to be recorded' (Pausanias, Description of Greece 1.39.3). In this we ought to note that Pausanias wrote at a time of Roman colonisation of Hellenic space and was, as it transpires from his work, particularly interested, even biased, to illuminate his readers on Hellenism and its history across the Mediterranean.

Periegesis has been widely used as a guide within the field of classical archaeology, relating to archaeological or monument locations but further also connecting to the movement and population of sites as well as artefact transportation and composition. It has been, for centuries, treated as an information repository, particularly for the discovery and interpretation of peoples, sites, and, subsequently, for Hellenic heritage artefacts and monuments. The complexity of his description as well as his selective working methods have led to several misunderstandings.

At the dawn of the 20th century, Willamowitz's peripatetic archaeological methods had rejected Pausanias's topography as inaccurate and biased at best. While there are certainly locations described in a selective and biased manner, Pausanias topographical descriptions of larger sites more often match the archaeological record, as demonstrated by the sanctuary of Apollo at Delphi by the École Française d'Athènes and the Athenian Agora by the American School of Classical Studies (Cundy 2018: 3). However, Pausanias's description of place does not necessarily map easily on to the archaeological record that emerges through excavation (see Hutton 2005). Instead, Pausanias topographical narrative entails past accounts of the places through which he passes and the objects in space he sees. It is a narrative time machine of sorts, a highly selective process that binds together place, artefact, origin, and purpose in space in disparate historical instances the author narrates.

Epistemologically, the complexity of this time-space matrix illuminates the time-depth problem of the Greek East – that is, by providing ways of compartmentalizing and marking these 'different temporalities of the long-study of urbanism in the Mediterranean East' (Hodder 1993: 279–80; Stewart 2013: 236). Pausanias's Periegesis is a manifestation of literary territories as conceptual and subjective, comprising a specific selection of data. The historic-geographic method has been criticized for the loss of subjective and local variation (Cocq 2008). Similar concerns have been raised by some archaeologists on GIS usage in archaeology, including the suggestion that the technology removes the human, subjective aspects of interpreting data (Conolly & Lake 2006; see Vassalo et al. 2018 for a review of discussions with respect to the use of 3D GIS).

Nature and culture in their tangible (settlements, artefacts, people) and intangible (movement) forms are thus studied here as spatial extensions and networks of disparate data. The application of data science and information systems does not remove the complexities associated with traditional cartography and even introduces new challenges. The aforementioned case study thus helps identify the validity of digital methods to understand the spatial dimensions of ancient narratives as a research, educational, and dissemination tool. In foregrounding the role of digital technology, this research takes, as its starting point, the inherent statistical bias.

Pausanias' Role: Extracting Heritage Data with Computational Methods

Heritage more generally, has come to mean the events, materials, or processes that have a special meaning for the memory and identity of certain groups of people. Heritage is a concept that springs from modernity's ambitions in ordering, classifying, and categorising, but also the idea of a threat or a risk that forces humanity to recognise identities and their tangible or intangible representation (Harrison 2013). Previous classical scholarship (including archaeology and reception) has examined the text in terms of: narratology of heritage (Akujärvi 2005; Habicht 1985; Pretzler 2007); identity and memory (Alcock 2001; Arafat 1996); and ethnicity and religion (Konstan 2001). Pausanias's spatial description of the towns, buildings, and monuments through which the reader moves has been widely used as a guide for interpreting those sites and their archaeology and classical heritage (Dyson 1988; 2006: 79, 251–254; Shanks 1996: 49–52. Cf. Habicht 1985: 70–77. Cf. Stuart 2013: 236).

We discuss here the potential for a digital conversion and rendering of this spatial narrative of Greek monuments and artefacts, using a number of methods, such as Recogito, a platform for semantic annotation of text as well as exploring the possibility for text mining, to tease apart the relationship between movement, space, and memory. In doing so, we group our inquiries into themes, notably examining Pausanias's description of locations of memory through geovisualisation, looking further at the potential for extracting dynamic relations of movement or origin. In what follows, we discuss previous scholarly attempts to geovisualise ancient narratives with digital technology, the complexity of mining *Periegesis Hellados* for spatial data, our close reading data-gathering methods, and our semantic annotation strategy and tools, notably the platform Recogito, and future plans.

Mapping Meaningful Journeys in Contemporary Cartographic Environments

Geographic in this case means a 'georeference', an actual location on the Earth, a place that can be represented on a cartographic map. There are a number of complexities associated with this endeavour. First, a location described within a text may have a mythological location. One example is 'Hyperborea', which is a mythical 'northern' (assuming of Greece) location that Pausanias refers to multiple times within the text and in relation to other real places. According to Pausanias's *Description of Greece*, 5. 7. 8, Hyperboreans were people who lived above Boreas, another name for Thrace, but in maps based on points and descriptions given by Strabo Hyperborea, shown interchangeably as a peninsula or an island (Strabo 11.4.3). This makes the place altogether impossible to locate as a point on a conventional map. Within the Recogito built-in maps, Hyperborea is only conventionally located (Figure 10).

A second issue is the very temporality of cartographic environments. A space becomes a place because of specific temporal parameters. Whole towns relocate and change names over time, and often colonies have identical names to the 'motherland'. One example of this in Pausanias is the town of Achaia, which according to Pausanias (7.1.1) himself refers to the land between Elis and Sicyonia, reaching down to the eastern sea, in his contemporaneity called Achaia after the inhabitants, but previously named Aegialus. Another methodological issue is using temporal data; libraries for the parsing of ancient dates are scarce and incomplete, so the present options are to draw upon time period and data gazetteers such as PeriodO (http://www.perio.do) and Trismegistos (https://www.trismegistos.org).

A third issue is environmental change. For example, in a contemporary map one might not be able to identify a now-submerged island or a drought river. One example is rivers in Asia minor that, while discussed in Pausanias's book seven, 'cannot be identified in the digital atlas of the Roman empire, or even the submerged island Vordonisi in the sea of Marmara'. Thus, mapping an already rich text with heritage data into a cartographic environment becomes challenging. The

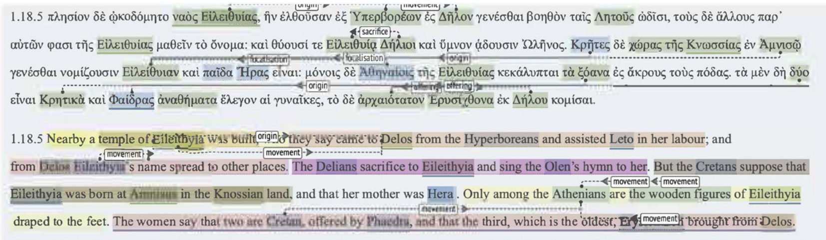

Figure 9: Greek and English translation of passage 1.18.5 of Pausanias's *Periegesis Hellados* with different relational annotations to display movement and origin in the semantic annotation platform Recogito. This displays the complexity of mapping narratives of heritage in different languages.

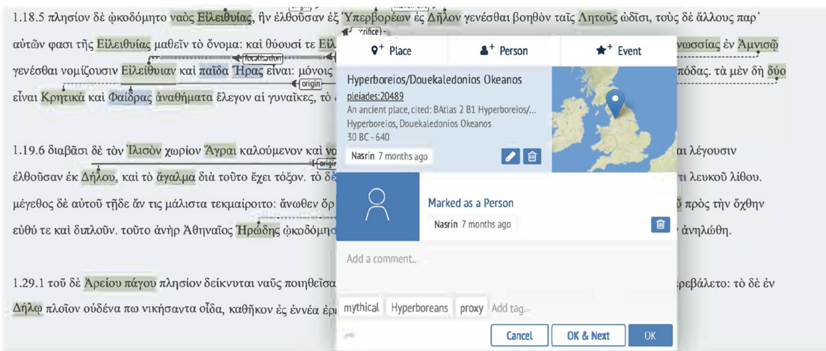

Figure 10: A conventional (and incorrect) mapping location for mythical Hyperborea as found in the built-in cartographic system of Recogito.

scholar must decide how this may be represented in a spatial manner. The decision may even be made to not represent it. However, a decision must be taken.

Working Method: Recogito and Some Preliminary Results

Currently, we have uploaded Pausanias's ten books to the local Umeå university server's instance of *Recogito* (http://recogito.humlab.umu.se) in order to curate the document as a database of heritage-spatial information. The working method is to align words to appropriate georeferenced data, found in several gazetteers. The most complete gazetteer for spatial data of the Balkan peninsula and the Eastern Mediterranean is Pleiades. For more granular topographic and heritage data we additionally use Topostext gazetteer. For art historical artefacts and monuments finds we use Judith Binders Art History Gazetteer and the German Archaeological Institute's (DAI) gazetteer for archaeological finds (e.g., districts, temples, statues, etc.). If no appropriate match can be

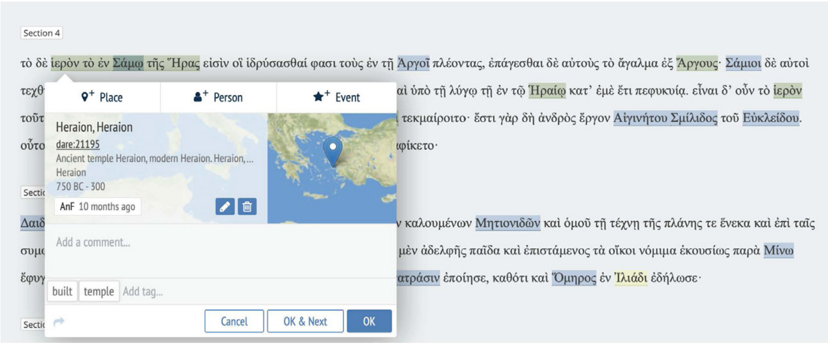

Figure 11: *Recogito* interface with marked- up, identified, and DARE gazetteer alignment of the Ancient Temple of Hera in the island of Samos (Heraion) including additional free tags such as ‘build’ and ‘temple’.

found, then we use the yellow flag option and the comments box for further details that are then returned to the gazetteer developers. Recogito supports further free tagging, that is, enriching each word with additional information (see Figure 11).

To this, we have a working ontology: a structured list of information pertaining to structuring and organising cultural heritage words and then enriching them with metadata. For marking spatial entities, we use the Place entity tab to mark the place in the document. Then, when the pop-up box appears, we align the place reference to an appropriate gazetteer entry using the map or Recogito’s automatic matching.

- If the place represents a human footprint on the landscape that denotes heritage data (e.g., city, temple, etc.), we use ‘built’ to enrich the word.
- If the place represents a physical feature of the landscape (river, sea, mountain, etc.), we use ‘physical’.
- If the place represents a conceptual area or territory (e.g., Messenia, ‘the Corinthian land’ (chora), ‘Greece’, etc.), we use ‘regional’.
- If the place represents a clearly mythical space (e.g., Hades), we use ‘mythical’.
- if the place represents an object in space (e.g., statue, xoanon [wooden image], dedication, column, etc.), we use ‘object’.
- If the place represents a material (e.g., Phrygian marble, Assyrian fabric) from a provenance other than the object or building it belongs to, we use ‘material’ – and use relational tagging > ‘provenance’.

We further use a second tag:

- For built, further defined as: ‘settlement’, ‘temple’, etc.; for physical, further defined as: ‘river’, ‘sea’, ‘mountain’, etc.

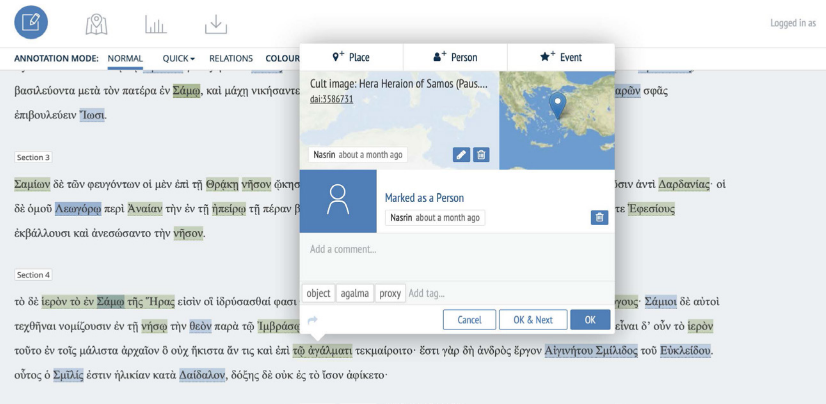

Figure 12: Object identification and tagging in book 7 section 4 of Periegesis, including mark-up and georeference alignment in the DAI gazetteer.

- For regional, further define if further information is given (e.g., 'deme', 'the Corinthian land' (chôra) etc.).
- For mythical, further define using the place mentioned: e.g., 'Hades'.
- When it comes to heritage objects we further define as: 'agalma', 'xoanon', 'anathēma', 'kiōn', etc. (see Figure 12).

Producing a geo-annotated version of Pausanias's Description of Greece means that we will identify and analyse the forms of space within Pausanias's narrative – the ways in which places, monuments, and other objects (heritage data such as sculptures, tombs, etc.) are described in the text, and how the narrative is organized spatially. Using Recogito, the team semantically annotates 'places' using the following method. First, an entity is identified in the text as a place (or object in space). Then it is mapped (where possible) to a global gazetteer. Third, tags are used to provide additional information for, and construct a schema for thinking about, place in more depth, such as: whether the place is physical (a river, mountain, etc.), built (a city, temple, altar, etc.), regional (a wider geographical area), or mythical.

Recogito further supports a range of export formats that can be enriched with additional information as metadata. The options presented in our private instance relate to downloading annotations in CSV, as a data table for importing into spreadsheet software or a GIS. There is a further possibility to download annotations and document metadata as RDF, encoded using Open Annotation and Dublin Core, in JSON-LD, RDF/Turtle and RDF/XML formats. For places, the user is able to download confirmed geo-located places in the document as a GeoJSON FeatureCollection. Geo-located places can finally be downloaded as a KML file, for viewing in Google Earth, for example. We take advantage of this aspect of Recogito to not limit data reuse from the project based upon the GIS or software system one uses.

Text Mining Possibilities

When mining text there are considerations that must be taken into account; decisions about these considerations must be made and then acted upon. The first consideration is the original language of the text. Will the text mining take place across the original language or will it occur across the language to which the text has been translated into? In this situation, the original language of the text is Greek. A decision must be made regarding mining the Greek or, for example, the English translation. If it is decided to mine the English translation, this must be documented to clearly identify to the reader that it was a translation and not the original that was mined.

If the original language is to be mined, then this will influence the applied text mining method and algorithm selection. Although this may be obvious to the skilled linguist, it may not be obvious to a novelist and may lead to incorrect conclusions about what text does and does not contain. Different languages are constructed in different ways and hence, in text mining, these must be considered and incorporated into the algorithms to be used.

Here Greek is the original text's language, while English is the book chapter language. Greek is constructed differently from English and hence the text mining algorithms must take this into consideration. Again, perhaps obvious to the linguist but perhaps not obvious to the spatial or computer scientist. In the case of Greek, an inflected language that utilises cases that alter the suffix of the given noun instead of prepositions, the question of text mining becomes a complicated issue. For example, if one needs to mine the term for sculpture, that is 'agalma' (ἄγαλμα), finding noun in another format (e.g., in genitive possessive: ἀγάλματος) means that one needs to mine another version of the word that is significantly changed – perhaps for Greek only focusing on the stem, excluding the suffix that denotes a case, for example, ἀγάλμ.

