Defining a Methodology for 3D Approximations in Archaeology: The Issue with Alternative Models

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3D reconstruction (here referred to as 3D approximation) is widely used today in archaeology, yet its methodology has not entirely been accepted within traditional practices. Partially due to a lack of standards and theoretical support, partially due to mistrust for new technology, key issues in the handling of 3D data are yet to be resolved. This is especially true with the management of imprecision and subjectivity within 3D approximations. The use of metadata and paradata have minimised concerns, but there is yet to be clarity on the preferred method of displaying uncertainty. One solution proposed has been the creation of alternative models, displaying conflicting theories within the 3D approximations.

Here we discuss the advantages and flaws of this technique, ultimately demonstrating its limitations and proposing a more theoretical approach to the issue. Creating alternative models of conflicting hypotheses can be of great use in specific cases, especially when the interpretation of an archaeological site is unsure. But it is not a general solution to the problem of uncertainty. Limited publishing space and a need to propose a clear narrative to the public seriously hinder the use of alternative models. Additionally, technical limitations in the approximation process can lead to prolonged design times. As a response we propose the establishment of solid guidelines and the investigation of the theoretical background of 3D approximation to align this methodology with traditional practices. Demonstrating the similarities between new and old practices will minimise issues of uncertainty and help establish the validity of 3D approximations. The use of metadata and paradata is also advocated, in order to avoid black-box research and allow accountability and replicability.

This paper is part of a process of assessment and analysis of the 3D method, in an attempt to create a solid philosophical background that can withstand current criticism and ultimately result in a wider use of high quality 3D approximations in archaeology.

Key words:
3D reconstruction, 3D theory, alternative models, hyperreality, metadata, paradata, 3D approximations.

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INTRODUCTION

The use of Visualisation techniques is on the rise in archaeology. From photogrammetry to VR, every year new and exciting projects are published, showcasing innovative methodologies and spectacular results. The field is ever expanding with inter-disciplinary collaborations which challenge previous understanding of archaeological phenomena and overall bring major benefits to the discipline.

Given the wide range of tools that now fit within the umbrella terms of Visualisation and Virtual Heritage, it is necessary to identify some distinctions. Although there is much crossover, 3D techniques tend to be divided into survey-based and reconstruction-based methodologies. The primary examples of 3D survey are photogrammetry (or SfM) and laser scanning, which use detailed recordings of archaeological objects and sites to create virtual geometry [Zheng 2000; El-Hakim et al. 2007; Karasik and Smilansky 2008]. This process is usually automated, producing a precise representation of reality within determined parameters.

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Reconstruction-based methodologies are instead mostly user generated from a variety of data sources [Barceló 2001]. 3D 'reconstructions' replicate reality through an artistic process, blending together photographic evidence, measurements and inferences. The virtual geometry generated is highly flexible, and allows the inclusion of elements that differ significantly from the present reality. The main advantage is the possibility of "rebuilding" complete sites from partial information. However, while 3D surveys are faithful to the reality they represent, reconstructions can be far removed from it: this can cause issues of precision and lead to misinformation [Eiteljorg 1998, 2000].

This paper discusses the importance of identifying imprecision in reconstruction-based 3D archaeology. It looks at their primary form, 3D approximations – also known as 3D reconstructions, 3D models or Virtual Reality. These terms often have different meanings, but in this context a 3D approximation observes the following criteria:

- User-generated: the virtual geometry is created by an individual and not generated automatically by a computer.
- Hypothetical: it contains at least some conjectural elements.
- Data-driven: the results are in some way quantifiable and recordable.

