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Archaeological Practice and 3D Modeling: A Medieval Ceramic Assemblage from Nemea, Greece

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Abstract

This paper explores the link between archaeology and the digital humanities, especially the adoption of 3D modeling technology, which is becoming an integral part of archaeological practice. Here we present a case study, a sample of 3D models from a large collection of well-preserved medieval ceramics from the excavations of the Sanctuary of Zeus at Nemea, Greece. This growing digital collection can illustrate the advantages, potential, and challenges presented by the incorporation of 3D technology into archaeological practice. 3D modeling technology can facilitate documentation, interpretation, and publication of archaeological datasets. However, the longevity of these datasets remains uncertain and require extensive dialogue and collaboration, as storage space requirements, support of current digital infrastructure, and long-term data accessibility and preservation are matters that do not have standardized solutions. More effort needs to be invested in preserving these large datasets before 3D modeling can become fully incorporated into archaeological practice.

Keywords: archaeology, 3D modeling, laser scanning, medieval ceramics, Greece

Introduction

This paper was presented in the CAA 2017 session "Exploring the Symbiotic Relationships of Archaeology and Digital Humanities." As the session's description emphasizes, archaeology is a discipline that is inherently spatial and temporal. It is also inherently interdisciplinary and fits comfortably within the Social Sciences, as well as the Humanities. It is closely affiliated with anthropology in North America but in Europe has a strong link to History and the Humanities. We consider this plasticity and interdisciplinarity as a strength rather than a weakness of our field.

Archaeology also cuts across the natural and computational sciences. These are real strengths that make archaeology one of the core fields in the transdisciplinary digital humanities. Archaeology was always among the first, along with geography, to incorporate new methods and tools, such as spatial analysis and GIS, which added new dimensions, and facilitated the documentation and analysis of spatial as well as temporal aspects of human settlement. New directions soon emerged, such as landscape studies, a multidisciplinary research area, where archaeology played a vital role (e.g., Ashmore and Knapp 1999; David and Thomas 2008; Muir 1999; Ucko and Layton 1999).

As new technologies, especially 3D technologies, have become widely adopted, archaeology has become a main contributor to Digital Humanities. This give and take, is a true symbiotic relationship between the two that has led, again, to new, multidisciplinary research areas, such as Digital Cultural Heritage. We can offer observations on the development of this fruitful and symbiotic relationship between archaeology and the Digital Humanities in our own institutions. The University of Nebraska-Lincoln (UNL) has been a leader in the field of Digital Humanities. When the Center for Digital Research in the Humanities was established, a decade ago, the core disciplines which contributed to the dialogue at the time were text-based disciplines, mainly English and History. However, it did not take long for archaeology to become one of the core Digital Humanities members and contributors, as interest, among students, and strong candidates with well-developed digital portfolios, led to the hiring of four archaeologists, in anthropology, art history, and classics, within the span of two years.

In this paper we reflect on the impact that these new developments had on our own work, as an example of the transformation that Digital Humanities approaches are bringing to established forms of scholarship. Here, we report on the ongoing experimentation with 3D modeling methods, in particular laser scanning, and their application to archaeological collections.

3D Modeling and Archaeological Collections

In the last 15 years the adoption of 3D modeling methods in archaeology has accelerated. These methods have found wide applications in the field and the laboratory and have brought rapid change to established practices (e.g., Forte et al. 2012; Olson and Caraher 2015; Olson et al. 2013; Remondino and Campana 2014). This new technology has also led to the growing digitization of archaeological collections of a wide variety of artifacts (e.g., Grosman et al. 2014). Some of the commonly discussed benefits that have accompanied the adoption of these new tools are increased measurement precision, ability to reconstruct artifacts (e.g., Barreau et al. 2014; Kampel and Sablatnig 2003; Tsiafaki et al. 2016), evaluation of morphological variability (Bretzke and Conard 2012), and ease of investigation, since the digitized objects represent accurate copies of the originals (Olson and Placchetti 2015). Another major advantage is that this technology facilitates virtual preservation and digital data dissemination. These qualities have led to the adoption of 3D technology by museums to enhance exhibits and provide novel virtual educational experiences (e.g., Payne et al. 2010; Sylaiou et al 2009).

Here we focus on the application of 3D modeling methods to the study and analysis of archaeological ceramics. Archaeological ceramics are one of the most common and important categories of artifacts, as they provide information on chronology, and cultural context. Because pottery is found in fragmentary condition, its documentation is labor intensive, as each fragment has to be described, measured, drawn, photographed and classified. The study of ceramics has benefited from the development of 3D modeling methods. The advantages of 3D technology over earlier methods are significant as they provide considerable support to traditional drawings and 2D recording and documentation methods (Ebolese, Lo Brutto & Burgio 2017).