The construction of a system permitting automated mining and comparison of the original and translated texts may further enhance the understanding of what the text contains and may highlight possible current era misunderstandings of a text's content.

Conclusions: Dynamic Relations, Spatial Complexity and the Future

Within the project Digital Periegesis, the task is to enrich character strings, words that have a semantic purpose with spatial data. In this chapter, we discussed the possibilities and complexity for discovering words that denote heritage and then enriching them with relevant data. The team tested several ways to mine and ascribe metadata, most notably working with the semantic platform Recogito. In spite of the complexities in close reading of the text, it is possible, using appropriate cartographic environments and gazetteers, to create a digitally enriched edition of Pausanias's description of Greece. The combination of a number of gazetteers for the ancient world as well as the use of an accurate cartographic environment makes the exercise of semantic annotation in Recogito a deep learning process of Hellenic heritage across and beyond the Mediterranean.

During the process of annotation, the importance of data relating to time and people was noticed. It was not only the case that people were being used as proxies for places; Pausanias also showed interest in inventories of people, either by ethnicity, by historical or mythical means, or even by genealogy, as an alternative means of structuring his information. Most importantly, it was observed that Pausanias not only moved through space but through time. LOD methods and tools in the Digital Humanities, however, are currently limited to place. The lack of appropriate LOD 'authority files' for temporal and prosopographical data entities can be further investigated in the future, as well as the possibilities for text mining spatial heritage information. Using the techniques described within, it may be possible to create an interface to map spatial information and consequently, a symbology that will fit the purpose of creating visual maps for historical geovisualisation for Hellenic heritage more generally.

Notes

[1] The project Digital Periegesis (www.periegesis.org) is a collaboration between Humlab at Umeå University, Uppsala University, The Austrian Institute of Technology, The Open University in the UK and the Pelagios Network of Partners. It is funded by the M&A Wallenberg foundation (2018–22).

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CHAPTER 5

Hybrid Interactions in Museums: Why Materiality Still Matters

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Abstract

The importance of physical and tangible qualities in museum visits has been established by extensive literature exploring the importance of materiality (Dudley 2013) and multisensory experiences (Levent & Pascual-Leone 2014) of heritage. A challenge for digital technology design is to ensure that these dimensions are not lost to visually heavy virtual experiences. This chapter examines hybrid interactions in museums, outlining exemplars of successful physical-digital installations and defining the key aspects to consider for their design and evaluation. The goal is to complement chapters on virtual approaches to heritage with insights on how and why to successfully bridge the physical and the digital in hybrid designs.

Introduction

Museums are still for the most part physical places, where heritage objects and environments are displayed, and where even intangible heritage is exhibited

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and made available also as part of physical exhibitions (Bortolotto 2007). Despite this, interpretation strategies very often neglect the materiality that characterises the experience of heritage.

The importance of materiality in museums has long been stressed by some heritage scholars and practitioners; this includes the materiality of spaces, of artefacts, but also the sense of bodily immersion and close contact with the past that add to a memorable visitor experience (Falk 2009). These aspects are often elusive, and visually and textually heavy interpretation tools (i.e., information panels, labels, illustrative videos, and other similar devices) have trouble capturing and conveying them.

Sandra Dudley (2013) made the argument for re-thinking the nature and general approach to education and interpretation that museums have had and that gives primacy to visual and cultural content, in favour of an approach in support of materiality. She defines materiality as the 'summation of physical characteristics, sensory experience and meaning' (Dudley 2013: 15) of heritage, and therefore as a human-centred concept capturing not only physical heritage assets, but the way in which they are experienced, understood, and felt. This is extremely relevant to the use of digital and virtual heritage applications in museums, as technology design has long followed a similar approach to that applied to 'traditional' interpretation: 'the "information over object" approach has influenced also the use of digital technology in cultural heritage ever since computers started to populate the exhibit floor' (Petrelli et al. 2013: 60).

This concern about the limited focus on the materiality of heritage assets is also at the core of critiques of some approaches to virtual heritage that consider virtual platforms as ultimate solutions to suit digital interpretation needs (Petrelli et al. 2013). Technologies such as VR have shown their worth in many instances, particularly in bringing engaging games and educational narratives to life (Champion 2011, 2015; Roussou 2004), but some problematic issues emerged when they were evaluated (Gillam 2017; Pujol-Tost & Economou 2007).

An approach to extensive virtualisation can indeed be invaluable, for example when sites or objects are no longer existing or accessible; however, it can cause drawbacks, particularly in certain heritage contexts such as historic buildings, or living history sites, where engagement is not just about specific artefacts, but about the atmosphere of a place, including the sounds and smells surrounding visitors, which the use of digital means of interpretation should also be sensitive to. While virtual heritage applications can enable experiences that would not be possible otherwise (such as the exploration of reconstructed sites and objects that are lost or not easily accessed), the risk is that some of the material aspects of heritage are too readily erased or excluded from the design process. This is particularly critical for those heritage sites and those museums that rely particularly on tangibility, such as, for example, living history sites.

Augmented reality (AR) has been an important step forward to recontextualising the virtual in relation to objects and to the environment (Beheshti et al. 2017), providing a way to embed virtual content in embodied and multi-sensory visitor experiences (Keil et al. 2013).

However, there is room for more experimentation with hybrid approaches (Bannon et al. 2005), where the virtual and the material (and the design thereof) are more tightly entwined. Hybrid approaches not only can be more mindful of augmenting (rather than substituting) material and tangible characteristics but can also extend the potential of digital technologies to a wider range of visitors and visitor experiences. For example, Dudley illustrates how powerful 'physical, real-time, sensory engagements – even those which may be imagined – with material things' (ibid.: 5) can be, and she argues that the material per se can be engaging where there are cultural barriers to, or limited interest in, other avenues of interpretation: 'through our sensory experience of them, objects have some potential for value and significance in their own right' (Dudley 2013: 8).

Museum visits are of course multi-sensory. Notably, the importance of touch has been widely recognised in heritage interpretation research and practice (Classen 2005), and it is something that can only be partially replicated through haptic technologies. There have been also examples where certain smells and foods to be tasted have been used to accompany exhibits (Levent & Pascual-Leone 2014). A notable example is the Sensorium exhibition at Tate Britain in London (Davis 2015), where several paintings in the museum were paired with multisensory exhibition content to be experienced together and complementarily by visitors. *Figure in a Landscape* by Francis Bacon was accompanied by an immersive soundscape and an olfactory display of bitter chocolate. *Full Stop* by John Latham was complemented by the sound of a heavy downpour and an ultrasound haptic device that made visitors feel the sensation of falling raindrops onto their hands (Vi et al. 2017).

Furthermore, it is important to consider tangible, material aspects of visiting museums not only in relation to specific artefacts (e.g., a painting, sculpture, historic space, etc.), but in terms of how they shape the experience of the wider context (e.g., a sequence of exhibits and the interrelations among them), and of the presence of others (e.g., companions, co-visitors, or other people who happen to be in the same space). Physical co-location is still key to engender and support social interaction: not only in terms of people being able to talk to or be close to companions, but also to be aware of others' physical proximity and presence in planning and practicing one's next moves, and spacing, pacing, and peripheral interaction in the exhibition space (Heath et al. 2002; Hornecker 2010, 2016).

The importance of materiality in digital heritage experiences extends to yet another aspect: the devices or artefacts that convey virtual content have their role to play as physical artefacts. The form factor, material, and feel of digital or hybrid devices also shape the experience of virtual content. For example, studies of tabletop installations (Block et al. 2015; Hornecker 2008) have shown that people's ability to cluster and gather around the display surface, and the gestures that they learn and develop to interact with it, are as important in delivering a positive experience as the virtual content that is presented and the way that it is displayed (Hinrichs & Carpendale 2011). A comparative evaluation study of a mobile phone app, smart cards, and augmented replica objects created to convey the same content in an interactive exhibition showed that the tangible means of interacting (cards and replica objects) were favoured by visitors of all ages when compared to using the mobile app (Petrelli & O'Brien 2018).

Overall, there is ample scope and definite potential to experiment with more hybrid virtual-physical forms where successful immersivity (Kidd 2017) is not obtained by surrounding visitors with virtual content, but by engaging narratives that blend the digital and the material. For all these reasons, there have been many explorations of interactions bridging physical and virtual: notable examples are mixed reality (Benford & Giannachi 2011), tangible interaction (Hornecker & Buur 2006), and hybrid design where physical and virtual components are crafted together (Bannon et al. 2005).

Furthermore, there have been different approaches to designing actual interactivity in the context of these hybrid experiences: while with virtual reality, quite often the metaphor is that of traveling (in space or time) or of stepping into a different reality. Interactivity with hybrid installations is more 'digging deeper' in the here and now, revealing qualities or aspects of spaces or objects that are being held, handled, or occupied in real time. These forms of hybrid interactivity can be articulated in various ways.

Approaches to Designing Hybrid Interactivity

Broadly, hybridity means that the interactivity blends the virtual with the physical and material; however, this can take different forms and therefore lead to different approaches to design affecting different sides of the experience of heritage. We identify four broad approaches to designing hybrid interactivity: virtual-physical overlay; hybrid objects; virtual-physical assembly; and hybrid takeaways.

Virtual-Physical Overlay

In a virtual-physical overlay design approach, the virtual and material layers overlap in some way in real time. A well-known example of this is augmented reality (AR), where the visitor unearths the virtual content by means of a 'see-through' device. This can be an off-the-shelf device such as a mobile phone or tablet, but also a specially crafted object with embedded electronics, whose physical form supports interactivity in different ways. One example is The Loupe (van Dijk 2019; van der Vaart & Damala 2015), where the AR device took the form of a magnifying glass, and the virtual content was triggered not just by pointing The Loupe towards an object, but also by handling it through a range of physical gestures that made it behave in different ways.

Another example of virtual over physical overlay are projection mapping installations. These can be realised on walls, or in entire rooms, such as for example in the Immersion Room installation at the Cooper Hewitt Smithsonian Design Museum in New York City (USA) (https://www.cooperhewitt.org/events/current-exhibitions/immersion-room/). Bespoke physical structures can be designed to be not only a projection surface for the virtual content, but to carry meaning and to shape the way visitors physically arrange themselves in relation to the installation and how they interact with it. A well-known example of this that was mentioned earlier are tabletop interactives (Hornecker 2008), which allow for multi-user interaction, shifts in physical orientation, and cooperative behaviours around the table (Hinrichs & Carpendale 2011). Another example in commercial exhibition design is the Weaving Time installation on traditional weaving patterns, realised as part of an exhibition on the Inca civilisation held at Pointe-à-Callière Museum in Montreal (Canada). In this case, the virtual content is displayed on and can be interacted with through a physical structure replicating a loom (https://gagarin.is/news/designing-tangible-interactions-from-across-the-ocean). In these examples of overlay, the interaction with the virtual can be more embodied and retain aspects of materiality and physical experience that virtual experiences through devices such as headsets or handheld tablets or phones could not replicate.

Hybrid Objects

Another approach is the creation of hybrid objects within which some aspects of the virtual and the material co-exist or are linked via real-time interaction. Bespoke hybrid objects have also crafted to suit period settings, such as historic houses, and to augment their atmosphere. For example, the Interactive Work-Table and Escritoire at Dr Johnson House museum in London (Patel et al. 2015) was designed to aesthetically resonate with the house, while offering visitors a novel interactive experience.

Another example are the smart replica objects designed for the historical exhibition The Hague and the Atlantic Wall held at Museon (The Netherlands). In this case, the hybrid replicas were small objects that could be carried in one's hand, and each object was the replica of an authentic museum artefact on display and corresponded to a different theme of virtual content (visual and auditory) to be unlocked during the visit (Marshall et al. 2016) (Figure 13).

In the Interactive Tableaux installation at the Bishops' House Museum in Sheffield (UK), replica objects were also used, but with an added layer of hybrid interactivity. They activated a set of diorama-like tableaux representing different historical periods in the life of the house and its inhabitants. Every tableau reacted with different behaviours when activated: from playing a sound or light to emitting a smoky smell from its frame, displaying a video on a miniature screen inside the diorama, or making an automaton inside the diorama move (Claisse et al. 2020) (Figure 14). Evaluation of the installation shows that visitors enjoyed the

Figure 13: The smart replica objects for The Hague and the Atlantic Wall at Museon (inset). Each replica reproduced an authentic object in the exhibition (inside glass case in photo). Replicas of each object could be picked up by visitors (left of exhibition stand in photo) to explore the exhibition and trigger virtual content representing different points of view. Photographs by Daniela Petrelli and Nick Dulake, used with permission.

Figure 14: The Interactive Tableaux at the Bishops' House Museum. Each tableau reacted with different behaviours when activated with replica objects. Photographs by Caroline Claisse, used with permission.

multisensory aspects of the experience because they resonated with physically exploring a fascinating and atmospheric ancient house (Claisse et al. 2018).

Hybrid objects can also be crafted for educational hands-on installations. For example, one exhibition by Maquil et al. (2017) for the Tudor Museum in Luxembourg resembled a scientists' workbench where visitors learned how a battery can be built. They could choose and assemble components such as electrolytes, plates, and active paste, test the battery by revving a handle, and view its performance on a simulated graph paper displayed on an embedded screen.

Virtual-Physical Assembly

In this approach, the experience of virtual behaviours and content is designed side by side with the physical/material one, within the time frame of the visit. In this case, the *assembly* (as defined by Fraser et al. 2003) is a blend of virtual elements and material ones, including portable objects that are low-tech and do not offer any virtual experience per se, but that become part of one at some point by virtue of an underlying narrative of interactivity. These components are all linked together by a unifying activity that follows the narrative and introduces virtual elements at various points.

One example is *The History Hunt* at Nottingham Castle (UK) (Fraser et al. 2004), where low-tech paper worksheets were used to collect and file clues in the grounds of the castle and were subsequently augmented with RFID tags to activate mixed reality exhibitions in the castle gatehouse. Another example is *Reminisce* (Ciolfi & McLoughlin 2017); in this case, visitors exploring an open-air museum could collect 'tangible tokens' – small packages containing meaningful objects as well as digital audio snippets representing each of the historic cottages they visited on the trail. In the final building of the trail, the tangible tokens became activators for a separate installation concluding the visit.

Hybrid Takeaways

In this approach, material or virtual artefacts relating to an exhibition or site are available to visitors pre- or post-visit as *hybrid takeaways*. Therefore, the strategy is to realise a blending of the virtual heritage experience with a relevant material component that features either before or after the visit. Time becomes an important variable in this approach, as the hybrid experience becomes fully realised beyond the frame of the actual visit. How the takeaways are designed and their degree of digitality varies. One example is *The Chantry*, a freely available VR ambient game that is intended to be played before or after a visit to Dr Jenner's House museum (UK). The game's environment is a 3D model of Dr Jenner's House; however, the game is not intended to be played while physically visiting the site but as a companion experience to be enjoyed at a different moment and possibly encourage repeated visits (http://revealvr.eu/2018/09/17/the-chantry-launched-on-european-playstation-store/).

Figure 15: The souvenir postcards (front and back) realised by the meSch project for Museon (left) and the Italian Historical War Museum (right), rematerializing virtual aspects of individual visits. Photograph by Luigina Ciolfi. Postcard design by Paddy McEntaggart for meSch.

