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BENEFITS AND PROBLEMS THROUGH THE APPLICATION OF 3D TECHNOLOGIES IN ARCHAEOLOGY: RECORDING, VISUALISATION, REPRESENTATION AND RECONSTRUCTION

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ABSTRACT

The application of 3D digital technologies in the archaeological research expands more and more during the last decades. 3D recording, visualisation, representation and reconstruction of archaeological sites, monuments and artefacts become almost a common trend in the archaeological work. Moreover, CAD reconstructions, 3D simulation, computer animation and other uses of computer systems change the traditional workflow. The archaeological experience, though, recognizes these tools more for the general public in order to offer a visualisation of the target object than as a mechanism that can offer new possibilities for the research itself.

The focus of this article is to explore the opportunities given to the research field of archaeology by 3D technologies. Specifically the article will look into technologies regarding the 3D recording, processing, visualisation and representation of archaeological data. Through the use of specific case studies we will investigate how applications can contribute to the understanding first and the interpretation later on of a certain archaeological object. Issues such as the types of questions and problems that can be faced and answered with these 3D technologies will be raised and discussed. The possibility to get an expansion of the archaeological research in new aspects, as it happens with other technological tools (e.g. databases), will be also examined. In addition to these, the disadvantages and limitations of the application of these 3D technologies in the archaeological field will be also looked at, in order to accomplish a more complete view of its usage.

KEYWORDS: archaeology, 3D technologies, recording, visualisation, representation, reconstruction, benefits, problems.

1. INTRODUCTION

It is during the past decades that Information and Communications Technologies (ICT) offer new tools to archaeologists in order to discover, study, interpret and present the human past in a more complete way than the traditional methods. Geophysics, Geographic Information Systems (GIS), electronic databases, multimedia applications, Internet websites, Virtual & Augmented reality and 3D, all try to serve and fit in with the purposes of the archaeology (Daly & Evans, 2005).

The 3D recording, visualisation, representation and reconstruction of archaeological objects, monuments and sites are among these technological trends that have proven to be applicable to archaeology and aim to bring science within this field of humanities. The relevant applications can range from 3D GIS to image-based or range-based recording and virtual 3D modelling; they can be conducted with a variety of hardware (less or more complex) and software (commercial or open-source); they can have a very wide range of cost; while the 3D digital model produced is offered in various formats and sizes, in order to be used for many purposes and within different digital platforms by everybody (experts, non-experts and general public) (De Reu et al., 2013).

The archaeological experience, though, so far recognizes these aforementioned technological tools to be more for use and benefit of the general public, in order to offer a visualisation of the target object, than a tool for the research itself that can offer new possibilities (Kourtzellis, 2009). One of the facts that have contributed to this mentality is the following: about a decade ago, a publication concerning 3D technologies in archaeology would have been (almost?) exclusively concerned with computer-aided virtual reconstructions and immersive environments or with the use of laser scanners. The end-user view (meaning that of the archaeologist in our case) would be totally absent.

But what can be really done today through 3D technologies for the archaeological research? This article examines the advantages and disadvantages of the so far application of certain 3D technologies in archaeology. Through the use of specific examples we will investigate how these applications can contribute to the understanding first and the interpretation later on of a certain archaeological object (Sylaiou & Patias, 2004; Kourtzellis, 2008).

2. BENEFITS

The actual benefits and advantages of using modern 3D technologies that concern this article are significant and relate to some obvious needs of archaeology: **reconstruction, visualisation.** Here the term "reconstruction" means that the cultural asset gets its initial form with possible additions and completions of the missing parts, since "fragmentation" is the rule for the preserved archaeological remains. In the same sense, the term "visualisation" refers to the definition of "making (something) visible to the eye" (Oxford Dictionary).

2.1. Limiting the destructive nature of excavating

Thus, firstly, these technologies contribute to the limitation of the destructive nature of an excavation (Lucas, 2001). The soil is removed during a dig layer by layer and various remains are unearthed, while the whole procedure justifies the destructive character of archaeology. Notes are recorded, photographs, samples of soil, seeds are taken and the researchers try to reconstruct in their minds or in two dimensions, as fully as possible, each time phase of the excavated site with all the architectural or other movable features (Anderson & Krsmanovic, 2008).