3D approximations have been used in archaeology as a means to present archaeological data to the public, or to investigate archaeological queries through simulation [for example, Holloway 2000; Dawson and Levy 2005]. Their rise has however been hampered by the growing concern of critics and enthusiasts alike that fear misuse [McCoy and Ladefoged 2009]. While on the surface the real and the digital are one and the same, ontologically they are vastly different: the digital is a representation of the real, and although it may retain many of the latter's behaviours, it can also differ considerably [Skagestad 1999]. The Treachery of Images by Rene Magritte demonstrates this: the painting shows a drawing of a pipe with the caption "this is not a pipe" (Fig. 1) [Magritte 1928-9]. The artist aims to demonstrate that the viewer sees no distinction between a physical object and its representation, but the representation may not be precise or realistic. The pipe may be vastly different from the drawing or it may not exist at all. The treachery of images is the ability of art to convince us something is real when it may be far from reality [Deregowski 1989].

A famous example of deceiving images in archaeology is the Viking horned helmet, as reported by Frank [2000]. The first association between Vikings and horns is from the 1876 production of *Ring des Nibelungen*, courtesy of costume designer Professor Carl Emil Doepler. Vikings of course never wore this item of clothing, but the image was used extensively in books, paintings and advertisements shortly after the production, becoming widely accepted. The public saw illustrations of Vikings with horns and concluded that they had to be real.

Fig. 1. The Treachery of Images by Rene Magritte [Magritte 1928-9]

The complex relationship between real and fake means that 3D approximations must be approached conscientiously or there is a risk of misleading the user [Miller and Richards 1995]. Hence, it is important to understand the theoretical basis of these methodologies, issues that may arise and possible solutions.

This paper will address the key issues with precision and subjectivity in 3D approximations. It will then demonstrate the similarities between 3D approximations, archaeological theory and the scientific method. The problem is quite complex, and as such the primary focus will be on replicability of the results, which is a core (but not the sole) tenant of the scientific method [Marwick 2016]. Further discussion is necessary to fully justify the 3D methodology, including experimentation and hypothesis building.

The paper will also discuss and compare the most used methods for dealing with imprecision. Particular attention will be paid to the use of alternative models, which are the most common solution to the issue.

SUBJECTIVITY AND UNCERTAINTY

The primary problem with 3D approximation recognised by its critics is the lack of precision (for example, [Gray 2016]). While 3D approximations are based on archaeological evidence, it is common for them to include hypothetical elements. In some cases these elements are kept at a minimum to preserve the overall reliability of the evidence, but more commonly the 3D approximations show only the most accepted representation of an archaeological site prior to destruction (for example, Forte and Siliotti [1997]). Nearly unanimously archaeological sites consist of rests of a much larger whole, and the elements added are produced by the designer based on uncertain evidence. This leads to subjectivity and uncertainty, which are inescapable [Lock 2003; Denard 2012b].

A 3D approximation will always be subjective as it is not a perfect copy of a reality but an interpretation of various sources filtered through the eyes of the designer [Molyneaux 1997]. It therefore relies on the understanding of a person, on the availability of information and on the cultural bias at the time of creation [Favro 2006].

Uncertainty is also an inescapable quality of the 3D process. In situ elements have a high degree of certainty, but often 3D approximations rely on comparison with other sites or guesswork [Sims 1999]. The further the approximation is from the archaeological evidence, the more uncertain it is. Yet without the hypothetical elements 3D approximations is simply a less precise approximation of reality, comparable but worse than photogrammetry or laser scanning. The true potential of 3D approximations is the possibility of incorporating hypothetical elements, but the payoff is imprecision.

ARCHAEOLOGY’S RELATION WITH 3D APPROXIMATIONS

While issues of uncertainty and subjectivity need to be addressed, the problem is a much wider archaeological one. The poor relationship between 3D approximations and archaeology is not a novel issue: archaeology has a tendency to ‘adopt’ methodologies and ideas from other disciplines but never fully implement them into its own theory [Okumura and Araujo 2019]. Lycett [2009] discusses the issues encountered in the field of “Geometric Morphometrics” (GM), which was originally developed in evolutionary biology and later adopted in archaeology for lithic analysis. Lycett records that amongst other practical issues such as training and cost, archaeologists tended to avoid GM due to a suspicion regarding the “reality of scientific or quantitative and statistical methods” (p. 80).