Conversely, the hybrid takeaway can be a physical token or object that is related to a virtual experience in some way. Instances of this are personal souvenirs that re-materialise virtual or intangible aspects of a visit. For example, Nissen et al. (2014) facilitated the making of takeaway objects by visitors themselves. The objects creatively represented what they had seen at a digital art exhibition. As part of the EU meSch project, takeaways took the form of personalised postcards that were automatically generated to represent the experience of virtual content that each visitor had, through the use of log data (Petrelli et al. 2017; Not et al. 2017) (Figure 15).

One of these postcards would be printed with different 'stamps' corresponding to virtual heritage installations that were interacted with in a large exhibition (Figure 15, left), or contain a written summary of the digital audio that a visitor had listened to at various points (Figure 15, right). In both these examples, the postcards also displayed unique URLs that each person could use to access further digital content through an online visit, leading the way for more interaction with virtual content.

Conclusion: Contextualising Virtual Heritage

These approaches to hybrid design, and the examples provided to illustrate them, show that there is a wide range of possibilities to blend the virtual and the material in interactive installations at museums and heritage sites. Indeed, we can argue that no interactive installation is ever fully virtual, simply given the fact that it is approached and experienced by people who have bodies and sensory capacities and who need to manipulate some kind of device in order to activate it. There is, therefore, no opposing dichotomy of virtual versus material; rather, they exist on a continuum of possible embodied experiences of digital and indeed virtual heritage, with varying degrees of overlap and interrelationship.

Practical instances of designing for human-computer interactions in museums demonstrate that there is no 'one size fits all' approach to realising pleasurable, effective, and meaningful virtual or hybrid heritage experiences (Hornecker & Ciolfi 2019). Therefore, understanding and thoughtfully responding to the heritage context is essential; a hybrid approach including elements of tangible interaction might be more relevant or feasible for certain types of museum or of heritage than others. Similarly, such contextual complexity should inform the decision of how the virtual should blend with the material and which instance of interactivity should be offered. Furthermore, the interpretation strategy of an institution is also an important factor. An institution's emphasis could be on historical aspects, or material culture, design, and crafting, or on intangible yet materially and bodily experienced aspects of folk traditions and oral history.

All these considerations also weigh on the approaches to evaluating hybrid experiences: for example, whether the focus of evaluation should be on the educational aspect of exhibits or on the empathic experience of encountering and appreciating traditions and cultures. Overall, the evaluation of hybrid experiences almost always puts a strong emphasis on their evocative nature, striving to document felt aspects of the visitor experience, as well as other more traditional indicators of memorability, flow, and learnability (Damala et al. 2016). Qualitative methods are very commonly used to capture emotional and embodied aspects of engagement, and naturalistic studies allow for documenting and reflecting on these experiences in context (Ciolfi & McLoughlin 2012; 2017). Furthermore, evaluation studies also might be concerned with the interweaving of the installations with the broader material context, from the hybridity and embeddedness of interactive behaviours in context (Hornecker 2010), to the aesthetic delight and surprise around hybrid exhibits (Taylor et al. 2015), and the environmental and atmospheric setting of hybrid interactions (McGookin et al. 2017).

As digital technologies and platforms become more and more powerful and cheap and are more pervasively used in museums, awareness of their material, cultural, and organisational fit with heritage institutions is even more paramount. Approaches to designing and evaluating digital interpretation, therefore, might need to align to these strategies, meaning different roles for virtual or tangible instances of interactivity and for any possible blend thereof.

In conclusion, this chapter particularly argues for the need to consider the key role that material (physical and tangible) facets of experience play when people approach museums, heritage sites, and heritage artefacts. While this is acknowledged by numerous heritage studies experts and practitioners, interpretation strategies often neglect these aspects, and so do digital designs. Due to the fundamental embodied, sensory, and embedded elements (as well as the emotional and intellectual ones) of the human experience of technology (McCarthy & Wright 2004), the practice of designing encounters with virtual heritage must be cognizant of this complexity.

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CHAPTER 6

Video Games as Concepts and Experiences of the Past

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More and more, people do not experience the past through books, museums, or even television, but through video games. This chapter discusses how these popular entertainment products provide playful and fun experiences of the past – something we refer to here as past-play for the sake of brevity. The video game industry has become a major, fast-moving player when it comes to creating, innovating, and distributing virtual representations of the past (Champion 2015). The study of such playful video game-based products as examples of virtual heritage is part of a growing field, called archaeogaming. Archaeogaming can be generally defined as 'the archaeology of digital games', with roots in a diverse set of analogue and digital archaeological themes and tools (Reinhard 2018). It also draws in a variety of tools and thinking from game studies, game user research, and computer sciences. Archaeogaming is also a movement born in and out of playful, digital scholarship that studies popular, digital culture but itself also seeks to be part of popular, digital culture (Politopoulos et al. 2019a).

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In contrast to other research in the field of virtual heritage, questions of accuracy of reconstruction and scholarly standards are of secondary importance in archaeogaming – although the question 'Is this historically accurate?' frequently serves as a point of departure for many entering the field. The reason for this is that video games are not primarily (or at all) meant to be accurate reproductions of the past. Instead, they are first and foremost entertainment and artistic products that are meant to be fun. So, instead of asking 'How accurate is this digital recreation of the past in this game?' game makers and most players will ask 'How much fun am I having with (this part of) the game?' An archaeogaming type of question can then be: 'How and for whom is this part of the game, which is a digital recreation of the past, fun?' One answer may be that it is fun because it is an accurate, solidly researched representation of a thing from the past, but this is only one of the possible explanations. Other answers may be that heritage in a game provides a fun challenge (e.g., it is something tall to climb), is emotionally affecting (because it tells an upbeat or dark history), engaging, and relatable (because the player can personally relate to a character/event/place), or makes you feel like you have gone back to the past in an actual time machine (because the game is interactive, immersive, and authentic).

Fun may not seem to offer particularly solid ground for a serious line of research, but do not be deceived by some conservative yet influential voices that tell you that making, having, or thinking about fun is not serious or productive. Fun is a highly intriguing and complex thing; we all know it when we are having it, but it is difficult to explain what it is exactly or to recreate it consistently. We often use the definition of fun as posited by cultural philosopher and game developer Ian Bogost: fun as a relation of commitment, attention, and care. The things you end up having these types of relations with is up to you to establish. However, having fun with (video) games is something that for a variety of conservative historical and economic reasons, go beyond the scope of this chapter (see Sharpe and Thomas 2019) but is somewhat of a taboo in academic circles. This is one of the reasons that a lot of archaeogaming work is done outside of traditional scholarly channels such as books and journal papers, but through social media, blogs, live-streaming, and video essays. No matter in which form it is presented, work on how video games let us create and experience the past in ways that are fun as well as personally and societally impactful is as intriguing, complex, and important as any theme in (virtual) heritage studies – although, we acknowledge, it is perhaps a bit more fun.

After providing some context to how past-play works and what forms it takes, we will review four different cases of past-play: the *Assassin's Creed* series, an action-adventure series set in various periods and regions of the past; *Never Alone*, a game that turned into a global success, co-developed by the Iñupiat, an Alaskan indigenous tribe; *RoMeincraft*, a project developed to raise awareness of Roman heritage in the Netherlands; and the *No Man's Sky Archaeological Survey*, a project developed to document the heritage of a procedurally generated galaxy with thousands of players. In each of these short reviews, we will answer four key questions related to heritage in games: what sort of heritages do we experience through video games, who has created these, for whom, and how are they fun? These will provide concrete examples of the potential and pitfalls of the diverse ways we play with the past in the present.

How Does Past-Play Happen?

Often described as 'magic circles', a term coined by the historian J. Huizinga in his seminal *Homo Ludens* (1938), games are frequently cast as things that mimic the 'actual' world. This definition of games is helpful to get a first understanding of how they provide experiences of the past: by creating a 'playground' set aside in space and time from the here and now (Politopoulos et al. 2019a). Even so, an expanding body of game studies has convincingly argued that a view of games as disconnected 'magic circles' minimizes the many ways in which this medium enduringly affects us as individuals and members of local to global communities, or how games themselves are entangled with 'outside' political, economic, social, and ideological forces (e.g., Keogh 2018; Dyer-Witheford & De Peuter 2009).

Video games are rooted in and intertwined with a complex set of technological, cultural, and societal factors. Firstly, video games are made possible through the processing of graphics, sounds, feedback, rules, and stories by computers (Newman 2010). Secondly, and as discussed above, they are generally speaking meant to be for fun. To begin to understand how they do what they do, it is useful to view games as a blend of mechanics (game rules and computer programming), dynamics (gameplay and goals), and (visual, aural, haptic, and emotional) aesthetic components that work together to create compelling, immersive, and affective experiences. Players do not passively consume these components but interact with them by providing input to a computer; in doing so games frame their players as powerful, creative, and performative agents. Player input is reacted to and evaluated by the computer or, in the case of social games, the computer and other players (Karhulahti 2015).

It is important to realize that games are designed and crafted using a range of digital specialties, often distributed among teams of tens, hundreds, or even thousands of highly skilled people. The production and consumption of their work constitutes a growing, global, hi-tech, and competitive entertainment industry, on par with or even eclipsing movies, books, and other media industries. While public history and heritage studies, as well as art history and media studies, have looked quite extensively at how the past is negotiated in all forms of media, comparatively little has been said about how video games function in this capacity. Studies of a subset of games, so-called serious games made for history and heritage outreach, provide an exception to this. Yet, according to recent overviews of this field, the picture is not clear and more research on their effects is badly needed (Champion 2016; Koutsabasis 2017). Moreover, serious games that are specifically designed to enable understanding of and access to

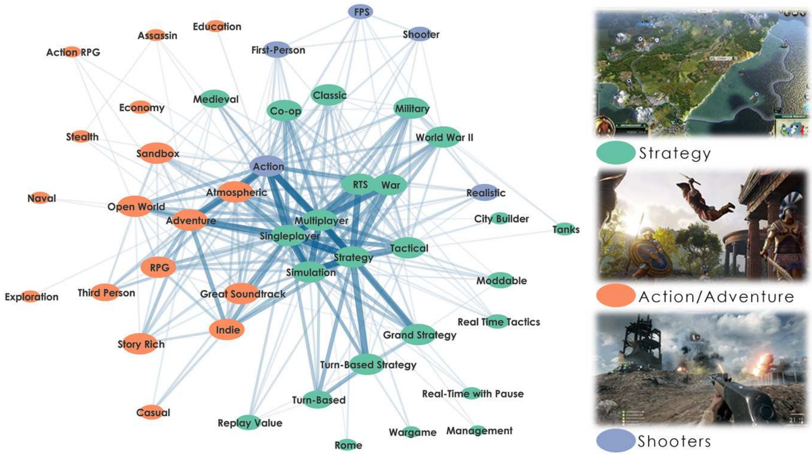

Figure 16: A network showing three 'families' of historical games, using data from Steam. Nodes represent game elements ('tags') that are identified and reported by the players of these games (produced by Angus Mol).

the past are certainly not the most impactful forms of past-play, at least in the quantitative sense. Instead, the vast majority of past-play takes place in popular games like *Civilization*, *Assassin's Creed*, and *Battlefield*.

What Forms of Past-Play Are There?

An estimated two billion people, or more, play games (Statista 2020). As a growing, global, and diverse community playing a large variety of game types, it is impossible to tell how many of those billions frequently play games set in the past and what sort of heritage and other experiences these games offer to them. Still, it is possible to get some sense of this by looking at what players themselves report on what they play.

We did this by using a web-scraper – a little 'robot' or computer script that collects information from specific pages on the web – that collects information on historical games on Steam, a leading game online marketplace (Mol 2019; Figure 16). Steam allows players to tag, from over 300 different types of descriptors, the games they play, which it uses to provide recommendations to all of its users. Based on the analysis of game contents tagged by millions of players, it becomes clear that most historical games build on a relatively narrow set of elements, leaning heavily on a view of history as conflict-driven (e.g., 'Action' and 'War' are commonly tagged game contents). While these games share many aspects, the study also showed they can be divided into three 'families': strategy games, action-adventure games, and first-person shooters (Figure 16).

User and sales numbers reported by industry members can provide a first insight into the popularity of past-play. For example, Firaxis, the creator of *Civilization*, stated that from 2010 to 2016 people collectively played more than 1.2 *billion* hours of this game – eclipsing, for example, time spent in some of the world's best-visited museums (Mol et al. 2017). The maker of the *Assassin's Creed* series, Ubisoft, has shared that since 2007 these games have sold more than 140 million copies, making it one of the largest game franchises of the last decade. The publisher Electronic Arts stated, in a 2017 report to its shareholders, that *Battlefield 1*, a 2016 game set in WW1, had attracted 25 million players in a little over a year (Minotti 2018).

Given these numbers, it seems difficult to overstate the popularity of past-play, yet high sales or engagement does not necessarily equate to cultural or societal impact. Yet some evidence already supports the idea that these popular games have a significant influence on how we relate to and think about the past, amongst which a survey of players of popular historical games recently undertaken by us and two of our students, Omar Bugter and Stefan Tibboel (Mol et al. 2020). For example, 93% of respondents to the survey (n = 1670) reported that games have inspired them to learn more about a historical person or event and 90% agree with the statement that video games can change people's viewpoints on a historical event.

Notwithstanding the deep interest individual game makers may have for history and heritage, popular historical games are traditionally and still frequently pitched as 'magic circles'. They offer forms of digital heritage that – for the sake of fun and finances and in the opinion of those in control – should be seen as separate from the cultural and societal dynamics of the 'outside' world. For example, Sid Meier, lauded game designer and creator of *Sid Meier's Civilization*, has stated that 'one of our fundamental goals [in making *Civilization*] was not to project our own philosophy or politics onto things. Playing out somebody else's political philosophy is not fun for the player.' A. Condelius (in Taylor 2018), COO of Ubisoft, the developer of the *Assassin's Creed* series, has similarly stated that 'People like to put politics into [our games], and we back away from those interpretations as much as we can [as they are] bad for business, unfortunately.'

Yet many smaller studios and independent creators do find new ways to provide players with an engaged, possibly fuller, sense of histories and heritages. Some of these so-called 'indie' titles also have been met with huge critical and commercial success. In addition, once a game is in the hands of its players, virtual heritage in it can take on all sorts of different shapes not intended by the developer – for example through the things players make in-game or through extensive modifications, 'mods', to the game. This provides a space for creative and surprising engagements with the past and makes new forms of virtual heritage. It is therefore important that any prospective archaeogamer has an eye for virtual heritage in a variety of forms: as produced and consumed in

Figure 17: Buildings at Delphi in AC: Odyssey and the same locations in reality (after Politopoulos et al. 2019).

'blockbuster' games such as *Assassin's Creed*, through the innovative interventions of 'indies', and as created by the many people who play with the past.

Assassin's Creed

The *Assassin's Creed* series (AC) is one of the most popular and enduring video game series set in the past. Twenty-one AC games and spin-offs have been released since its initial appearance in 2007, across several platforms, all using various historical settings and characters. Eleven games belong to the core set of releases and can be described as third-person action-adventure games. The action-adventure aspect of the game revolves around three main mechanics: fighting, stealth, and parkour. However, as it is evident from the title of the series, killing is central to how the stories of the games play out.

