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The past, now showing in 3D: An introduction

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A range of new measurement and visualization technologies are allowing archaeologists to document and interact with the past in ways that were previously impossible. The potential impacts of the effective implementation of these tools are dramatic and exciting. Applications range from allowing archaeologists to stand in a virtual recreation of an excavation while writing their interpretations, to emailing and then 3D printing copies of artifacts. Digital replicas enable remote analysis by allowing scholars to inspect and measure the objects from all possible angles, enhance the visibility of the surface topography, produce technical drawings, and even automate searches for matching measurements across multiple objects. The analysis of fragile artifacts is now only made possible through their digitization (Tokovinine, 2017).

The usefulness of 3D models is not solely academic in scope, as this new technology allows for different forms of interactions with the public. Students can do a virtual walk-through of an archaeological site in their classroom and museums can allow people to touch and play with 3D printed replicas of objects they have on display. This change in how we relate information to the public can bring the past to life for people, and make the field of archaeology more accessible to a broader audience. With this new technology, though, comes many potential issues centered around questions of ownership and access. This special issue seeks to discuss not only how 3D technology can be used as a tool for archaeological investigation, but also how to ensure that data is curated effectively, thus ensuring it is accessible.

Every archaeological or museum project faces multiple choices upon deciding to implement 3D documentation and visualizing technologies. It is easy to get lost in an ever-growing array of commercial and non-profit tools and solutions, their makers and advocates. Should a project entail actual documentation or digital reconstruction from plans, photographs, and drawings? After all, some of the largest digital archaeology projects are almost exclusively based on reconstruction rather than direct 3D documentation (Der Manuelian, 2017a). If documentation is chosen, would a simple exercise in structure-from-motion photogrammetry suffice? Is there a need for a triangulation or time-of-light laser scanner? Should a structured-light scanner be used instead? Access and time frame are important here, as well as the fact that archaeological investigation often causes whole or partial destruction (immediate or eventual through exposure to a different environment) of the object of investigation. The latter point may outweigh one's concern with the cost or the time frame of 3D scanning (Tokovinine and Fash, 2008). Once the data is collected, how should it be processed? Last but not least, there are issues of data management and dissemination. For example, should a project create and maintain a dedicated web page or rely on an existing commercial web platform for sharing 3D files? The issue of cost looms large, given the modest size of a typical budget, yet higher project costs and longer time frames may be justified, if a researcher can clearly articulate the reasons for a choice of documentation and dissemination options. Yet the publications guiding the archaeologists and museum professionals through the abovementioned stages and associated challenges and choices (e.g. Wachowiak and Karas, 2013) are still relatively rare. This special issue, rather than being focused on the improvement of photogrammetric and scanning methodologies, is comprised of practical case studies. In doing so, it addresses the need for concrete examples of the ways in which archaeological projects can effectively implement 3D techniques in the specific circumstances. The goal is to go beyond mere demonstration of plausibility to the actual application and its outcomes. To this end, the articles included in this volume discuss various stages throughout the 3D process, including data capture, data storage, experimentation using 3D models, and finally public outreach. The authors also highlight challenges and choices at every stage of the projects.

The interest in 3D and digital approaches to archaeology is continuously growing, as demonstrated by the fact that two new journals dedicated to this topic have been launched in the first few months of 2017, the first being Studies in Digital Heritage, published by Indiana University Press, the second being The Journal of Computer Applications in Archaeology, published by CAA international. Chapters on 3D documentation and visualization are included in nearly every volume on archaeological illustration (e.g. Pillsbury, 2012; Bonde and Houston, 2013). In 2016, the University of North Dakota published an open access edited volume called Mobilizing the Past for a Digital Future: The Potential of Digital Archaeology (Averett, 2016), which discusses various topics relating to the uses of technology in archaeology. The proceedings of the annual Digital Cultural Heritage conference (e.g. Ioannides et al., 2016) illustrate the rapid adoption of digital 3D documentation by European archaeologists and museum professionals.