Progressively, archaeologists are collaborating with different disciplines to develop new and interesting techniques, and there are certainly examples of biology, mathematics and computer science successfully being integrated into archaeological theory (i.e. DNA analysis, dating techniques and agent-based modelling). However, archaeological theory is still predominantly humanistic, with a focus on interpretation derived from unfalsifiable hypotheses [Dunnell 1982]. Hunt et al. [2001] suggest archaeology is primarily based on systematic empiricism, which consists of generalisations based on observations without the deductive role of theory. This produces interpretations that can never be absolutely true or scientific. A more rigorous scientific method can aid communication between disciplines (Fig. 2).

At the very base of any scientific exploration we have the Hypothetico-Deductive method, which can be simplified to:

> *“[…] a theory, or more specifically a sentence of that theory which expresses some hypothesis, is confirmed by its true consequences.”* [Andersen and Hepburn 2015]

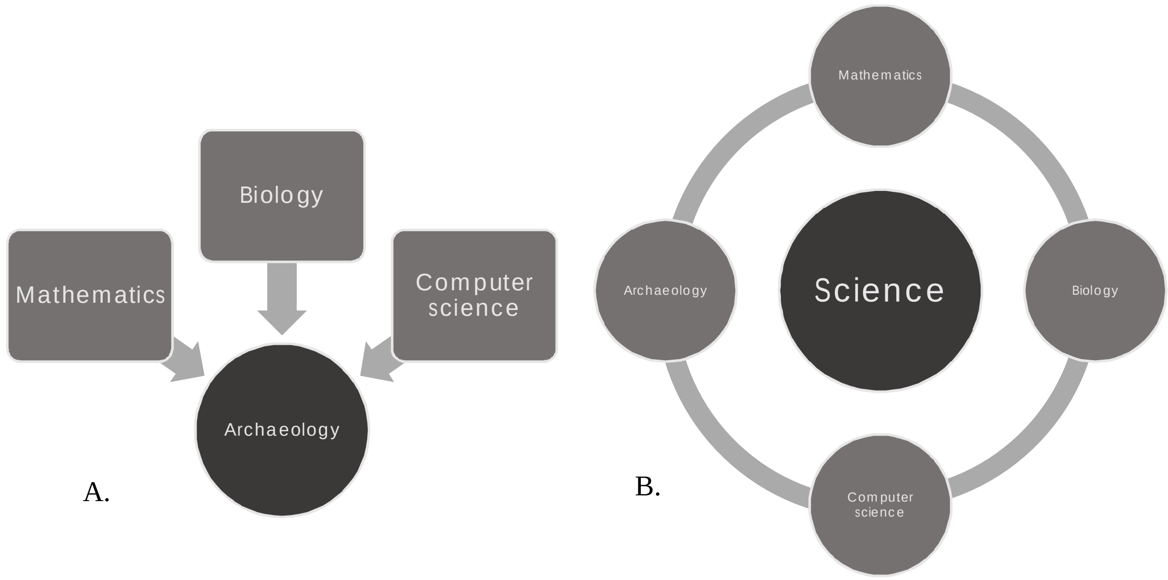

Fig. 1. Archaeology as adoption (A) and as belonging (B)

Archaeological interpretation follows this rule: any theory that is presented must be congruous with the evidence available [Hempel 1966]. Should the evidence change, the theory should be allowed to change accordingly.

The theory cannot therefore be immutable, nor can it ever be definitive. It can allow for elements such as subjectivity and uncertainty, and in fact it requires them to function: an archaeological theory is produced by an archaeologist (a subject) and it represents the best possible interpretation based on evidence (uncertain).