The backstory of the game presents two shadowy organizations, the Assassins and the Templars, which fight for the acquisition of ancient artefacts and technologies belonging to a precursor advanced civilization. One of these technologies, the Animus, allows individuals to visit the past through memories of their ancestors. Using this as a core narrative device AC allows the player to visit multiple periods and places of the past. This broad theme, which gives an opportunity to the developers to revisit pretty much any historical (or fictional) location and time, combined with a detailed and attentive reconstruction of past places, has been central to the success of the series. This is exemplified in the highly detailed reconstruction of Athens or Delphi in *AC: Odyssey*, the latest addition to the series (Politopoulos et al. 2019b; Figure 17).

All the games are developed by Ubisoft, one of the largest video game companies globally, with development studios around the world. Different development studios have been responsible for the various releases, providing a form of diversity in the development process; however, one would be hard-pressed to argue that AC games have been considerably different from each other, despite the diversity of settings. In that lies both the success, but also the pitfall of the series. AC games offer a widely popular yet relatively repetitive approach to both gameplay and the past. While the player gets to experience beautiful settings and meet historical characters from several periods, this experience can only be had through killing. In the end, the game creates a weird balance of killing and heritage tour, making the past an enticing yet violent place to be.

Never Alone

In *Never Alone*, you play as the Iñupiaq girl Nuna and Fox, who seek to find the source of a blizzard that has destroyed her village. The two-dimensional game marries platforming (i.e., jumping and running) with puzzles that can only be solved when Nuna and Fox work together. As a player you will encounter all sorts of obstacles that are part of the cultural and natural world of northern Alaskan, from being chased by a polar bear to having your head taken off by Northern Lights Spirits. The game is based on the living history and heritage of the Iñupiat (the plural for Iñupiaq), an Alaskan indigenous group. One of the game's mechanics is 'Cultural Insights', collectibles that let the players watch video interviews with Iñupiat in which they tell about all sorts of their life and histories with information that can be directly related to the puzzles, enemies, or items you as a player are encountering.

The game is the result of a co-creative process between The Cook Inlet Tribal Council (CITC), a tribal non-profit serving the Iñupiat people, and E-Line Media, a game developer originally based in Seattle. Looking for something that would be a way that would allow them to keep their traditional culture alive but also speak to the younger members of their tribe, the CITC decided to invest in game development. The story of this development of *Never Alone* – which involved a first visit by E-Line in the middle of a January blizzard, getting the permission of the person who was the owner of the main story told in *Never Alone*, the creation of a unique art style based on Iñupiaq art, the decision to narrate the game in Iñupiaq – is an enormous success (for the rest of this fun history, see CITC 2016). Not only did the game manage to teach Iñupiaq values and tradition to their children, but it also became a commercial and critical success.

The game is beautiful, and the Cultural Insights are enthralling, providing a window for non- Iñupiat into a world they may never visit but will come to respect or even love through play. Perhaps more importantly, it is also fun, something that is achieved through the cooperative puzzle-solving between

Nuna and her Fox friend. As is explained in the first Cultural Insight, the idea that we are never alone is a key part of Iñupiaq worldview – the alternative title is *Kisima Innjitchunja*, Iñupiaq for 'I am not alone'. Making connections with others through cooperative or social gaming is a game activity that is found fun by many. The human connection at the heart of *Never Alone* is a great example of how mechanics and aesthetics vested in a culture's most cherished heritage, as well as a key part of the culture of gaming, come together to create something truly special and fun.

RoMeincraft

RoMeincraft is a project developed and carried out by the VALUE Foundation, of which the authors are founding members. The project's aim was to raise awareness of existing or lost Roman heritage in the Netherlands, and particularly the Dutch Limes, through the reconstruction of Roman cultural heritage sites in the popular video game *Minecraft*, together with the broader public (Politopoulos et al. 2019a).

Minecraft is best described as the LEGO of the video gaming world. It is an open world sandbox game without a real purpose but to build whatever the player likes. The *Minecraft* world consists of pixelated blocks of various materials that the player can dig up, collect, and use to construct pretty much anything. The game is offered in two modes: the survival mode, where the player is thrown in a randomly generated map and has to survive by any means necessary, and creative, where the player has limitless access to every material in the game. This latter mode is what made *Minecraft* ideal for our project.

For *RoMeincraft*, we designed scaled maps of the Netherlands (ranging between 1:2–1:4), with the locations of Roman forts being 1:1. In Minecraft every block is 1×1×1m, which makes it easier to measure space. We then conducted a number of public events in museums, plazas, and cafés, where our visitors could use one of the provided computers (or even a laptop they brought themselves) to go to a given location and start reconstruction of Roman forts. We provided players with supplementary material with historical and archaeological information about how these forts looked, but generally, players were free to construct anything they imagined would exist in Roman Netherlands. This resulted in a number of impressive constructions, several ancient Greek temples, as well as a polar bear infestation (Figure 18).

The *RoMeincraft* project and other projects like it show that a game does not necessarily need to be set in the past to still become an object of virtual heritage study and outreach. It is, rather, the use we make of them that has the potential to create new and engaging ways of presenting virtual heritage to a wider audience. The open and creative nature of the project gave an opportunity to visitors to engage with Roman heritage in a new way, but also in their own way, either by building in *Minecraft*, watching other people build, discussing, reading,

Figure 18: Screenshot of the reconstructed fort Matilo in *Minecraft* that had been built over several *RoMeincraft* events held in Leiden, 2017 (Authors).

or simply by being there and experiencing the event. This is an example of what happens when fun, rather than historical or graphical fidelity, is the aim of virtual heritage projects.

The No Man's Sky Archaeological Survey

The No Man's Sky Archaeological Survey (NMSAS) is arguably the most strictly archaeological project undertaken within a video game (Reinhard 2018: 88–160). Conducted by Andrew Reinhard as part of his PhD study, its aim was to demonstrate the viability and validity of archaeological methods for the study of digital spaces.

No Man's Sky is an online multiplayer exploration-survival game developed by Hello Games. It is set in a procedurally generated galaxy, which spawns an infinite amount of algorithmically generated planets. The player is dropped in a random location of the galaxy and has to work their way to its centre, all while visiting planets to extract resources that can either be sold or used to construct or buy equipment and improvements for the player's spaceship. The planets, however, not only contain natural landscapes but also randomly generated ruins of extinct cultures or even remains of players' settlements that have been ruined by software updates.

Reinhard implemented a full-scale community-driven survey to record all of this in a systematic manner based on the archaeological methodology of field survey. This project aimed to record now-extinct player and algorithmic heritages, as well as secure information on existing ones, before another catastrophic event would wipe them out. The NMSAS was opened up to Twitter and the Reddit community of the game, which allowed Reinhard to collect significantly more data than any given survey projects can realistically collect, through playing archaeology in a virtual, player-created world. This demonstrated both the importance but also the possibilities archaeogaming offers in doing research together with a wider audience as well as how it can research at larger scales and using archaeological frameworks, virtual heritage that is itself born digital. The NMSAS was both fun for its participants and offered new ways of thinking about digital spaces and heritage.

Conclusion

While many of the qualities of video games overlap with other (popular) media, the interplay of all of these – computational, fun, immersive, affective, interactive, performative, crafted, industrial, 'magic', entangled – means that games provide one-of-a-kind experiences, not only *in the present* but also *of the past*. The examples presented above highlight only some of the potential virtual heritage experiences produced through video games. It is exactly this combination of qualities alongside the wide diversity of past experiences that make video games stand out from other popular media. Video games are useful not (only) because they can offer us accurate representations of the past; in fact, one could even say that this is the least interesting of their potential uses. Rather, video games are a crucial form of digital heritage because they can offer us *concepts* of the past, ways of thinking in, around, and about the past, as well as experiences of the past through play.

Assassin's Creed games give players an opportunity to walk around cities of the past, and talk and interact with historical figures that you only read about in books. Games such as *Never Alone*, produced by indigenous populations, allow developers to safeguard cultures and players to encounter new ones virtually, and in the process provide access to concepts of the past that would otherwise remain inaccessible. The *RoMeincraft* project illustrates the space video games offer for promoting digital heritage, not only as educational but perhaps more so as pure play. This also underlines the co-creative and co-mediated side of heritage outreach. Finally, the *No Man's Sky* Archaeological Survey shows that heritage is not only something that can be put in video games but can also be born virtual. This requires new ways of studying these virtual cultures, as well as new room to play around with the concept of recent, fleeting, and born-digital pasts.

The common denominator, however, in all these experiences is fun. These games not only offer diverse approaches to share, study, and create virtual heritage through past-play past, but also as a relation built on commitment, attention, and care – in other words as something fun. Work in archaeogaming and other forms of past-play has already shown some of the potential of games but the breadth of experiences that can be had in these games as virtual heritages shows that there is much more to be done and much more fun to be had.

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CHAPTER 7

Mixed Reality: A Bridge or a Fusion Between Two Worlds?

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Abstract

Virtual heritage (VH) is one of the few domains to adopt immersive reality technologies at early stages, with a significant number of studies employing the technologies for various application themes. More specifically, virtual reality has persisted as a de facto immersive reality technology for virtual reconstruction and virtual museums. In recent years, however, mixed reality (MxR) has attracted attention from the VH community following the introduction of new devices, such as Microsoft HoloLens, to the technological landscape of immersive reality. Two variant perceptions of MxR have been observed in the literature over the past two decades. First, MxR is perceived as an umbrella/collective term for a virtual reality (VR) and augmented reality (AR) environment. Second, it is also presented as a distinctive form of immersive reality that enables merging virtual elements with their real-world counterparts. These

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perceptions influence our choice of immersive reality technology, interaction design, and implementation, and the overall objective of VH applications.

To address these concerns, this chapter attempts to answer two critical questions: (1) what MxR from VH perspective is and (2) whether MxR is just a form of immersive reality that serves as a bridge to connect the real world with a virtual one or a fusion of both that neither the real nor the virtual world would have meaning without a contextual relationship and interaction with each other.

To this end, this chapter will review VH applications and literature from the past few years and identify how MxR is presented. It will also suggest how the VH community can benefit from MxR and discuss limitations in existing technology and identify some areas and direction for future research in the domain.

Introduction

Despite the significant advancements observed in the technological landscape of immersive reality and its expanding applicability across various domains, the perceptions of immersive reality technologies in general or at least their depiction in the VH literature remains influenced by earlier theoretical and technological perspectives – missing current contextual and domain-specific views. For instance, one of the earliest and widely accepted definitions of augmented reality (AR) by Azuma (1997), a segment of the reality-virtuality continuum proposed by Milgram and Kishino (1994), depicts AR as 'a system that combines real and virtual content, provides a real-time interactive environment, and registers in 3D.'

In addition to AR being presented as a system/technology, the characteristics that identify the segment from the rest of the continuum are that it 'combines real and virtual' content and 'provides real-time and 3D interactive environment'. These properties are observed similarly in MxR systems and environments, making AR and MxR identical or interchangeable as they attempt to combine real and virtual content and provide 3D interactive environments. As such, distinguishing AR from MxR relying on such properties is difficult. One of the primary objectives of this chapter is, therefore, to delineate a boundary between AR and MxR, at least from the VH point of view (the assumption is that the boundary between MxR and VR is much clearer as much as it is between AR and VR). To this end, establishing the current depiction of AR and MxR in the literature is required. Furthermore, distinguishing MxR from the rest of the segment requires identifying key factors from the VH perspective.

To date, there are two widely conveyed definitions of MxR in the literature. First, MxR is perceived as a combination of AR and VR. For instance, Elrawi (2017), Makino and Yamamoto (2018), and Plecher et al. (2019) present MxR as a combination of AR and VR environment and/or a collective term representing both AR and VR. This has led to the consideration of AR and VR as the primary platforms for highly immersive and interactive VH applications (Haydar et al. 2011; Papagiannakis et al. 2018). Further to this, the technical complexity and requirements of fusing real and virtual elements, which is a unique property of MxR, to the extent that the blended environment appears as real as the real world has remained extremely challenging. This has to some extent resulted in a lower number of MxR applications and paved a favourable path for AR's and VR's position as the default platforms/technologies.

Second, contrary to the first view, some studies consider MxR as a unique segment of the reality-virtuality continuum that is characteristically and technologically different from both AR and VR. For instance, Jacobs and Loscos (2006), Okura et al. (2015), Bekele and Champion (2019b), and Hammady et al. (2020) present MxR as a technology and virtual environment that amalgamates real and virtual worlds into a single and shared real-virtual spectrum.

Hence, it is evident that a common understanding of MxR is required before an attempt is made to answer the critical question 'Is mixed reality a bridge between two worlds or a fusion of two worlds?'

Contextual Relationship in Augmented and Mixed Reality

The widely accepted definitions of AR and MxR in the literature rely on systems and technological perspectives. Distinguishing MxR from AR and the rest of immersive reality technologies, therefore, requires identifying additional factors from a different perspective rather than the underlying technology and theoretical basis. To this end, an article published by Bekele and Champion (2019b) identifies a contextual relationship between users, the real world, and the virtual environment as a factor that differentiates a specific form of immersive reality from the rest of the segments of the spectrum.

The contextual relationship is realised when the combination/blend of the real and virtual environments enables a three-way interaction between users, reality, and virtuality. Establishing a contextual relationship also relies on how the blended environment resembles and feels as real as the real world. The outcome is an enhanced and engaging real-virtual space that ultimately allows users to establish a contextual relationship with the real-virtual environment. The fusion and the three-way interaction are equally important factors to outline a boundary between AR and MxR. From a VH point of view, communicating or obtaining meaning and cultural significance through immersive reality without a mechanism to establish such a contextual relationship will be a difficult task. Considering fusion and contextual relationship as additional differentiating factors, AR and MxR can be outlined as follows.

Augmented reality is a form of immersive reality that enhances our perception of the real world and allows users to interact with reality and virtuality. Usually, virtual content is superimposed onto our view of the real world. The content could be in any multimedia format ranging from text to 3D models.

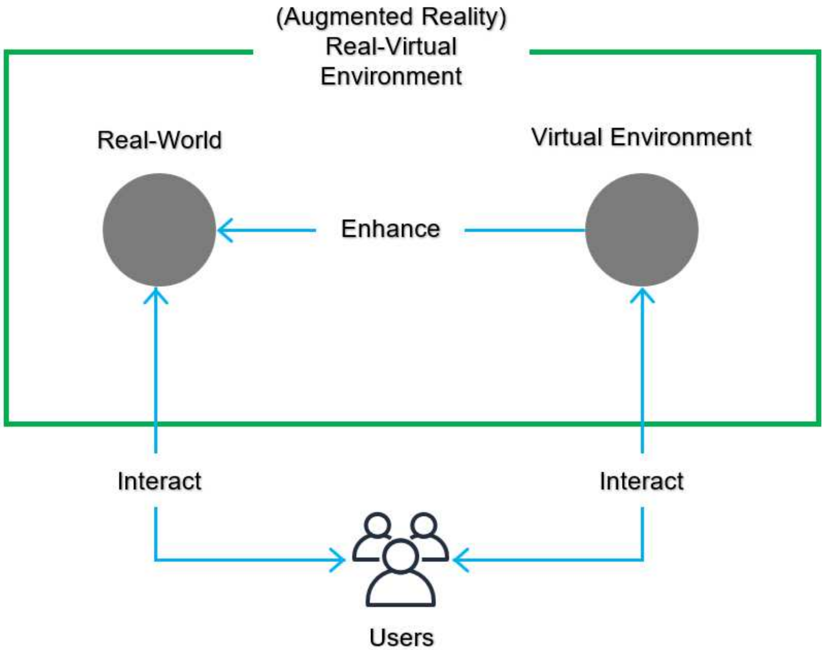

Figure 19: Augmented reality is a form of immersive reality that enhances our perception of the real world and allows users to interact with reality and virtuality (figure produced by the author).