The contribution of a digital model of an excavation, created with the combination of 3D and GIS applications, would be to re-bring to life the state of a stratum in a certain point (Núñez et al., 2013). The registration and recreation of excavations after they are undertaken have a great value, especially when considering that the layers unearthed are forever lost after excavated along with the information containing. Graphic and metric information of high accuracy and quality can be easily retrieved, various 2D plans, sections, ortho-photographs etc. can be extracted, whenever an issue arises or needs to be considered differently from before (Katsianis et al., 2008). The 3D excavation data can be even compared with results of geophysical surveys undertaken prior to excavation, in order to validate the latter (De Reu et al., 2014).

A very useful and systematic example of modern application of such technologies is the excavation in the **Boudelo-2** (See Figure 1), in which the whole 3D procedure resulted that the recording of the excavation proceeded faster and more efficiently than with the traditional methods (De Reu et al., 2014).

The excavation explored part of a reclaimed medieval wetland, which was part of the monastic outer court of the former Cistercian abbey of Boudelo. Due to the variability in archaeological features and the soil characteristics, the Boudelo-2 excavation offered ideal opportunities to test the 3D-recording workflow.

Figure 1. Screenshot from the promotional video of the image-based 3D documentation of the Boudelo excavations http://youtu.be/2rncVW3mkhE

Another similar project, **"3D-Digging at Çatalhöyük"** (a Neolithic site in Turkey; http://www.catalhoyuk.com/uc_merced.html, see Figure 2), aims to virtually reproduce the entire archaeological excavation both on site, during the dig itself by using different 3D technologies, and in lab, through tele-immersion by using 3D Virtual Reality (Forte et al., 2012). It is a project that has identified from the beginning the issues in archaeology that the 3D technologies would try to deal with, focussing especially in the enhancement of interpretation by these technological tools (Forte et al., 2015).

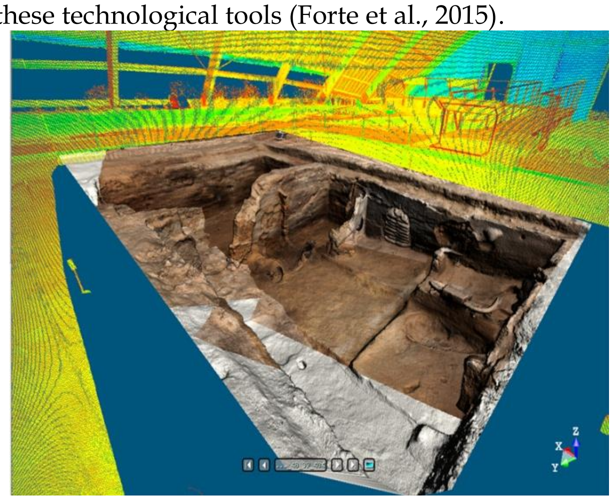

Figure 2. Image of the excavation 3D model http://www.catalhoyuk.com/images/merced/image005.jpg

Moreover, the project team has tested different protocols and technologies in order to achieve full standardization of different categories of data for different software platforms (Forte et al., 2015). It has adopted a robust methodological workflow that allowed the quick and functional integration of 3D data recording, handling and interpretation in the daily conventional fieldwork and study process. Thus, it worked with a 3D system reliable for archaeological documentation, with sufficient accuracy, reasonable time frames and budget. Indeed, the project team acquired new information otherwise hidden through the manipulation of 3D data and achieved outstanding results (Forte et al., 2015).

2.2. *Placing excavation data into the bigger picture*

Secondly, 3D GIS applications contribute further to placing the data and finds of one excavation into the bigger picture of a site or even of a whole excavated culture. Archaeologists dig, record various information, use stratigraphy for context retrieval, study their material, look at parallel finds in order to understand and interpret the area and its content. They meet their scholarly needs by recording their finds into their context, by comparing their site and artefacts to other ones and putting their information into the bigger picture of archaeological research in their area, in their country, in the culture in concern.