Examining the focus of various digital archaeological projects emphasizes the wide array of questions that can be explored and answered using digital approaches. For example, many labs and institutions have been using 3D technology to document and disseminate information on

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smaller artifacts and particular aspects of archaeological sites. The DIVA lab, directed by Heather McKillop and housed at Louisiana State University, 3D-scans artifacts for digital archiving, study, and display as virtual models and 3D-printed replicas (McKillop and Sills, 2013). The archaeologists at the Research Laboratories of Archaeology at the University of North Carolina have also been scanning objects in their collection and adding them to Sketchfab online platform, which is useful both for digital preservation, but also allows greater access to the objects (Davis, 2017). Other projects have been 3D scanning and modeling particular architecture at archaeological sites. Alexandre Tokovinine and the Corpus Project of Maya Hieroglyphic Inscriptions have been 3D scanning architecture, stucco facades, monuments, and artifacts in the museum collections and in the field throughout the Maya area, notably at the sites of Copan, Tikal, and Holmul (Tokovinine, 2013). A larger project of Text Database and Dictionary of Classic Maya at the University of Bonn has also incorporated high-resolution 3D scanning into its documentation workflow (Gronemeyer et al., 2015).

Other archaeological projects have been modeling larger complexes within the sites or the entire site. The Digital Heritage Lab at Indiana University, headed by Dr. Bernard Frischer, has been generating an intricate model of ancient Rome over the past ten years. This virtual reality experience allows users to walk through the majority of ancient Rome at the height of the Roman Empire (Dylla et al., 2010). Maurizio Forte's Lab at Duke University has 3D scanned every phase of their excavations at Çatalhöyük, the lab's ultimate goal is to make the entire excavation process reversible in a simulated environment. Nicola Lercari and his team have also been working at Çatalhöyük, but they have been using virtual reality to recreate ancient households (see Lercari this issue).

3D technologies have also enabled great advancements in the field of experimental archaeology. 3D scans and reconstructions bring to life lost artifacts and even entire buildings. Archaeologists then can test new research hypotheses and even physically interact with the objects, once they have been re-created using additive 3D printing or milling. The Harvard Giza Project's attempt to digitally reconstruct and then fabricate the throne of Queen Hetepheres using a combination of ancient and modern technologies is a great example of this approach, its benefits, and potential pitfalls (Der Manuelian, 2017b).

Another promising experimental application of 3D data is the analysis of the ancient acoustics and music. Dr. Rupert Till's lab, based out of the University of Huddersfield, has made a free app which allows the user to explore Stonehenge, the Cave of Altamira in Spain, and the Paphos Theatre in Cyprus. Each of these spaces were acoustically modeled, thus allowing users to gain an understanding of how music would have interacted in the different spaces (Till, 2017). Carlo Fantozzi and his team have 3D modeled an ancient pan flute from Egypt. The flute cannot be played, but using 3D modeling, x-rays of the interior of the flute, and mathematical models based on available measurements they have reproduced the tones the flute would have produced. They have created an interactive 3D exhibit placed next to the artifact allowing museum guests to interact with the digital object (Avanzini, 2015). Miriam Kolar has been performing acoustic analyses at the site of Chávin, in Peru, in order to understand how sound interacted in the space (Kolar, 2013). Jared Katz has been working to create a database of 3D scans of ancient Maya musical instruments, and has been modeling and 3D printing playable replicas of the instruments (Katz, 2016). Archaeology tends to be a visually dominated field, but using 3D technologies, it allows scholars to better understand the role of sound in the past.

3D technologies have also created new ways of making information accessible to both other scholars, and to the public. The interactivity of 3D material helps bring the past to life for people. The MayaArch3D Project, co-directed by Heather Richards-Rissetto and Jennifer von Schwerin, has been creating a platform in which Maya archaeological projects that engage in 3D research can post their geo-referenced 3D models associated with archaeological data, thus making them available and accessible to the broader community. The 3D Giza Project is an example of how 3D technologies can be used to make archaeological research more accessible to the public (Der Manuelian, 2017a). They have created an interactive website allowing visitors to explore their 3D reconstructions of the Giza pyramids and surrounding area. They have also included the archaeological records on the website, allowing visitors to see the actual data the reconstruction models are based on.