As a result, there is relatively less expectation of the real-virtual environment resembling the real-world.

In addition to this, the resulting real-virtual space in AR does not allow a three-way interaction between users, reality, and virtuality. Users are usually at the centre of the interaction establishing a direct relationship with the real world and the virtual environment. For instance, digital content (text, video, audio, 3D models) of cultural heritage assets can be superimposed over our view of the real world. In some cases, such as virtual reconstruction, digital content can be superimposed on top, or projected next to the same heritage assets in the real world. In this scenario, the virtual environment that is visible to users through AR technology relies on the assets in the real-world to communicate the complete meaning of the multimedia content. The physical assets in the real world would have meaning on their own but users' understanding of the assets' cultural significance would be enhanced with the AR technology. Figure 19 presents AR as immersive reality technology that allows users to interact with a real-virtual environment, enables a contextual relationship between users and the real-virtual environment, and enhances the users' understanding of the real world.

Mixed reality, on the other hand, is a distinctive form of immersive reality that enhances our perception of both the real and virtual environments and

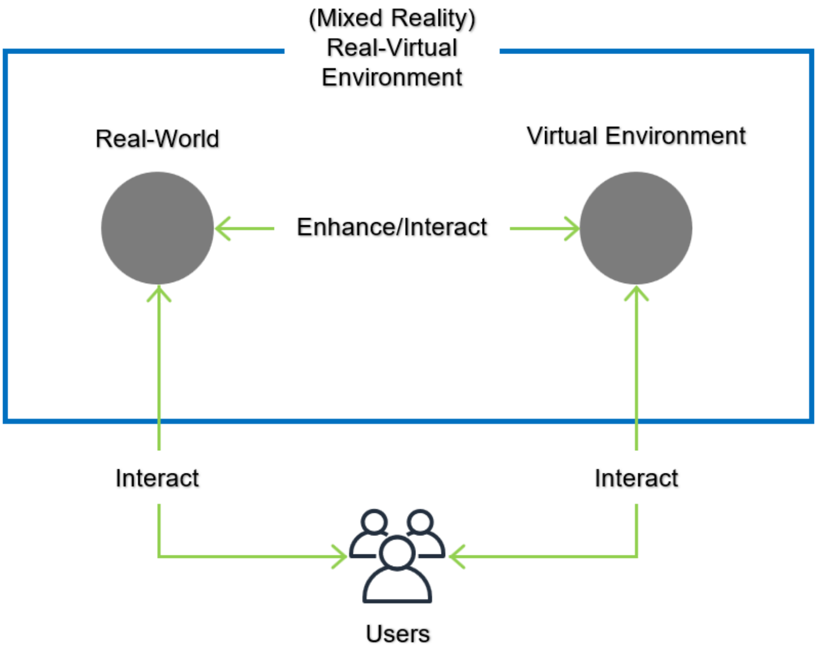

Figure 20: Mixed reality is a form of immersive reality that enhances our perception of both the real and virtual environments and allows interaction between users, reality, and virtuality (figure produced by the author).

allows interaction between users, reality, and virtuality. Figure 20 presents MxR as immersive reality technology that allows users to interact with a real-virtual environment, enables a three-way contextual relationship between users, the real world, and the virtual environment, and enhances users' understanding of both the real world and the virtual environment.

The real-virtual environment (a combination of real and virtual) provides a shared space that elements from both worlds utilise to enhance our understanding of both worlds. In this regard, the difference between AR and MxR is that the virtual environment in AR is limited to enhancing our understanding of the real world. Hence, the relationship between the real and the virtual environment in AR is limited to a one-way direction. The virtual environment in MxR, however, is not limited to enhancing the real world. It also benefits from the real word for delivering enhanced meaning. This arrangement results in a three-way relationship between users, reality, and virtuality.

For instance, consider shipwrecks or physically recreated replica of ships in a museum. Conveying the history and cultural significance of the ships to visitors can be realised via AR (superimposing multimedia content and 3D models) or via MxR (blending virtually simulated 3D animated model of the crew and the physical recreation of ships). Both approaches can enhance visitors' understanding of the ships. However, the MxR approach provides a shared space for both the physical ship and the virtual simulation to communicate the complete picture of the story of the ship. Because, in this scenario, the simulation and the physical heritage asset are highly dependent on each other.

In summary, VH can adopt multiple forms of immersive reality technology to achieve a similar objective (i.e., whether explicit or implicit, VH applications tend to aim at communicating/transmitting the significance and value of heritage assets to visitors/users of the applications). However, considering the available technologies (AR, VR, AV, and MxR), a specific form of immersive reality can deliver the expected outcome more effectively than the rest. This is even more evident when comparing AR and MxR against their potential to enable a three-way contextual relationship between users, reality, and virtuality and blending the real and virtual environments.

As Table 1 shows, MxR exhibits unique aspects especially in terms of establishing a contextual relationship between reality and virtuality and blending the real and virtual environments to the extent the fusion is as real as the real world that results in benefiting both worlds. These unique features of MxR make the technology an ideal choice for VH applications that aim at virtuality recreating or simulating partially or completely lost tangible and intangible heritage assets and blending them with their counterparts that still exist in the real world.

Table 1: Comparison of AR and MxR against their potential to enable a three-way contextual relationship between users, reality, and virtuality and blending the real and virtual environments.

Factor	Augmented Reality	Mixed Reality
Blending the real and virtual environments	Overlays virtual content onto the real world	Virtual content is blended with the real environment resulting in a shared real-virtual environment
Interaction between users and the real world	Users can interact and establish a contextual relationship with the real world	Users can interact and establish a contextual relationship with the real world
Interaction between users and virtual environment	Users can interact and establish a contextual relationship with the virtual environment	Users can interact and establish a contextual relationship with the virtual environment
Interaction between the real world and the virtual environment	There is no interaction between the real world and virtual environment in AR and the sole purpose of the virtual content is enhancing the real world	There is a continuous contextual relationship between the real world and virtual environment in MxR to the extent that specific meaning (e.g., cultural significance in VH) can only be derived from the relationship

Mixed Reality: Bridge versus Fusion

Having the boundary between AR and MxR outlined, this section attempts to determine whether MxR is a bridge that connects the real and virtual world or a fusion of the two worlds that serves as a shared space where contextual relationship, collaboration, and engagement can be realised to a higher degree of realism. To answer this crucial question, we need to establish the aspects and scope of *immersive reality as a bridge* and *immersive reality as a fusion* from the context of VH and the objectives of this chapter.

Immersive reality technology can serve as a bridge between two worlds connecting us to past and/or lost cultures and heritages. In the context of the applicability of immersive reality in VH, the 'two worlds' refer to the existing physical world and a virtually simulated environment that is spatiotemporally distant from the existing physical world. The bridge analogy is, therefore, characterised as a spatiotemporal vehicle that can transport us to a different time and/or a different place. A typical immersive reality technology with such capability is VR. This technology can deliver a platform for highly immersive virtual environments that can simulate multiple dimensions of past traditions, cultures, and heritages. The immersivity of VR is not limited to the spatial and geometrical aspects of the simulated virtual environment. An ideal simulation will consist of multidimensional aspects of the simulated culture/heritage such as temporal, attributive, and environmental parameters. Such simulations can effectively transport us to the past to the extent that we are tricked to believe we are situated there and then.

Alternatively, immersive reality technology can also fuse the real and virtual worlds. From a VH perspective, the fusion of the two worlds is a real-virtual environment that serves as a shared space for the past and the present to coexist (Brondi et al. 2016). Past cultures and civilisations can virtually reoccupy or blend with the existing physical environment. Unlike the bridge analogy, which transports us to a past and distant world, the fusion of two worlds lets us experience the same past and distant world interacting with the existing physical reality that surrounds us. The fusion, therefore, exhibits properties of both the real and virtual environments that ultimately enables a contextual relationship between the two worlds.

All forms of immersive reality technologies except VR can blend real and virtual environments at different levels of interactivity, immersivity, and contextual relationships between components. For instance, a properly designed and implemented augmented virtuality (AV) system can blend the real and virtual environments in real-time. In this case, a live scene from the real world is streamed into the virtual environment rather than cases of AR where the fusion results in virtual content augmenting the real world. With both AV and AR, there is always a dominance of one environment over the other. The third alternative is an MxR technology where the fused real-virtual environment serves as an equally shared space for both realities. However, technological advancement is far from a state that such fusion can be realised to its full extent. Considering existing technologies, however, MxR is a typical form of immersive reality that is best suited for fusing the real and virtual environments.

Relying on how MxR is outlined in the context of VH in this chapter, the environment in MxR is a fusion of two worlds rather than a bridge between two worlds. This is because:

- MxR enables a contextual relationship between users, reality, and virtuality.
- MxR provides a balanced and shared space for elements from both the real and virtual worlds to interact with each other.
- Both the real and virtual worlds can be meaningful by themselves (unlike AR, where the virtual environment relies on the real world to be meaningful).
- Both worlds depend on each other for enhanced meaning.

Mixed Reality and Virtual Heritage

A significant number of studies have demonstrated the role of immersive reality technology in terms of enriching cultural heritage sites and museums with engaging, interactive, and immersive experiences (Hammady et al. 2020). Recent technological advancements have made MxR even more beneficial and accessible to VH applications that tend to target virtual reconstruction in situ. Considering such recent development and trends, the followings have been identified in the literature as viable application themes of VH:

1. Virtual reconstruction. Virtual reconstruction relates to the recreation of fully or partially lost tangible or intangible cultural heritages. MxR is the best choice for VH applications with such themes because the technology can blend the reconstructed virtual environment with physical objects that exist at the historical location of the cultural heritage assets (Montagud et al. 2020).
2. Virtual exploration. VH applications designed for virtual exploration aim at knowledge and insights discovery because of the VH application's capability to afford manipulation and meaningful interaction with the underlying data and real-virtual environment (Okura et al. 2015; Tennent et al. 2020).
3. Virtual exhibition. Virtual exhibitions either replace physical museums and heritage sites with simulations in VR or improve/enhance users' experience at museums and heritage sites by blending virtual content with the real world, for instance, virtual tour guides in MxR (Trunfio & Campana 2020).

4. Virtual educational tools. To some extent, all the above applications serve as tools to educate/inform users regarding the historical and cultural aspects of the content presented in the applications. However, effective dissemination of cultural significance (cultural learning) requires VH applications that primarily focus on the outcome and learning aspects of the virtual content, application design, and implementation of immersive reality. To this end, MxR is a viable choice as the technology enables engagement, interaction, and contextual relationship with the real-virtual environment (key characteristics of VH applications that aim at cultural learning).

Current Issues and Future Directions

Mixed reality technology as it stands has several limitations hindering its wider adoption. The limitations identified in existing studies include rendering performance, lack of robust environmental tracking solutions, and a lack of easy-to-use multimodal interaction interface (Bekele 2019). Considering ongoing research on cloud-based immersive reality and human-computer-interaction (HCI), it is expected that future research will focus on the following areas:

1. *Cloud-based rendering*. Rendering is perhaps one of the key technical issues that MxR applications face across domains. It is even more problematic in VH applications that present sophisticated 3D models with millions of polygons. Even the market-leading MxR device, Microsoft HoloLens, struggles to render 3D models with such a large number of polygons. As a result, decimation is required to reduce the number of polygons, which will then deduce details from the model impacting user experience and the vividness of the rendering. However, Microsoft Azure announced a cloud-based remote rendering service as part of their MxR solutions. The remote rendering service will handle all the graphical computation workloads from the MxR device. Meaning, sophisticated 3D models can be rendered remotely and streamed to the MxR device, which is the Microsoft HoloLens.
2. *Cloud-based tracking*. Sensor and camera-based tracking solutions are commonly adopted in existing VH applications. However, these solutions, particularly in outdoor settings, remain error-prone, impacting user experience. In this respect, new cloud-based services, such as Microsoft Spatial Anchor, provide the possibility of utilising cloud computing to store, share, and retrieve location data of points of interest for MxR applications across multiple platforms and devices. Meaning, VH applications can target multiple devices for user experience while maintaining a shared and centralised pose tracking solution.

3. *Multimodal interaction interface*. An ideal multimodal interaction interface combines multiple modes of interaction allowing users to interact with virtual environments as they would interact with the real world (Bekele & Champion 2019a). This is a key property of MxR experience. Existing technologies rely on gaze, gesture, and speech inputs to enable multimodality in interaction interfaces. For instance, Microsoft HoloLens utilises all three inputs. As research advances in sensor technology, artificial intelligence, and tangible interaction, more advanced multimodal interaction interfaces will likely become a common method of interaction in VH, thereby enabling engaging, interactive virtual environments that users can effectively relate to and interact with through all their senses.

Conclusion

This chapter has presented different perceptions of MxR, especially in the VH domain. It has also outlined a boundary between AR and MxR before attempting to answer the key question raised in the chapter 'Is MxR a bridge between two worlds or a fusion of two worlds?' Immersive reality technology's capability to establish a contextual relationship between users, reality, and virtuality and believability and realism of the real-virtual environment resulting from the fusion of the real and virtual worlds were used as differentiating factors. I have identified application themes and limitations for MxR and VH applications as well as future research areas and directions that I invite you to explore.

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CHAPTER 8

Getting It Right and Getting It Wrong in Digital Archaeological Ethics

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Abstract

Though the ethics of archaeological practice have changed over the life of the discipline (and have arguably become more robust), full consideration has not yet been given to how digital methodologies and the emergence of digital technologies have created new areas requiring ethical introspection. The pace of adoption of digitally centred archaeological data and digitally facilitated archaeological practice has not been met by the adoption of discipline-wide standards related to archaeological ethics. The result of this mismatch in ethics and practice is the creation of archaeologists who utilize digital forms, but whose archaeology is ungrounded in frameworks that specifically consider the ethical burdens of digital tools, methodology, and theory. This chapter details views of digital archaeological ethics related to digital archaeology as tools, digital archaeology as methodology, and digital archaeological pedagogy.

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Introduction

As archaeologists, we operate from an inherent place of privilege regarding our access to direct evidence of the past. We get to handle, study, and analyse artefacts that for a variety of reasons, are not available to the public in the same way. Because of this privilege, we have what is called a 'duty of care' to act responsibly towards the sites we excavate, as well as to the public who relies on us to produce data that is accessible, understandable, and thoughtful. The chief way in which we consider whether we are meeting that responsibility is through our practice of 'archaeological ethics'.

Archaeological ethics are the discipline-wide standards that archaeologists have agreed to uphold. They inform everything from how new archaeologists are trained (Mills et al. 2008) to how excavation data is published (Kansa & Kansa 2013) to how we work with paying clients and the many different publics that are the ultimate recipients of our knowledge production (Fowler 2017). However, these ethics are not static. As the discipline of archaeology has changed, so have the accepted ethical practices, as archaeologists have dealt with profound changes in the context of archaeology and profound changes in ethical concerns (Wylie 1996).