A practical example is the issue of temple roofing in the Maltese Neolithic, which has been amply discussed based on unfortunately scant evidence [Trump 1966; Xuereb 1999; Torpiano 2004, 2010]. The roofs of these prehistoric temples could have been made of stone or wood, and evidence subsists for both hypotheses [Trump 1971]. Various authors have argued for one theory over another based on the limited evidence, but an absolute solution is impossible [amongst others, Ceschi 1939; Evans 1959; Bonanno 1988]. As each author adds their own biases to the theory and due to the limited evidence, this archaeological theory remains subjective and imprecise. Nonetheless, it is an important discussion that can fit within the scientific method.

Archaeology and 3D approximations are therefore not too dissimilar, as they both require uncertainty and subjectivity. Shanks [1997] argues (albeit on the subject of photography):

> *“Consider archaeology: a statement about or image of the archaeological past is not strong and good because it is true or objective; but because it holds together and makes sense when interrogated it is described as objective.”* [Shanks 1997, p.82]

While inescapable, subjectivity and uncertainty can be minimised through interrogation and comparison to the evidence.

HYPERREALITY

Imprecisions in 3D approximations and archaeological theory derive from the subject they investigate: a hyperreality.

Hyperreality is a term popularised by Jean Baudrillard, although used here with slightly different connotations [Baudrillard 1983, 1988; Horrocks and Jevtic 1996; Forte 2011]. A hyperreality is a reality in which real and fake are so intertwined they are indistinguishable. An example could be ‘reality TV’, in which scripted elements, real action, editing and acting are so intermingled it is impossible to distinguish machination from true emotion. For

Baudrillard the ‘truth’ of a hyperreality is in no way accessible to a user, the very nature of these realities concealing their true identity. In the current context, a slightly different definition is used, in which hyperrealities are distinguishable if the user has knowledge of the process that created it. Going back to the example, if the viewer had access to a script they would be able to determine some of the elements of the show that are fictitious.

3D approximations are a prime example of hyperrealities: in situ elements, archaeological records, hypotheses and pure guesses are intermixed, creating a reality which is partially real and partially fabricated. With access solely to the approximation, it is impossible to determine its precision.

Yet hyperrealities are not only a 3D problem, they are lurking in all archaeological theory. An archaeological interpretation is a mix of in situ evidence and hypotheses, and without access to the archaeological records it would be impossible to determine the validity of a theory. For example, the description of a Neolithic Malta funeral procession in the seminal Malone et al. [2009] *Mortuary customs in prehistoric Malta* blends archaeological reports, interpretation and hypotheses to create a first person account of burial practices. The narrative is compelling and evocative, but it would be impossible to determine its precision without access to the site report published in the preceding chapters.

The processes of theory building and 3D approximation are very closely related (Fig. 3). The aim is identical: accessing knowledge of a lost past reality (a historical period). The ‘archaeological past’ is an inaccessible reality, which can never be completely known [Lock 2003]. Parts of it are however still available in the form of archaeological finds, which provide clues on the composition of the past. The archaeological finds are replicated in the archaeological records and literature, which provide constraints for archaeological theories. Once established, theories and approximations feed back into the literature.

A good example of this process is the 3D approximation of a Mausoleum described by Pliny, and created by Hermon [2012]. Although no archaeological remains survive, the procedure is based on literary sources and feeds back into the literature through a careful scientific recording of the process and results.

UNCERTAINTY SOLUTIONS

As discussed, 3D approximation is inescapably subjective and imprecise, due to the input of the artist and its hyperrealistic nature.

As for subjectivity, the consistency and validity of the results acts as a failsafe. So long as the results are replicable, subjectivity can be tested and minimised [Bentkowska-Kafel 2012]. The scientific process doesn’t terminate when the approximation is complete, but it is an on-going procedure that improves with subsequent work and replication [Hermon 2012]. Should further results - building upon the approximation - demonstrate an error due to subjectivity, this can be amended and the new results can replace the erroneous ones. This can happen once the research is complete, but also during the approximation process. Gann [2001] highlights the importance of sharing results with other experts to gather feedback: their approximation of the San Agustin Mission was discussed by a team of archaeologists and the resulting model is therefore less subjective (and more precise).