The contributions to the special issue illustrate distinct approaches to generating, storing, sharing, and using 3D models. Three contributions specifically deal with data collection. The article by Tokovinine and Estrada Belli highlights the benefits and challenges of high-resolution 3D scanning using an expensive high-precision (± 0.08 mm) structured-light system. The authors demonstrate that, contrary to the received wisdom, this type of scanners can be used in difficult field conditions (archaeological tunnels in a tropical rainforest) to record entire sections of ancient buildings. The contribution by Katz, on the other hand, details the more accessible alternative to 3D scanning in the form of structure-from-motion photogrammetry. In addition to a drastically lower cost, the author underscores other benefits of the approach, especially the lack of bulky equipment and relative flexibility with respect to the size and resolution of 3D models, which solely depend on the choice of camera lenses and the number of photographs per object. The article by Hermon et al. advocates for a mixed approach as their field documentation strategy combines data from a total station, a laser scanner, and digital photographs.

The contribution by Lercari illustrates an alternative to 3D documentation where 3D data is effectively constructed from two-dimensional photographs and drawings. The simple geometry of the resultant 3D models makes it possible to add other kinds of data, such as multiple construction phases, alternative archaeological interpretation, and animation, without compromising accessibility. Such models are also much easier to integrate with commercial software and hardware to produce highly interactive simulations across multiple platforms including portable devices. The articles by Hermon et al. and Katz describe an approach that combines capturing 3D data with reconstructing missing sections of buildings and artifacts. Katz's project takes it even one step further by physically replicating hybrid 3D models to study their acoustic properties.

That point takes us to another major component of the contributions to this special issue – the use of 3D data. For Tokovinine and Estrada Belli, the primary goal of the documentation is to address conservation concerns and to enable detailed study and visualization of the buildings outside of the narrow tunnels. In contrast to this rather limited approach, the articles by Katz and Hermon et al. illustrate how 3D data may be used in experimental archaeology in the specific contexts of a prehistoric well complex at the archaeological site of Santa Cristina, located on the Sardinian Island, Italy, and ancient Maya clay flutes and ocarinas. The authors ponder the issues of meaning and function, as well as some properties of the documented objects, which are only available through digital reconstruction or even subsequent physical replication. The 3D models in Lercari's project are even more interactive and add the dimensions of time and alternative interpretations. Lercari's reconstructions of Çatalhöyük buildings enable multivocality by exploring how virtual reality can provide different viewpoints of the past depending on race, class, ethnicity and gender. The contribution by Richards-Rissetto and von Schwerin also addresses broader epistemic issues of using 3D records and reconstructions. Finally, the Maker Bus project discussed in the article by Compton et al. intends to put the actual technology used to make these digital heritage models in the hands of students and community members. The bus is equipped with 3D scanners, drones, printers, and virtual reality headsets in order to explore how such technology is important to the humanities and social sciences.

The last theme of the 3D documentation in this special issue is the challenge of long-term data curation and accessibility. This is probably the least developed and most problematic aspect of 3D documentation as rapid changes in hardware, software, and file formats imply high risks of data loss. The contribution by Tokovinine and Estrada Belli offers only limited solutions with respect to data sharing and the authors express concerns about the long-term prospects of data storage and management. The article by Katz outlines the intended outcome of the project as an internet database, but does not discuss data management strategies. The problem is addressed fully in the contribution by Richards-Rissetto and von Schwerin whose MayaArch3D project aims to create a sustainable system of archaeological data storage and access. The authors outline key challenges to and propose several specific solutions in classifying, curating, and accessing 3D data. In addition to creating dedicated viewing and analytical tools, the project relies on explicit strategies in how 3D data should be stored and disseminated in order to ensure its long-term security.

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