Most recently, archaeologists have begun to consider the ethical implications of the digital in our work. This has come in many ways, two of which we will discuss in more depth. The first issue is how archaeological ethics should consider the digital tools that we use. The second issue is how archaeological ethics should consider the digital methodologies we employ. A critical, though as yet under-discussed, third issue is how we should consider archaeological education and the digital. (This third issue is what we sometimes call 'digital archaeological pedagogy.')

As a dedicated practice, digital archaeology is too recent to be included in the published guidelines and codes of ethics that are provided by organizations such as the Society for American Archaeology (SAA), the Society for Historical Archaeology (SHA), and the European Association of Archaeologists (EAA). This does not mean that digital archaeologists should operate without ethical oversight though! Digital archaeology has expanded into mainstream archaeology, and the ethics of practice of that expansion have just not been kept up with by the professional organizations in their documentation (Dennis 2020).

One of the first discussions of what would result in 'digital' archaeology occurred in 1967, when Chenhall considered the electronic computer as a tool for data storage and retrieval (Chenhall 1967). Cowgill, also that year, discussed the introduction of computers for statistical and computational analysis (Cowgill 1967), and between the two, the push to a digital archaeology had begun. A series of arguments for and against the use of computers in archaeology occurred throughout the 1970s, and by the 1980s there was an explosion of computer-based archaeological data production. This is when total data stations and GIS began to enter archaeology. By 1992 the concept of a digital archaeology and digital archaeologists had become prevalent enough to support the founding of the Computer Applications & Quantitative Methods in Archaeology organization (CAA), a professional group focused on digital archaeology. A digital archaeology interest group followed shortly after within the SAA. Despite all that, it was not until 2003 that the first direct mention of ethics in digital archaeology was published (Bayliss 2003). Even then, CAA did not have a dedicated ethics policy for digital archaeology until 2018, and SAA and EAA still do not, though both organizations are in the process of updating their codes of ethics more broadly as of 2021.

Current Archaeological Ethics

There are two circumstances under which most archaeologists encounter formal processes of archaeological ethics. The first circumstance is through the need to comply with mandated ethics frameworks, usually provided by universities and research bodies who grant funding. These organizations ask archaeologists, both as student researchers and as faculty researchers, to detail how we're going to undertake our projects, and how we're considering ethics in those projects.

The second circumstance is less common, but is on the rise, and occurs when archaeologists meet at professional conferences or submit papers for publication. Professional organizations, like the previously mentioned SAA, SHA, EAA, and CAA groups, ask members to follow what are known as 'aspirational' codes of ethics.

Aspirational codes of ethics are intentionally general and are meant to apply to the majority of archaeological projects that follow the traditional physical excavation and journal publication model of archaeology. Aspirational codes of ethics are sometimes called 'principles', as they're not meant to dictate behaviour, but to 'define general and fundamental propositions that affirm the tents of the profession, which can be adopted to guide action in a wide variety of specific settings' (Colwell-Chanthaphonh & Ferguson 2006: 116–117). Failure to meet an organization's code of ethics has few, if any, consequences under an aspirational system. It is assumed that violations will be handled more formally by universities and employers. This is sometimes sufficient, but not always.

Within archaeology it has historically been the case that ethical behaviour is believed to be assured by an archaeologist's participation in professional membership societies and that the field should set its own standards of acceptable and unacceptable practice. Aspirational codes of ethics typically fulfil this role, due to archaeology's relationship with academic departments and organizations.

In contrast to aspirational codes of ethics, 'prescriptive' codes of ethics are more like systems of rules. A prescriptive code of ethics specifically lists acceptable and unacceptable behaviours within the discipline. As an example, the *Code of Conduct and Standards of Research Performance* of the Register of

Professional Archaeologists (RPA) is purposefully prescriptive, listing what an archaeologist 'shall' and 'shall not' do (RPA 2018). These standards are enforced via a grievance process, which is overseen by an elected officer whose role is to handle, 'allegations of violations of the Code of Conduct and Standards of Research Performance of the Register, in accordance with the Disciplinary Procedures of the Register' (RPA 2018). Prescriptive codes of ethics are more common in organizations that deal with contract or commercial archaeology, such as the Register of Professional Archaeologists and the Chartered Institute for Archaeologists (CIfA).

Because the ethics of digital archaeology are not provided as aspirational suggestions of 'good behaviour' and 'bad behaviour' nor as prescriptive directives of 'shall' and 'shall not', the onus is on those who work in digital archaeology to more carefully consider how they view their ethical relationship with the three areas of digital archaeological practice: digital tools in archaeology, digital methodologies in archaeology, and the digital education of archaeologists. We will turn now to discussing each of these areas.

Digital Tools in Archaeology

One view of digital archaeology holds that the digital aspects of archaeological practice should be considered tools (Zubrow 2006). This view holds that the use of a program such as QGIS, for spatial and relational mapping, or a digital camera and Adobe Photoshop, for site photography and creating a digital site archive, or a laser scanner, to create point clouds for 3D modelling of historic structures, are tools, to be used by archaeologists to meet an end, but without any larger ethical implications. They are equated to the trowel, the measuring tape, and the Munsell Soil Color Charts, in that they are utilized for a specific function, and their digital nature is irrelevant to the impact of their use on the completed archaeology.

While this view is not inherently incorrect, there is a danger in assuming that the ethics of using a digital tool are the same as the ethics of using a manual tool. Both digital and manual need to be considered in light of their 'ethical burdens'. An ethical burden is the weight an archaeologist must give to whether any given thing is ethically appropriate, or inappropriate. As an example, the ethical burden of a trowel is typically low for archaeologists; it is regularly a necessary tool to be used in the process of excavation. However, if the use of the trowel in an excavation would disenfranchise indigenous peoples through unwanted exhumations of human remains, the ethical burden of the trowel becomes much greater.

A common problem with ethical burden and digital tools in archaeology is what is referred to as 'black box' technologies. A black box is an object, piece of software, or system in which the user can direct input but cannot examine or verify the processes that occur before the produced output. Some potentially black-box digital tools in archaeology include the previously mentioned digital photography, geographic information systems (GIS), and photogrammetry. Most of these tools are facilitated through proprietary software, where the code that creates the output cannot be viewed. For most archaeologists, even open source software packages, such as QGIS and R, are black boxes, as they are used without a full understanding of what underpins the packages.

For those interested in further discussion of the concept of a black box in archaeology, the topic has been discussed extensively via discussions of Latour (1987), and more recently and applicably by Huggett (2017) and Caraher (2016: 434). Caraher explains its use in digital archaeology as the result of:

> …growing pressures on both academic archaeologists and those in the field of cultural resource management to produce results at the pace of development and capital. In other words, as digital tools accelerate the pace of archaeological work, more aspects of archaeological practice become obscured by technology.

Digital Methodologies in Archaeology

Another view of digital archaeology holds that the digital aspects of archaeological practice should be considered for their value as methodological and theoretical approaches (Perry & Taylor 2018). This view is concerned with how the digital is being deployed in research designs, and how digital archaeology is meeting larger issues related to public outreach and interaction with marginalized and indigenous populations. Again, we turn to the concept of ethical burden.

When considering digital archaeology as a methodological approach, the ethical burden occurs almost immediately, during planning at the outset of the project. Digital methodologies should be subject to the same level of ethical scrutiny as the use of any manual toolset or analog methodological approach. A series of simple questions, asked at the beginning of research design planning, may result in the addition, or elimination, of digital aspects of the project.

For every tool under consideration, we should ask, 'Is the use of this tool in a digital form adding value to the project that is balanced by the ethics of its use?' For every methodological consideration, we should ask, 'Is this approach, mediated digitally, fulfilling all of our needs for it, without adding undue ethical burden or breach?' If the answer to either of those questions is no, the use of the digital form should be weighed against the analog form.

Just because something can be accomplished faster, or easier, with a digital approach, doesn't mean that the ethics of that approach are equal! The ethical burden might be too high. Understanding how that burden is borne by methodological and practical choices is the responsibility of everyone on a project.

As an example, consider a project involving human remains. There are potentially widely different ethical considerations between an analog methodology and a digital methodology (Ulguim 2018).

In an analog methodology, human remains are excavated, laid out (if possible) for examination by an osteoarchaeologist, photographed, and either stored physically for future study or re-interred. The data that is collected from analysis of the remains is a tangible, physical dataset, and who can interact with both the remains and the dataset is access limited. The longevity of the dataset is determined by how well the physical medium in which it exists is maintained. In this situation, the ethical burden on those involved with the project is to fulfil their research agenda while treating the remains with dignity and to do so (if applicable) through consultation that respects the wishes and cultural rights of descendant populations.

In a digital methodology, human remains are excavated, laid out (if possible) for examination by an osteoarchaeologist, photographed, scanned for 3D modelling, sampled for digitally mediated analysis, and either stored physically for future study or re-interred. Digital records are produced of the remains, and digital copies may be created of the remains to be manipulated for methodological testing models and to be made available to the public via outreach and museological interactives. The data that is collected from the analysis of the remains is a collection of digital files, and though who can interact with the remains is access limited, the digital files are often distributed more openly. The longevity of the dataset is determined by how dispersed the digital files are and how long the digital formats in which they are stored are viable, technologically. In this situation, the ethical burden on those involved with the project is the same as in an analog methodology, but with the added burdens of negotiating the potential differences in views towards digital permanence by indigenous populations and marginalized populations.

No widespread study on how indigenous groups view their rights regarding digital archaeology related to their ancestors has been undertaken within archaeology and the ethics of digital archaeology related to human remains is being determined largely by non-indigenous archaeologists. A special issue of *Archaeologies* (Alfonso-Durruty et al. 2018; Hassett et al. 2018; Hirst, White & Smith 2018; Ulguim 2018; White, Hirst & Smith 2018) is the most thorough discussion to date concerning these issues.

Digital Education in Archaeology

Though archaeologists differ in their views of digital archaeologies as tools or methodologies, they share a common foundation in the process of education that leads to their professionalization within the discipline (Shaeffer 2016). How digital archaeology is conveyed to students, whether as tool or methodology, is arguably less important than that it is being conveyed to students, and that it is preparing them for the reality of the digitally mediated archaeology that is modern practice. Problems occur, however, when students are taught to use digital tools without teaching the accompanying ethical consideration of those tools (Dennis 2020). Students need to be educated in a process of ethical questioning concerning their digital outputs and in the resources available to address those questions.

The practical issues that professional archaeologists encounter, both in academia and commercial practice, are common to issues encountered by student archaeological researchers. These include issues in approaching and consulting with the public, issues in utilizing technology and digital tools, issues in decision-making concerning data storage and deposition, and issues in publishing and outreach, amongst others. All of the ethical issues present in these situations for more advanced practitioners are there for student researchers, but students must frequently negotiate these ethical concerns without recourse to networks of colleagues for consultation, or professional memberships for guiding principles.

Graduate students are often asked to consider the ethics of their practice through submissions to ethics review boards; however, that is frequently the first time that students encounter practical ethics in archaeology. Increased attention to undergraduate and entry graduate student-level interactions with ethics in digital archaeology, combined with an increased focus on the ethics of digital archaeology among those tasked with teaching students, is necessary to create a corpus of practitioners who are fully versed in the ethics of their profession.

As students, and as educators, we have a shared responsibility to push the discipline of archaeology forward into a more equitable, ethical practice. Part of this shared responsibility means publishing the whys and hows of the digital practice we undertake. There is little peer-reviewed literature around teaching ethics to archaeology students concerning digital applications, which means that educators have few sources to draw on to inform their teaching practice and to share with students to demonstrate best practices. Notable exceptions to this include Perry (2018) on humanizing digital archaeological and heritage practice, Graham (2016) on the creation of digital humanities notebooks, the work of participants in MSUDAI (2015) on collaborative cohorts in digital archaeological projects, and Cook (2018) on working with students to create ethically grounded digital exhibitions for museums.

Conclusions

Though the considerations of ethics within archaeology have arguably become more robust through the discipline's evolution, and digital archaeology has become more standard practice within the discipline, digital tools and digital methodologies have yet to be synthesized fully into archaeological discussion.

Alongside this, the pace of adoption of digitally centred archaeological data and digitally facilitated archaeological practice has not been met by the adoption of discipline-wide standards related to archaeological ethics. The result of this mismatch in ethics and practice shows itself most clearly in the pedagogy of digital archaeology, where little literature exists to educate newly inducted archaeologists who utilize digital forms.

Digital archaeologists, and indeed all of us who are engaged with archaeology as professionals, have a responsibility to consider the ethical burdens of our research, as well as the tools and methodologies that we utilize to accomplish our knowledge production goals. It will be only through a shared effort that digital archaeology will come to be on par in terms of ethical consideration with established practices in excavation, analysis, publication, outreach, and education.

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CHAPTER 9

Evaluation in Virtual Heritage

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Abstract

Evaluation in virtual heritage is concerned with learning about and assessing the extent to which an interactive system offers a satisfactory user experience (UX) and meets user goals and expectations. Evaluation in virtual heritage is an empirical process of research, which reaches for conclusions about the quality of a system by observing, measuring (aspects of), and interpreting the UX. It is inherently a complex activity that requires careful planning and selection of methods. It does not rely on underlying technology; however, adaptations of process and methods must be made to allow for results and feedback in context. Therefore, it must be designed so that it is useful, reliable, valid, and productive. Evaluation methods and processes are of interest to both cultural heritage (CH) professionals and technology designers, who aim to provide systems that address the widest range of potential users. This chapter discusses basic concepts, processes, and empirical evaluation methods in virtual heritage, with examples.

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Introduction

Virtual Heritage Technology

An increasing number of interactive systems aim to enhance the user experience (UX) of visitors at CH places and sites including museums, exhibitions, archaeological places, historic cities, or settlements. These systems have various goals, such as information presentation, learning, visitor engagement (when users assume roles and pursue learning goals), digital representation, preservation, or reconstruction of monuments, sites, or the like, combined with gamification elements or developed into a game. They are developed with contemporary and emerging technologies such as interactive walls, tables and surfaces, virtual/augmented/mixed reality (VR/AR/MR) systems, 3D virtual worlds, mobile location-based services and games, and so on. In a recent review article, Nikolakopoulou and Koutsabasis (2020) reported on the most common interactive technologies and interaction styles of virtual heritage: 3D game engines, mobile technologies, kinaesthetic interaction, physical computing, VR, and AR.

Importance of Evaluation of Virtual Heritage

From a design and a user-centred perspective, evaluation in virtual heritage is concerned with learning about and assessing the extent to which an interactive system offers a satisfactory UX meeting user goals and expectations, adapting ideas and methods from fields such as human-computer interaction (HCI) and interaction design.

The evaluation of virtual heritage leads to findings and recommendations about user acceptance, which interest both CH professionals and technology designers. Evaluation in virtual heritage is an empirical process of research: it reaches conclusions about the quality of a system by observing, measuring, and interpreting (aspects of) the UX. An indicative list of empirical evaluation methods includes observation, interview, user testing, field testing, field studies, questionnaires, surveys, and diary studies. Evaluation concepts, methods, processes, and tools are generic: they are independent of interactive technology; however, some adaptations or specifications may have to be made. Furthermore, to achieve useful recommendations for (re)design, the affordances of interactive technologies must be considered.