Imprecision is a larger problem. While subjectivity has a smaller impact on the results, imprecisions can multiply. Nicolucci and Hermon [2004] show how each step increases the imprecision, similar to error propagation in statistical analysis. They associate a ‘reliability’ value to each phase of approximation, which steadily decreases with every hypothetical element. Hypotheses are a cornerstone of the scientific method, but without an understanding of their reasoning they can be mistaken for fact. This is particularly true in 3D approximations, as they are generally non-textual and it is difficult to convey complex ideas with limited schematics [Van Gool et al. 2004]. It is therefore necessary to create a system that records the hypotheses and reasoning behind each step of the approximation.

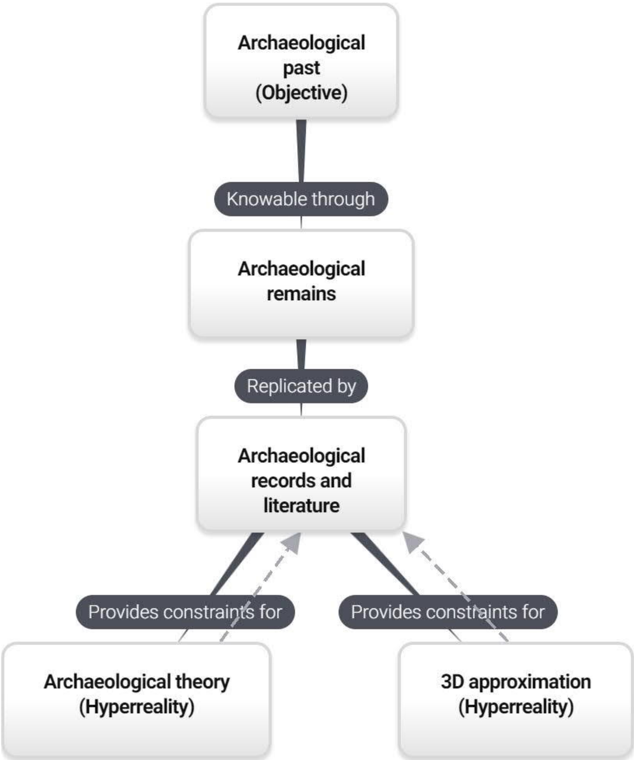

Fig. 2. Comparison between archaeological theory and 3D approximation. At each step more uncertainty and subjectivity are inserted

ALTERNATIVE MODELS

In the literature, alternative models seem to be the most accepted method to record uncertainty [amongst others, Mathur 1997; Huggett and Guo-Yuan 2000; Nicolucci and Hermon 2004; Haegler et al. 2009; Teichmann 2009; Sifniotis 2012]. They are even included in the ICOMOS Charter [ICOMOS 2008]. This practice involves the creation of a number of approximations rather than a singular one. Each approximation has the capability of showing a different hypothesis, therefore giving equal space to possible ideas and reducing the risk of mistaking a hypothesis for fact.

> *"Researchers in general, and archaeologists in particular, should be very careful when using computer reconstructions. Alternative models should be provided to present a range of variables. The past is powerful and any distortions or misrepresentations of it can create havoc."* [Mathur 1997]

Alternative models can be of exceptional use for presenting different theories in publications and exhibitions, when a number of equally interesting hypotheses exist and their discussion is the primary focus of the publication. Sturt et al. [2007] present different versions of the roofing in the approximation of Casa Sollima, Sicily. In this case, the main focus of the article is the original shape of the roofing, and given a number of equally valid possibilities the alternative approximations are necessary.

