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

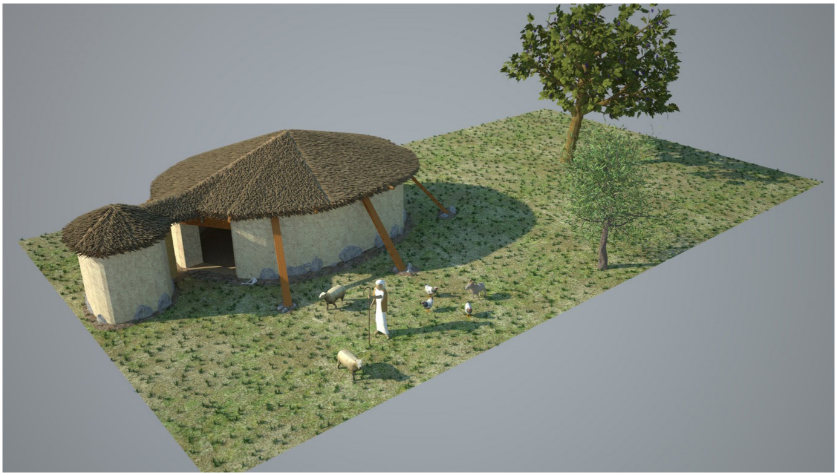

Figure 1: A 3D reconstruction of a Neolithic hut in Malta. The model has been used in publications and exhibitions to show the original form of the structure prior to destruction.

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

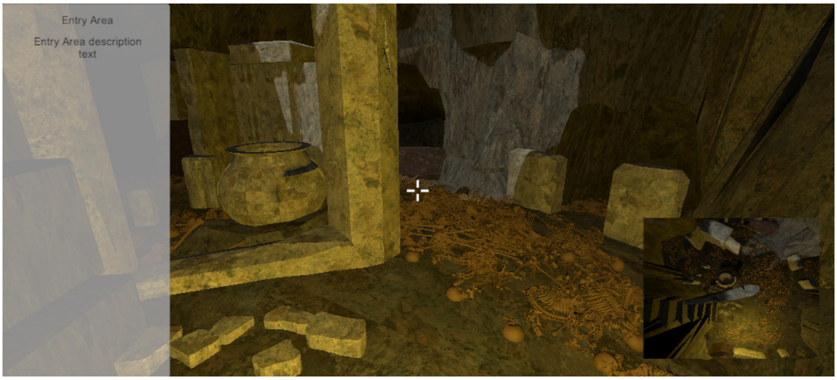

Figure 2: A serious game that allows exploration of a burial site in Malta. The interface provides tools for self-guided learning. [Author].

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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