The purpose of this chapter is to highlight important concepts and present practical guidelines for the evaluation of virtual heritage. Here, the term *virtual heritage* denotes any type of computer-based interactive systems that promote CH. A visual model of the main concepts discussed is depicted in Figure 21.

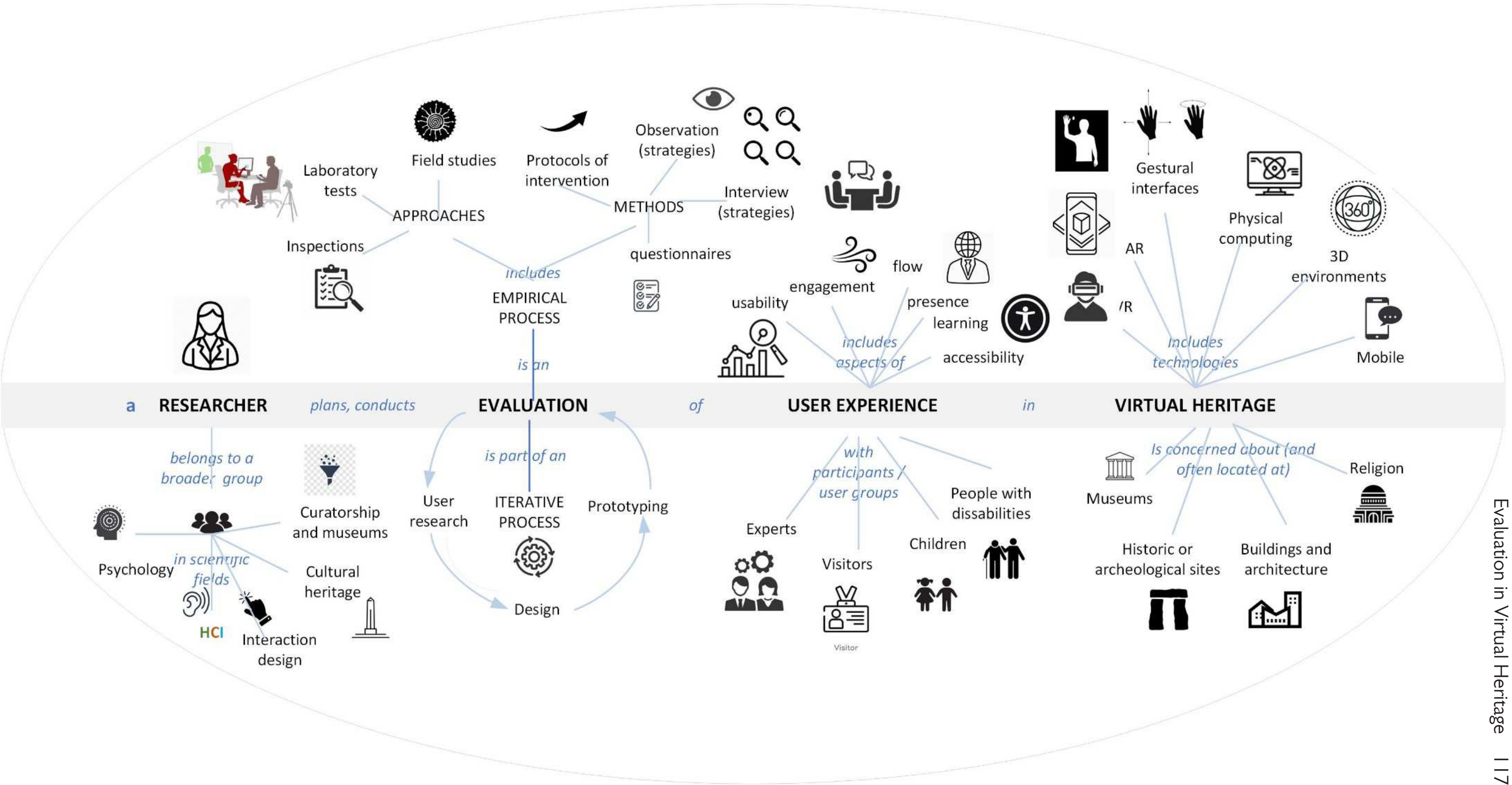

Figure 21: Visual model of the concepts about evaluation in virtual heritage[1].

Evaluation Process: Empirical and Iterative

Evaluation in virtual heritage is an empirical process of research; it reaches conclusions about the quality of a system by observing, measuring (aspects of), and interpreting the UX, which consists of various elements that arise during interactions such as usability, accessibility, engagement, sensitization, findability, learning effect, and so on. Empirical evidence, that is, the record of one's experiences, can then be analyzed quantitatively or qualitatively. Users are the most important factor in an evaluation process: they do not have to be many, but good representatives of real users representing a wide range of the intended audience or experts (in the case of system inspections).

Evaluation in virtual heritage essentially happens iteratively during system development, to feed through the design, and operation, to help reflect on experience and impact. At design time, evaluation is exploratory, such as seeking required features. At the prototyping stage it is formative, generating issues for redesign. At the piloting or operation stage it can be summative, reaching to conclusions about the outcome. Each iteration differs in terms of the technical maturity of the system, the process and intended outcomes, the intended participants' (evaluators') profiles, and data collected and processed.

Dimensions of Evaluation

The evaluation of virtual heritage usually emphasises one or more dimensions that arise during interaction with technology. In the review of 83 evaluation studies, Nikolakopoulou and Koutsabasis (2020) identify the main dimensions of evaluations in:

- User experience (19.9% of studies).
- Usability (19.1%).
- Perceived usability (8.5%).
- Engagement (7.1%).
- Learning (6.4%).

In this section, we briefly present some of these dimensions, for which there is a large corpus of background work in many fields related to humanities and human sciences, culture, design, and technology. These dimensions are often not seen in isolation in evaluation of virtual heritage but in combination with each other and others.

User Experience

UX is a general, fluid, changing, personal, and subjective concept, with many definitions. According to ISO 9241-210 (Ergonomics of Human-System

Interaction), UX is 'a person's perceptions and responses that result from the use or anticipated use of a product, system or service'. According to Norman and Nielsen Group, UX 'encompasses all aspects of the end-user's interaction with the company, its services, and its products'. Many models of UX have been proposed, such as those of Forlizzi and Battarbee (2004) and Karapanos et al. (2009). It is now widely agreed that UX incorporates pragmatic and hedonic product qualities: the former refers to the utility and usability aspects, while the latter consider the aspects of pleasure and emphasize stimulation, fun, identification generated by the use of a product or system.

Usability

According to ISO 9241, usability is 'the degree to which a product can be used by specified users, to achieve specified goals, with effectiveness, efficiency, and personal satisfaction, in a specified context of use'. Usability professionals have developed a whole corpus of evaluation methods and techniques (e.g., Nielsen 1994; Cairns & Cox 2008), and they all share the following (Lewis 2014):

a) a careful plan of study, including initial instructions and debriefing protocols;
b) participants who are members of the population of interest; and
c) appropriate tasks and environments.

By definition, usability evaluation refers to performance and preference; the former is measured by metrics such as task success, task time, and errors, while the latter is obtained directly or indirectly via interviews, observation, questionnaires, and so on. UX evaluation builds on usability methods or includes them as an essential part of the process (Albert & Tullis 2013).

Engagement and Flow

There are many definitions of engagement in HCI. According to O'Brien and Toms (2008), 'engagement is a quality of user experiences with technology that is characterized by challenge, aesthetic and sensory appeal, feedback, novelty, interactivity, perceived control and time, awareness, motivation, interest, and affect'. According to Doherty and Doherty (2018), engagement is often related to flow theory, which posits the existence of a state of optimal and enjoyable experience characterized by challenge, immersion, control, freedom, clarity, immediate feedback, temporal insensitivity, and changes in one's sense of identity (Cowley et al. 2008). In virtual heritage evaluation, flow has been explored in CH projects of mobile museum narratives (Roussou & Katifori 2018). Engagement has been measured (Doherty & Doherty 2018) with various techniques and tools, including questionnaire, behavior logging, observation, task outcomes, interviews, eye tracking, and the like.

Presence

The concept of presence originates in telepresence research. Minsky (1980) broadly described it as the feeling of being present (by appearance) or having an effect at a place other than their true location via technology mediation. Since then the concept of presence has been extensively discussed in computer-mediated communication (CMC) and VR research, where it has been defined (Lombard & Ditton 1997) as 'the feeling of being there' or 'an illusion that a mediated experience is not mediated.' In virtual heritage, the concept of cultural presence has been proposed (Pujol & Champion 2012), as the feeling of 'being – not only physically but also socially, culturally – there and then.'

Learning

There are many definitions of learning in general as well as in relation to technology as a mediator or to CH. Relevant to virtual heritage is non-formal and informal learning that is pervasive, self-regulatory, active, and participatory,[2] in contrast to formal learning processes involving tutors, learning goals, and a classroom setting. Technology-mediated learning is typically assessed in comparative evaluations in a control versus test group of learners.

Accessibility

According to ISO 9241, accessibility refers to the usability of a product, system, service, or facility to people with the greatest extent of abilities. Thus, it can be evaluated with the same methods as those of usability, provided that people with disabilities are included. In addition, the accessibility of mainstream technologies has been specified into detailed guidelines that translate to technical features to which an accessible system must comply with. This is particularly relevant for the Web, where there are many open standards which promote Web Accessibility.[3]

Evaluation Approaches

Main evaluation approaches can be broadly classified into inspections, laboratory tests, and field studies.

Inspections

An inspection of virtual heritage typically takes place during the design process, by experts who experience the system, when this is not yet fully functional or operable. Inspections are productive processes, but unless a systematic procedure is followed, it can easily get out of hand.

Inspection methods have been proposed in HCI several years ago; two of the most common are the cognitive walkthrough (Mahadoty 2010) and heuristic evaluation (Nielsen 1994). The latter includes:

- A set of guidelines or heuristics to which the system must comply with, such as system visibility, consistency, persistence, and recovery from errors.
- A systematic common process followed by evaluators, which:
  - firstly, includes atomic inspection and identification of findings matched to the heuristics list, and
  - secondly, requires from evaluators to meet and combine their findings into a common list with severity marks and priorities.

In virtual heritage, we neither have well-established sets of guidelines or heuristics nor can we easily identify a small number of experts that possess all required knowledge and skills to perform an inspection; thus, inspections are uncommon in scientific literature. Until we have these resources, inspections in virtual heritage are typically performed in practice by expert evaluators about aspects of the UX (e.g., usability, accessibility, presence), content (e.g., museum curators and other CH professionals), and interaction technology. To put some method in the process, these experts should work in a systematic manner, perhaps with a set of goals and guidelines that are produced in-context, to produce a common set of design recommendations that the system under evaluation must conform to.

Laboratory Tests

Laboratory testing takes place at the final stages of the design, or a design iteration. It involves test users who provide direct and indirect findings and feedback. The process has been detailed in many HCI textbooks (e.g., Albert & Tullis 2013; Cairns & Cox 2008; Nielsen 1994). It is generic and can be adapted considerably depending on target technology, availability of users, time, and other resources; it also requires considerable preparation.

It essentially involves the following steps:

(a) defining the place, time and prototype for evaluation,
(b) recruiting representative users,
(c) defining user tasks for testing,
(d) defining measures and data analysis,
(e) conducting the test – for each user the process is identical and data collection takes place,
(f) summarizing the test,
(g) data analysis and reporting.

It is the most common method for general evaluation of interactive systems, where the evaluation may be repeated in an iterative development process. In literature about virtual heritage evaluation, it seems that most approaches are laboratory tests of various configurations (Nikolakopoulou & Koutsabasis 2020). Testing is often comparative, between/among alternate systems, such as reported by Jylhä et al. (2015). They evaluated their wearable interface for exploring urban POIs by assigning 12 users in two groups: a baseline group that used a mobile phone app and the test group that used the wearable app. Comparative testing can also be performed between/among user groups, for example, expert/novice users (e.g., Panayiotou and Lanitis 2016, on 3D animated paintings) or between adults/children (e.g., use of a gesture-based app of Koutsabasis and Vosinakis 2016) or within system configurations. It may also be formative, that is, emphasizing on qualitative analysis and generating design recommendations, or summative, that is, emphasizing quantitative analysis and statistical testing.

It might also happen in online platforms, if the system under evaluation permits, although the researcher loses contact with users; or it might occur in the field, which is useful but must be well planned so that the process is controlled for all users.

Field Studies

A field study is a general process of observing actual users interact with technology located in the real place, time, and context, gathering data and reaching conclusions about aspects of user interactions with technology. Field studies are invaluable for assessing the quality and impart of virtual heritage. They may be employed not only to assess dimensions of user interaction with a recently introduced system as well as to evaluate existing interactive technologies in cultural places and sites. Essentially, a field study boils down to sophisticated observation and technology-mediated recording of user activity.

There are several field studies in virtual heritage literature, such as, for example, the work of Rubino et al. (2015); they integrated a location-based mobile game in the museum visit and evaluated visitors' behaviour and learning by inviting them to play the game during their visit. Or consider the work of Caggianese et al. (2018), who installed a gesture-based interactive holographic projection in the museum and evaluated visitors' engagement and the attractiveness of the system. While some aspects of the study can be controlled, especially the tasks that users or visitors are asked to perform, it is still a form of field testing. Another example of a field test is the work of Koutsabasis and Vosinakis (2018), who invited teenage museum visitors to digitally sculpt Cycladic figurines in an interactive kinaesthetic game.

Evaluation Methods and Techniques

Various methods and techniques for the evaluation of virtual heritage have been employed. In the review by Konstantakis and Karidakis (2020), they examine a long list of evaluation methods. According to the review of 83 cases of virtual heritage evaluations (Nikolakopoulou & Koutsabasis 2020), most make use of questionnaires (39.9%), observation (19%), and interviews (16.1%).

Questionnaires

Questionnaires may be either standardized or developed by evaluators. The former has gone through the process of psychometric validation for several dimensions of evaluation, like UX (e.g., User experience Questionnaire, Strepp 2017), usability (e.g., System Usability Scale, Brooke 2013), presence (Witmer & Singer 1998), and so on.

Observation

Observation can be organized into many metaphors (Shafer 2009), such as: 'fly on the wall' (observe unnoticed), 'shadowing' (discretely follow a user), and 'secret agent' (play the role of a user).

Interviews

They can take many forms, such as structured, semi-structured, directed storytelling, group interviews, site walkthroughs, contextual inquiries (Bayer & Holtzblatt, 1995), and so on, and can happen in the field (preferably), in the office, online, or by phone.

Intervention Protocols

These protocols are mainly employed in user testing, besides post-hoc interviews, and they usually include (Van Den Haak 2003):

a) concurrent or retrospective think-aloud, that is, when users are encouraged to speak their thoughts about their interactive experiences, as in Correia et al. (2014), who encouraged users to think aloud during the use of their interactive installation, which enabled them to reconstruct medieval illuminations of old books, and
b) constructive interaction, that is, testing in pairs of users who interact with each other, which is a very productive method for formative assessments (Koutsabasis et al. 2007).

These are all empirical methods of research and therefore

a) they all yield knowledge and results, with a limited scope,
b) they can be all useful, but their application can yield errors,
c) errors of one method can be corrected by another, and
d) different methods must be combined in a comprehensive evaluation.