However, in more general situations, to aid the recognition of uncertainty in 3D approximations a solution must be detailed, easily implemented and congruous with traditional methods. Alternative models unfortunately do not reflect these needs. Presenting multiple scenarios allows for the main theories to be explored, but it leaves smaller issues unanswered. Realistically, a publication or exhibition has space for a limited amount of images. Online libraries and specialised repositories are becoming increasingly common for the storage of 3D data, however even these have limited space compared to the theoretically infinite number of possible variations in 3D approximations. Kensek et al. [2004] created a script to allow users to change various elements of the approximation of the Great

Aten temple at Amarna. With only three variables, the columns alone allow for 105 different scenarios to be presented. There is simply too much data to be presented efficiently and visually.

The act of choosing the possible approximations to display is also highly subjective, yet the end result doesn't record the reasoning for the choices made. Furthermore, production time is increased as alternative models require the creation of many approximations with different details [Sifniotis 2012].

Overall, alternative models show a limited range of possibilities while requiring more space and time to process.

PARADATA AND METADATA

An alternative solution to the issue of imprecision is the use of metadata and paradata [Beacham 2011; Seville Principles 2011]. These are well described in the London Charter [Denard 2012a; also Watterson 2015], but for the purpose of this paper they are defined as

- Metadata: objective technical data associated with the software used.
- Paradata: subjective data derived from the approximation process.

Unlike alternative models, metadata and paradata are usually separate from the approximation itself, often presented as an appendix to a paper, as a separate paper or published in an online repository. The use of these data can be compared to baking a cake. Metadata is the ingredients and oven settings that were used to make the cake, while paradata is the recipe with comments from the chef. An example of metadata and paradata workflow is presented in Demetrescu [2015] and Demetrescu and Fanini [2017], based on the established Harris Matrix used in archaeological stratigraphy. A similar approach is also suggested by D'Andrea and Fernie [2013].

The 3D approximation of the Għajnsielem Road house constructed as part of the FRAGSUS project is an attempt to use metadata and paradata to allow replicability [Barratt 2018]. The project was first shown in an exhibition at the National Museum of Malta, and the associated paper details the approximation steps, the thought process and decisions made, and the overall uncertainty of each element. The article focuses less on the results and more on the connection between sources and the finished product.

Metadata and paradata are an instruction manual for the approximation. They highlight potential issues and allow the approximation to be replicable: by following the metadata and paradata the user should be able to achieve an identical approximation to the one presented. While it is impossible to achieve complete clarity on every aspect of the approximation process, these data allow the recording of all major steps and most minor ones. They allow the designer to explain uncertainty and justify subjectivity [Richards-Rissetto and von Schwerin 2017].

Furthermore, metadata and paradata provide a white-box approach to 3D approximation, i.e. they allow the user to understand how the raw data and the results are related to one another [Pletinckx 2012; Goddard 2014; Demetrescu and Fanini 2017]. Understanding how data was created helps replicate the results [Ducke 2012]. Without access to the internal process, it is impossible to determine elements that could lead to errors or imprecisions due to subjectivity. A white-box approach allows future researchers to compare and contrast results, ultimately concluding which is more valid.

An example is provided below:

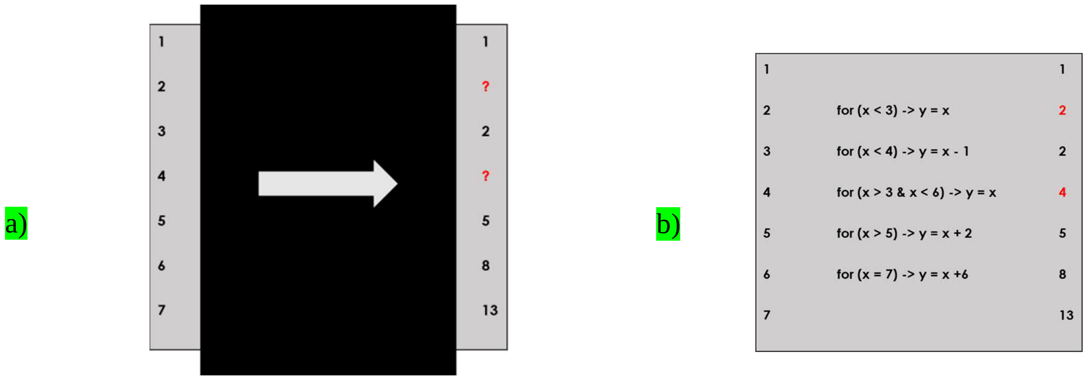

Fig. 3. An example of black box research (a) and white box research (b)