The possibility to geo-reference the site and artefacts not only locally but also globally, gives to the research another fresh look to the finds (Núñez et al., 2013). The context information can be readily available through not only texts and pictures, but also detailed metric and graphic information combined (De Reu et al., 2014). The possibility to alter the transparency of digital layers allows a different understanding of spatial relationships (Forte et al., 2012). Comparisons can be made; similarities and differences can be deduced helping on the interpretation, a necessary process in the archaeological workflow, and providing rather easily information on the geographic spread of certain features.

Similarly, in the excavation of the **Can Sadurní cave** (in Begues, Barcelona, see Figure 3) the finds (objects, layers etc.) were located in the complete model of the cave and a GIS was implemented to achieve a more complete and complex analysis of the artefacts (Núñez et al., 2013).

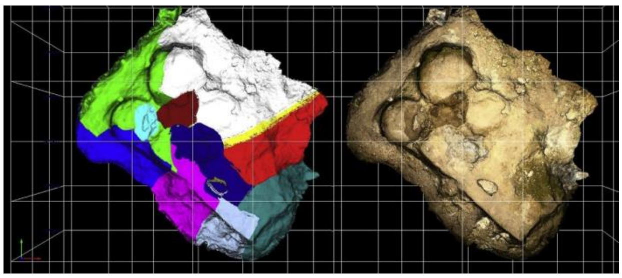

Figure 3. Isometric view and model with contour lines of a combustion structure in Can Sadurní cave (Núñez et al., 2013: 4425)

There, four human skeletons have been discovered dated at about 6,400 years ago (beginning of Middle Neolithic), which were buried following an unknown ritual in the Iberian Peninsula (http://www.ub.edu/web/ub/en/menu_eines/noticies/2013/11/044.html). The system used provided both the location of the context in which objects were found, i.e. the archaeological stratigraphy and its sedimentation process, and the texture and colour information related to the different objects. The data produced were efficiently managed due to a database linked to geographical objects.

2.3. *Limiting "fragmentation" of archaeological remains*

Thirdly, the 3D technologies that concern this article contribute to limiting "fragmentation" of the preserved archaeological remains. Archaeologists with the help of conservators and draughtsmen are called to reconstruct/visualise in two dimensions, as accurately as possible, or to restore occasionally the partially preserved finds, monuments or sites insuring that all measures taken are reversible (ICOMOS, 2004). Moreover, scholars with the help of written sources, relative images in ancient iconography, archaeobotanical or other remains, try to reconstruct the human and natural environment of an ancient site.

A digitally reconstructed and restored 3D model can be created for example, with the help of 3D scanning or photographing, along with CAD, 3D computer graphics and Virtual Reality (VR) software, for filling in the missing parts. The significance of this contribution to research can be understood, when mentioning that the model is always readily available for accurate measurements and detailed view and study in a computer, far away from the site of discovery or a museum storeroom. Moreover, the 3D model is an electronically preserved site, object or monument, free from any other alteration or destruction (Forte et al., 2012). Also, various alternatives can be applied for the digital restoration of the find, in search of the optimum one, without giving second thought to their reversible or irreversible nature. Ranging from virtual reconstruction of small objects to virtual visits to entire sites, archaeologists have a significant tool for the recreation of the past.

The reconstruction i.e. of an ancient Greek ceramic vessel, a fruit stand -*karpodoche*- (see Figure 4), has been repeatedly used for archaeological study (Tsiafakis et al., 2006; Tsiafaki, 2012). This 3D reconstruction of pottery from the ancient selltement located in Karabournaki, is created and stored within the digital database of the whole excavation, along with relevant photos, drawings, profiles and trenches, making the study of a particular shred as versatile as possible. When one goes one-step further, to 3D printing, the 3D technologies allow the real-size (or in scale) reproduction and manipulation of models (Forte et al., 2015). This becomes extremely useful again for long-distance measurements and views in a remote workstation (De Reu et al., 2014).

Figure 4. Image from the process of 3D reconstruction of a fruitstand from Karabournaki (Tsiafaki, 2012: 159).