Other General Issues

Important issues to consider in the evaluation of virtual heritage include:

User representativeness

The selection of representative users is the most important aspect for a successful and valid evaluation. Preferences, knowledge, and skills vary among people; therefore, we often observe significant variability in performance and preference. Thus, it is important to recruit representative users, if it is not possible to recruit people who will actually use the system.

Ethical issues and privacy

Any empirical evaluation requires the participation of users, who must always participate freely and willingly. Cairns and Cox (2008) use the acronym VIP (vulnerable participants, informed consent, privacy) to denote the three major ethical issues that must be addressed at any evaluation process. Another ethical issue, from a scientific perspective, is about evaluation data, which must be either open or readily available to potential reviewers or colleagues.

Evaluator knowledge and skills

Currently, evaluation of virtual heritage is performed by researchers from fields including HCI, cultural heritage, design, psychology, learning, and the like. We do not foresee that this will change in the near future because evaluation is a holistic process that requires multifarious expertise taking into account technology affordances and digital curation, and can provide insights about digital content, user interface, and interaction design, software engineering, usability, and user experience.

Planning the evaluation and managing trade-offs

An evaluation of virtual heritage requires planning in terms of goals, approach, participants, measures, place, and time. As with any practice-oriented activity, planning must consider practical constraints and trade-offs regarding availability of main resources such as time, users, and technology.

Conclusion

Virtual heritage is a highly suitable domain for contemporary interactive technology development. Cultural heritage organizations are addressing the widest possible range of potential visitors, with an emphasis on younger people and children, who are attracted by interactive technology. Visitors of cultural heritage sites are interested in maximizing their experience in terms of sensitization and learning, mediated by technology. Technology developers pursue novel designs in virtual heritage, which provides a challenging context welcoming novel interaction with technology for a wide range of user requirements. Evaluation of virtual heritage can be performed with various approaches and methods to reflect several dimensions of UX. If it is conducted with care and rigour, evaluation can ensure that the requirements of interested parties are incorporated into the technology solution.

Notes

[1] Free icons obtained from https://www.flaticon.com/
[2] https://museum-id.com/informal-learning-museums-opportunities-risks-gina-koutsika/
[3] https://www.w3.org/WAI/

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CHAPTER 10

Preserving Authenticity in Virtual Heritage

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Abstract

This chapter examines why we wish to preserve heritage objects and practices via virtual heritage, and why the issue of authenticity is so important here but so seldom addressed. If we could give criteria to select and to create useful and even authentic-oriented virtual heritage projects, what would they be? Or are there methods and solutions out there waiting to be discovered?

Why Aren't 3D Models Used, Wanted, or Archived?

If virtual heritage is a preservation medium (and not just a communication medium), an immediate question might well be: why are virtual heritage projects worth saving? Are they worth saving? In the case of 3D and game environments, some have suggested even knowing what they are to be used for can be extremely unclear.

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Digital Heritage – The Vanishing Virtual

Are they being saved? Digital Humanities is/are all around us, yet 3D models, especially 3D cultural heritage models, are seldom discussed as part of scholarly arguments (Di Benedetto et al. 2014; Huggett 2012), nor are they valued as research output, made accessible to the wider public (Talboom & Underdown 2019), or generally evaluated for significance, engagement, or impact.

UNESCO's *Charter on the Preservation of the Digital Heritage* warned of the increasing risks to heritage (UNESCO 2009):

> … the rapid obsolescence of the hardware and software which brings it to life, uncertainties about resources, responsibility and methods for maintenance and preservation, and the lack of supportive legislation.

According to Hal Thwaites (2013), '…digital heritage [is] disappearing faster than the real heritage' and there is urgent need for greater accessibility, consistent interface design, global infrastructure, archival standards, and ongoing curation.

Formats and Platforms

Although there have been useful recent surveys on 3D model formats (Fernie 2020) and an upcoming survey on digitalisation quality (Iliofotou 2021), we still lack sufficient surveys on required features and procedures for 3D file formats, their relative dependability, accessibility, playability, graceful degradeability, scalability, and range of device-suitability, even if their long-term cost and proprietary status can be determined. The problem is not through a lack of 3D formats, there are over 140 3D formats (McHenry & Bajcsy 2008), but they don't always allow for ease of use across various applications (Neamţu et al. 2014; Tsiafaki & Michailidou 2015).

Another immediate problem is access. In previous work, with Dr Hafizur Rahaman (Champion & Rahaman 2020), we reviewed virtual heritage platform hosting solutions. None offered all of the basic interactive features we thought would be most useful for virtual heritage. The commercial Sketchfab website offered the most features and hosted the most models, with a variety of import and export formats. Common platform formats were FBX (Autodesk), glTF/GLB, DAE (Collada), and OBJ, but there was also USDZ (a 3D file format that displays 3D and AR content on iOS devices), and application-native formats (such as UNITY). U3D and VRM/X3D did not seem to be popular formats on these platforms. IIIF 3D is an interesting 3D format but is still under development and discussion.

We have also surveyed the availability of 3D models and related media (Champion & Rahaman 2019) in virtual heritage conference presentations. From a group of 1483 conference papers over the period of 2012 to 2017, we selected 264 of the total papers published in VSMM, CAA, CIPA, EuroMed, and Digital Heritage Congress. Only 17.9% referred to and contained images of 3D assets or 3D digital models. Only nine papers contained accessible 3D assets or 3D models. Nineteen articles contained external web links to 3D models but not a single link worked on the final day of our survey: 1 September 2018.

UNESCO (UNESCO 2016) provides several criteria to ensure the preservation of documentary heritage (including multimedia), reflected in its Memory of the World program (https://en.unesco.org/programme/mow/). A document itself 'is preservable and usually moveable ... [and] ... content may comprise signs or codes (such as text), images (still or moving) and sounds, which can be copied or migrated.' UNESCO states documentary heritage 'should be permanently accessible and re-usable by all without hindrance … with due respect to and recognition of cultural mores and practicalities' and suggests that every country (state) '... should develop training and capacity-building schemes as appropriate to ensure the identification, preservation and access to documentary heritage training.'

Use and Reuse

To fulfil these objectives, UNESCO's Guarding Against Loss Of Heritage states we must build cooperation between all relevant public and private sectors, develop training and research, and encourage research organizations to preserve research data. One extra ingredient is needed; building on the FAIR Principles (https://www.go-fair.org/fair-principles/), ideally the project provides not just *Findability, Accessibility,* and *Interoperability*, but also the *Reuse of digital assets*.

Even academic reuse is uncommon. Although there have been virtual heritage conferences such as Virtual Systems and Multimedia, academic proceedings do not host the 3D models. There is an increasing number of academic journals providing an online display of 3D models, but they are not archives. They don't easily allow for maintenance and upgrading of the components.

Is the whole issue of 3D model preservation just too difficult? Is it really outside the scope or capacity of major players in the GLAM (galleries, libraries, archives, and museum) sector, or are these 3D models just not engaging to the public? Although the London Charter (Denard 2016) and various UNESCO Charters (UNESCO 2009, 2015) advocate the use of paradata and measures to counter technical obsolescence and physical decay, one major element is missing. Without doubt, we need to preserve and integrate 3D/multimedia; provide access and record the ownership of models, sites, and paradata; develop suitable guidelines and shared procedures; collate and distribute standardized evaluation data; and incorporate data tracking audience engagement and feedback. But we are still sidestepping a more fundamental challenge: the user experience.

We also need to develop incentives – incentives for developers to provide showcases; ongoing funding through critical mass; use, reuse, and critical feedback in teaching; delivering to a wider audience; providing prizes, awards, or other recognition for technical collaborators; long-term depository citation and dynamic linking; modification of creative commons specifically for 3D heritage models, components, and sites; and providing a variety of level of data, access, or components.

There are research consortiums that handle their own online and archival functions, such as Europeana (Ubik & Kubišta 2017) and the Smithsonian Institute (with their X3D beta), but academic research collaborations such as ARIADNE, 3D Icons, CARARE, and EU Epoch relied on regular research grants to continue or transferred their tools and case studies to their partners. They can provide expert and scholarly information on these models and sites. However, they are not geared towards use and reuse, streamlined and shareable across a variety of platforms with a standardized interface. Sketchfab (https://sketchfab.com) is one, and the Smithsonian (Daher 2020) and CYARK now use it.

Commercial online hosting solutions like Sketchfab are designed for presentation rather than for preservation and don't require scientific overview (Statham 2019). Conversely, for traditional libraries and museums, digital archives are relatively new and not particularly suited for 3D models. The GLAM sector lacks the requisite financial resources let alone enough time or adequate staffing. Unfortunately, virtual museums do not curate and preserve the models. And, according to Birrell (2019), many projects lack clear plans or even an understanding of who the end-users are (Bettivia 2016).

Communal groups, such as Micropasts (https://crowdsourced.micropasts.org/), by contrast, rely on volunteers. What they have in common is critical mass, features, and shareability. Micropasts has an added attraction, you can collaborate on archaeological problems and upload your own additional media.

Given virtual heritage implies the use and reuse of projects, I suggest there are at least six components required for preservation:

1. The dataset (2D, 3D, textures, sounds, scripts, etc.) of the virtual heritage itself.
2. The paradata that helped the research and development of the virtual heritage project.
3. The authorship, institutional links and accreditations, and teamwork.
4. The intentions of the authors.
5. The metadata and system structure and any relevant classification data.
6. Evaluation data (audience tracking, usability studies, audience engagement results, and an attempt to capture usable and useful audience experience and feedback).

Are Virtual Heritage Models Authentic?

Must we slavishly copy, preserve objects in glass or cotton wool, and reproduce them with the most expensive equipment with the greatest possible digital file sizes? Every extra byte of a digital file requires hosting somewhere. Every computer server accessing the internet is powered, with a related environmental cost (Griffiths 2020). Despite improvements in the features, capacity, reliability, and precision of 3D formats, there is another, deeper underlying issue: what are these models preserving and what are they communicating to their audience?

The question of authenticity is not merely a question regarding the model, but also a question on the intentions of the modelmaker. Arguably the authentic is not only the saved object and the intentions of the preserver or modelmaker, but also the relationship people had with the object and the care shown. Care cannot be maintained behind glass even if artefacts left behind are as close as we can get to the past; they are inscrutable and mysterious ciphers to that culture. And the authentic is not merely the exterior, the similarity to the past, because we typically don't know the past. But the work and respect that went developing, maintaining, and handing down that cultural heritage object, belief, or performance is authentic. Can virtual heritage provide some sense of the relationship past people had to distant, remote, half-remembered, and disappearing places?

The user experience relies not only on technology and access to that technology but an experience of cultural heritage that is considered in some sense authentic and meaningful by the participant (Gilmore & Pine 2007; Van Balen 2008).

In *Authenticity: Depicting the Past in Historical Videogames*, James Sweeting noted that authenticity could refer to "'of undisputed origin of authorship', or in a weaker sense a "reliable, accurate representation"' (Sweeting 2019). Authenticity could, however, mean more than authorship or accuracy. Could the virtual heritage experience also be viewed in terms of authenticity?

These considerations lead us to the following interpretations of 'authentic':

1. 'Authentic' might mean the results are seen by shareholders or experts as belonging to them or are accurate renditions of the original source materials.
2. 'Authentic' could be the interpretation by the original shareholders that the depictions or recreations are as per their trans-generational practices and beliefs.
3. Parallel to option 2, 'authentic' can refer to the authenticity of what is made, and how is it made (is the creation process true to tradition? Does it show care?).
4. Or 'authentic' could be an allusive but illusive relation to the experience, or expectation of character, by a shareholder or domain expert.

We can focus these different strands of authenticity in terms of virtual heritage.

1. How an object is made.
2. Who owns or connects to the heritage depicted.
3. Who understands the culture from which an object is made or intangible heritage is performed or shared, or the experience itself.

These are all different but intertwined notions of authenticity. So, when virtual heritage is seen as authentic (if indeed, it is ever viewed through the lens of heritage), it could be seen as the safeguarding of ownership, identity, memory, craft, and art practices and so on. 'Authentic' could indicate ownership, of cultural affinity, but also authenticity in terms of where it is made or how it parallels experience. Authenticity leads to more questions, but when detected it can lead to increased engagement (Bunce 2016):

> . . . visitors who perceived the rabbits as authentic were more likely to ask a question than those who judged them as inauthentic. Perceived authenticity also promoted more why questions.

Given the above and considering there are cultural distinctions in the understanding of 'authenticity', I suggest the goals of virtual heritage preservation are to preserve:

1. Projects and related data: the virtual heritage projects themselves.
2. Ideals: through raising awareness of the original materials and intangible assets or practices through the depiction and safeguarding of virtual reality and related digital media.
3. Specific generative and transmissive knowledge: The cultural knowledge, and current understanding *of the specific* cultural knowledge that gave the development and maintenance of cultural heritage meaning. For example, virtual heritage is not a collection of mere objects. It is the learning mechanism that transmits values of cultural heritage. Even with physical heritage sites, we preserve the material heritage to safeguard the related intangible heritage.

Conclusion

The Nara Charter (ICOMOS 1994) stipulates that authenticity is an essential component of cultural heritage. If we follow UNESCO's stipulation of the importance of cultural significance, what is worthy of preserving is the useful, the unique, the memorable, and the inspiring. So it seems we must aim to preserve 'the authentic', and this implies an objective yet universal truth. Interpretations differ, and resources are limited. A related thorny question for virtual heritage might be in determining the purpose of a virtual heritage model in terms of people's decisions, resources, and lives. The concept of authenticity has more recently been stretched and teased by theorists arguing over what heritage can be saved and lived with (Harrison 2013; Holtorf 2018).

How can digital heritage fulfil the noble aims of cultural heritage and the needs of society if it cannot even maintain, preserve, and sustain itself? There are too many divergent formats, no universal standards, missing case studies, and little agreement on protocols, standards, or parameters. Plus, the GLAM sector has increasingly limited resources (Münster 2019) to keep pace with changes in technology, hardware, applications, or social media trends. These problems are solvable but also depend on an improved understanding of authenticity, not only in terms of accuracy and precision and authorship but also in terms of illusive, perceived authenticity.

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William Michael Carter is Director of Industry for the Faculty of Communication and Design at Ryerson University and a scholar in the field of Digital Media, with an extensive twenty-four-year professional career in the 3D and 2D computer animation and visual effects (VFX) industries, in both the software and the Film, TV & Gaming production environments. He is a 2015 Team Award recipient for the Ryerson University President's Blue and Gold Award of Excellence, in the design, development, and implementation of the Master of Digital Media program.

Virtual heritage has been explained as virtual reality applied to cultural heritage, but this definition only scratches the surface of the fascinating applications, tools and challenges of this fast-changing interdisciplinary field. This book provides an accessible but concise edited coverage of the main topics, tools and issues in virtual heritage.

Leading international scholars have provided chapters to explain current issues in accuracy and precision; challenges in adopting advanced animation techniques; shows how archaeological learning can be developed in Minecraft; they propose mixed reality is conceptual rather than just technical; they explore how useful Linked Open Data can be for art history; explain how accessible photogrammetry can be but also ethical and practical issues for applying at scale; provide insight into how to provide interaction in museums involving the wider public; and describe issues in evaluating virtual heritage projects not often addressed even in scholarly papers.

The book will be of particular interest to students and scholars in museum studies, digital archaeology, heritage studies, architectural history and modelling, virtual environments.

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