Fig. 4.a) is showing a black-box research. The numbers to the left are transformed into the images to the right using a process that is unknown. By looking at the numbers it may seem that the ones on the right are following the Fibonacci sequence. Fig. 4.b) instead shows the same research but as a white box. It is now clear that the process used is completely unrelated to the Fibonacci sequence. By having access to the process it is possible to determine the overall precision of the results based on the data provided.

As a bonus, the white box approach contains an imprecision which the reader may be able to identify. Only by having access to the process is this possible.

LIMITATIONS

While alternative models are more commonly used, metadata and paradata are more flexible and encompassing. They are also more aligned with traditional publication methods, as they can be included in appendixes or separate traditional papers.

There are however issues that remain unresolved. Metadata and paradata are suitable for publication, but they are less conducive to displays and exhibitions. When presenting 3D data to the general public this methodology is not available due to spatial limitations and the attention of the users. This is in fact a wider archaeological problem, as often exhibitions are forced to present a single narrative based on limited hypotheses. In this case, techniques such as alternative models or pink cement are more suitable [Fletcher and Spicer 1992; Lock 2003].

Other limitations regard a lack of guidelines: metadata and paradata are a relatively novel concept, and as such it is often unclear what they should entail, how they should be presented and their level of detail. Publications such as the London Charter and the Seville Principles have attempted to create a structured approach, but more work is needed [Seville Principles 2011; Denard 2012a].

Finally, an issue that is amply discussed in 3D archaeology is the preservation of these data. With ever changing digital repositories and formats, there is a risk that the metadata and paradata produced will have a limited shelf life. A poignant case is the model of Old Minster of Winchester, one of the first approximations ever created which was thought lost due to changes in formats and being saved solely on an old computer. Luckily, it was recently found and is now available online to view [Reilly et al. 2016].

CONCLUSIONS

The aim of this paper was to present a theoretical background to 3D approximation, comparing it to established methodologies and attempting to position it within archaeological theory.

3D approximation is shown to be replicable, an important element of the scientific method. It is also comparable to archaeological methods. Some issues have been raised, specifically dealing with subjectivity and uncertainty. These have been addressed by recognising the inescapable hold of hyperrealities, but also proposing ways to minimise risks. The most common way of displaying uncertainty (alternative models) has been challenged, and an approach based on metadata and paradata is proposed instead. The main advantages of this solution are the accountability of the results and the possibility of replicating them. Some limitations have however also been identified and require further consideration.

While this is far from a encompassing theoretical background to 3D approximation, it identifies key areas of interest and proposes some new ways of assimilation in traditional archaeological practices.

A NOTE ON TERMINOLOGY

The paper here presented introduces new terminology as part of a more reliable 3D theory, based on terminology used in other scientific disciplines.

The terms ‘3D reconstruction’ and ‘3D model’ are discarded in favour of ‘3D approximation’, following Favro [2006]. 3D reconstruction implies the return to an original, as if the designer had reassembled pieces of archaeological sites into a cohesive whole. This ignores the imprecise and hypothetical nature of the methodology, and may lead users to mistake approximation with certainty.

Similarly, modelling is an ambiguous term that can be confused with scientific models, such as mathematical models. This may also lead to misunderstandings (especially as 3D simulations can work with scientific models) and an overestimation of certainty. The term 3D approximation has been chosen after a discussion with individuals from different scientific backgrounds, as it reflects similar methodologies in other scientific fields. To reflect this change, the term ‘modeller’ has been replaced with ‘designer’. The term ‘alternative model’ is used to avoid confusion with the literature, although ‘alternative approximation’ would be more appropriate.

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