2.4. *Classifying archaeological finds*

Fourthly, databases with 3D models can contribute to classifying archaeological finds, an issue identified as crucial by various researchers (Forte et al., 2015). Classification or typology is one of the most essential works of archaeologists aiming to place their finds, based on one or more attributes, into a group with shared characteristics. This task is very important, since it provides guidance for dating artefacts, it leads to conclusions about technology, decoration and other features and it also helps scholars to see patterns in society, economy, trade and other factors as well. Of course material finds can be sorted in various ways, according to the purposes of archaeologists (Adams & Adams, 2007).

In a database of reconstructed and/or restored 3D models, one can search and pose a query regarding a find, in terms of i.e. shape, size, form or any other shared characteristic. Thus, it can be understood that the archaeological work of sorting, classifying and in general analysing objects or monuments becomes faster, easier and more objective (Lin et al., 2010). The 3D content-based retrieval (3DCBR) systems are a very active research area and attempts have been already made that try to match pottery shape with this technology, reducing significantly the time needed for researching 3D digital content (Koutsoudis & Chamzas, 2011).

The **Virtual Hampson Museum** (http://hampson.cast.uark.edu/) is a similar, though more simplified, project. It showcases a series of 3D digital artefacts from the collections at the Hampson archaeological Museum State Park. Within the virtual museum, visitors can browse the 3D collection, download data, read descriptions for each artefact and interact with them on-the-fly. 3D visualisations of sites, where the artefacts come from, are also provided to the visitor. Such and similar efforts to create virtual archaeological exhibitions can be used for both promotional purposes and cultural or educative reasons (Bruno et al., 2010).

Figure 5. 3D model of a headpot from the Virtual Hampson Museum http://hampson.cast.uark.edu/artifact.php?IDart=1

2.5. *Limiting subjectivity and publication delays*

Moreover, a holistic approach and recording of an archaeological excavation and its various finds through 3D and GIS systems can limit the subjective character of any archaeologist's notes and note books, as well as the often failure of the researcher to publish and share with the scientific community the excavation data (Tiverios, 2010). This subjectivity is inevitable, while the issue becomes more complicated depending on the professional expertise of the excavator. The delays in publishing full excavation reports and presentations are a common problem in many countries and they can become even radical for the excavation's and finds' life cycle.

A complete and safely stored digital record of an archaeological dig and its finds can combine all the aforementioned technological solutions in a digital note book (Tiverios, 2010). Several relevant applications are being used and tested in sites, such as the on-going excavation in **Karabournaki** (Tsiafakis et al., 2004; Tsiafakis & Evangelidis, 2006; Tsionas et al., 2009), **Dispilio** (Pfoser et al., 2007) or **Pompeii** (Apollonio et al., 2012; Dell' Unto et al., 2015).

In Karabournaki (http://karabournaki.ipet.gr/, see Figure 6), through the collaboration with "Athena" Research Centre, 3D technologies are used for the recording and reconstruction of certain portable finds and the registration of the dig layers with 3D GIS. In Pompeii useful comparisons are being conducted between the various processes in terms of cost, time and geometric and reflectance quality providing an adequate assessment of the pipeline.

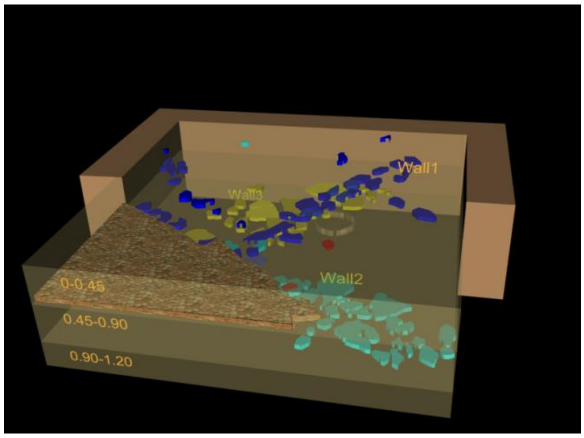

Figure 6. 3D GIS recording of the Karabournaki site

2.6. *Enriching and extending archaeological research*

Last, through quantification of the dig data, various conclusions can be deduced through statistical processing and the spatial span of finds (Baxter, 2003) (VanPool and Leonard, 2010). Through these technological helping tools the archaeological survey can get enriched and extended. An example that demonstrates this was created through a profound 3D digitization project, **3DICONS** (Tsaouselis et al., 2015), conducted for providing 3D content for Europeana, the online collection of cultural heritage resources in Europe. In one of the resulted models of monuments of world heritage significance, the St. Apostles church in Thessaloniki, Greece (see Figure 7), through the manipulation of a detailed 3D model of the church an unpublished inscription was located reused as a drain pipe (Koutsoudis et al., 2014). The finding of such an inscription on the roof of the church would be otherwise much more difficult.

3. PROBLEMS

Of course the disadvantages and problems related to the use of modern 3D technologies in archaeology, regarding recording, visualisation, representation and reconstruction, are not to be discarded. Only when having these in mind, one can decide the best technological solution for the excavation and the task in concern. The so far experience and performance evaluation of the various hardware and software solutions have resulted in valuable conclusions (Boehler & Marbs, 2004; Opitz, 2012; Hörr & Brunnett, 2013; Koutsoudis et al., 2013; Koutsoudis et al., 2014).

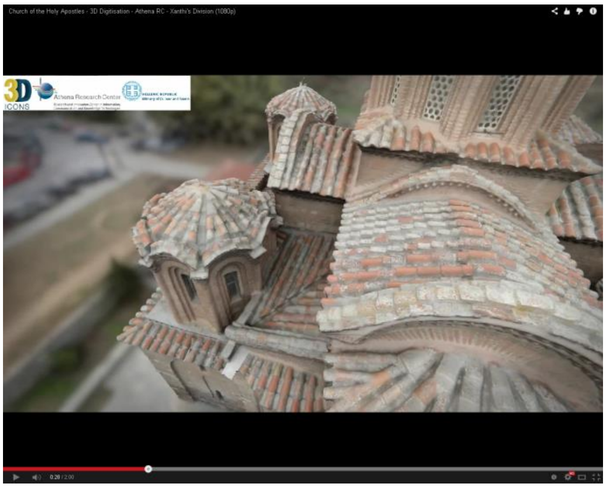

Figure 7. Screenshot from the animation of the 3D digital replica of the Church of the Holy Apostles http://youtu.be/SvASaCuhaNI

3.1. *Neither a panacea nor an automated procedure*

First, it cannot be argued that the use of 3D technologies in archaeology can be an automated procedure (De Reu et al., 2014; Forte et al., 2015) or that there is a single solution that can be considered as a panacea (Koutsoudis et al., 2013). Thus, it is true that involving acquisition, processing and management of 3D data during an excavation or study of a monument or artefacts is rather challenging and time-consuming in relation to more traditional recording methods (Remondino & Campana, 2007). Various efforts, though, are being made in order, first, to compare the different methods in terms of time consummation and, second, to provide new techniques which are low-cost, time efficient and provide high accuracy (De Reu et al., 2013). Within these efforts it is clear that there is a slight change in the workflow of the excavation, since there is the need for controlling and processing the data captured, as fast as possible to keep up with the pace of the excavation and the post-excavation processes (De Reu et al., 2014). As mentioned before, the **"3D-Digging at Çatalhöyük"** project has adopted a robust methodological workflow that allowed the quick and functional integration of 3D data recording, handling and interpretation in the daily conventional fieldwork and study process.

3.2. *Requirement of technical expertise*

Moreover, a decision to incorporate 3D recording and visualisation technologies in archaeology requires a certain degree of expertise, since a number of operators need to work close with the archaeologists, who have usually basic computer literacy, understand them and adjust their knowledge to the scientists' needs. The usual case in the past was that there was total dependence on the technical expert for the 3D implementation, often without the involvement of the archaeologist or without considering the real archaeological requirements and needs. The final scope should always be of course to provide a system that is user-friendly, which is not always the case, and that satisfies the end-user after successive evaluations (De Reu et al., 2014). Since 3D content is more demanding in terms of processing power, data storage and network bandwidth facilities, special consideration should be given in its incorporation in an archaeologist's work. To this end a project called 3D-COFORM (http://3d-coform.eu) attempted to establish 3D documentation as an affordable, practical and effective mechanism for cultural heritage (Koutsoudis, 2012).

3.3. *Cost factor*

The cost, also, is a very important factor that can be radical in terms of incorporating or not 3D technologies in an archaeological study (Caprioli & Scognamiglio, 2009; Kersten & Lindstaedt, 2012). The cooperation between the archaeological sector and Research Centres or Private companies within the context of shared projects has given us so far valuable insight and practice. This fruitful relation is sure to have more results in the future that will benefit the whole sector. Nevertheless, smaller, provincial, less "important" and more remote excavations, monuments or museums will have to wait at least for some years, until 3D technologies become part of archaeologists' everyday practice.

3.4. *Management of 3D data*

Last, but not least, a basic issue of the 3D applications used in archaeology (and not only) is the management of the data produced. Of course there is the need for high-resolution 3D data, which can record large and complex areas and objects (Guidi et al., 2009). This can result in enormous amounts of digital data, which in their turn create vital issues of storage, processing, accessibility and preservation (Chen, 2001). Research in the sector of ICT and 3D technology has to proceed and find clear and sustainable solutions regarding this.

On the whole, technologies suffer from problems of **longevity, compatibility, accessibility, updating and change very rapidly**; on the other hand, the methodological workflow for use and interpretation of archaeological data changes very little over time (Forte et al., 2012). Thus, special attention should be given to the collaboration between IT and archaeology experts in order for archaeological questions to be really answered with the help of 3D applications.

4. DISCUSSION

Archaeology is about the Past, the contemporary use and understanding of old things. Archaeologists, when they dig up, study, interpret and present the various aspects of the past human activities, are limited due to various factors. These factors, analysed beforehand, narrow the possibilities of easily recording and analysing all finds in a site or a monument.

In our digital life today we are dominated by mixed media realities of variable mediated sources, voices and presence. In that sense, archaeology is an example of capturing and documenting experience. The new information and communication technologies and especially 3D applications, regarding recording, visualisation, representation and reconstruction, can give a new bust to both excavation and further study. Any problems faced are surpassed by the possibilities, which exceed the limitations mentioned (De Reu et al., 2014).

4.1. *Enhancement of Interpretation*

Thus, on the whole, 3D applications in archaeology can be used as an interpretative tool for research. It is a way to represent the past more vividly than any architectural drawing or 2D photograph. It comprises the significant ability to make distant objects available for scholarly autopsy. As an added benefit, quick, cheap 3D representations created through computational photography provide a new way for mass audiences to engage with the physicality and materiality of objects, both in an academic publishing environment. A 3D model can serve as the connection or bridge between the active excavations and archaeological sites with the museum collections. A 3D model could make the cultural asset “speak”. It could be used as a visual guide for archaeologists.

4.2. *Need for standards*

Of course in order for the archaeological research to be enhanced by 3D applications regarding recording, visualisation, representation and reconstruction there is absolute need for standards to ensure data quality, consistency and efficiency (Forte et al., 2015). The London charter (Denard, 2009), setting out the principles that should underlie the use of 3D visualisation technologies in heritage research and dissemination, and the Seville Principles (López-Menchero Bendicho, 2013), implementing these principles specifically in the field of archaeological heritage are tools that could be used globally as a common initial point of reference in any relative effort or project.

Important issues, such as the traceability and documentation of the whole procedure of using 3D technologies in archaeology, are raised within these charters, in order to clarify the relation between the real object and the virtual “copy” and promote the lasting availability of 3D data, too (Breuckmann et al., 2013).

5. CONCLUSION

In conclusion, it can be stated that the 3D technologies mentioned in this article can document the same archaeological data (i.e. levels, sections, samples etc.) as the more traditional methods; only the way of recording differs (De Reu et al., 2014). If the effort to include lectures, practical experience and extensive testing in universities regarding the possibilities of ICT and 3D technologies in archaeology continues and expands with compliance with standards, the young generation of archaeologists will be more computer and 3D literate and will be able to take advantage of the tools available. Thus, archaeological research will be able to extend its questions, enhance its interpretations and on the whole benefit from modern technologies, which are penetrating every aspect of our daily personal and professional life.

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