Several studies have demonstrated that 3D modeling is not only more accurate than manual illustration, it also provides more information, and is actually a more efficient method. Karasik and Smilansky (2008) used 3D scanning technology to identify the rotation axis and profiles and obtain models of more than 1000 pottery fragments from several sites and time periods. They concluded that it was more cost effective compared to traditional methods. This and other studies have utilized 3D scanning for accurate data acquisition, including 2D profiling, and the calculation of attributes that are harder to measure by traditional means, e.g. volume, surface area, and symmetry.

Furthermore, digital libraries of 3D models of artifacts have become a reality. Early efforts (e.g., Rowe et al. 2002) aimed to develop a storage, archival, and sketch-based query and retrieval system for 3D objects. The process and results provided a model for a digital library of 3D data for further study and analysis. Another similar project, the Ceramic Technologies Digital Library (CTDL), involves the creation of an integrative, web-based database on medieval ceramic technology from Central Europe, particularly the Germania-Slavica area (ca. AD 600–1400). It applies 3D scanning technologies to ceramic vessels, in addition to analytical software for vessel symmetry. The primary goal of the CTDL project is the creation, support, and long-term curation of a digital library (Simon et al. 2008). A more recent project is “Digitizing Early Farming Cultures” (DEFC), which has standardized and integrated research data of Neolithic and Chalcolithic sites from Greece and Anatolia (c. 7000–3000 BC). The digital exhibit includes a 3D pottery gallery and associated metadata (Štuhec et al. 2016; https://defc.acdh.oeaw.ac.at/).

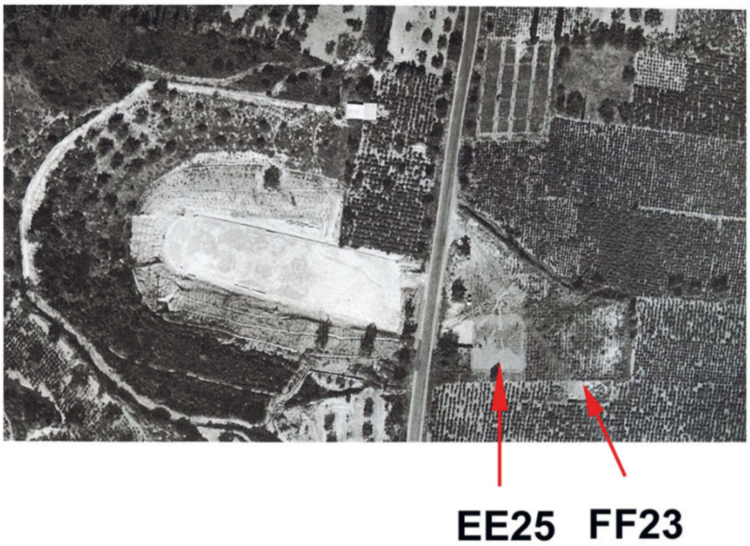

Figure 1. Nemea Stadium, aerial view: arrows indicate the location of grid squares EE25 and FF23.

A Case Study from Nemea, Greece

Next, we reflect on the impact that these new technologies had on our own work as an example of the transformation that 3D modeling methods are bringing to established archaeological practices. The case study is a collection of medieval pottery derived from the excavations at the Sanctuary of Zeus at Nemea, carried out by the University of California-Berkeley in the 1970s and 1980s. The pottery came from a series of closed deposits, from the Nemea Stadium, which were excavated in 1975 and 1980 (Miller 1976; Miller 1981). These deposits yielded ceramics dating mainly to the 12th and 13th centuries CE. The excavated pits (located in sections FF23 and EE25, Figure 1) stand out among the deposits with medieval material from the Nemea excavations because they produced large quantities of well-preserved ceramics, diagnostic fine wares, as well as coarse wares. This material is being studied in order to identify representative shapes, styles, and dates, which are the backbone for further analysis. This assemblage can also serve as a reference guide for other projects, since comprehensive studies of ceramics from the medieval period in Greece/Aegean are few compared with those dating to earlier times, i.e., the Bronze Age and the Classical and Roman periods. Thus, the adoption of 3D modeling methods was part of the overall research goals, to provide a better form of visualization for the study and publication of medieval ceramics from Nemea. Furthermore, creating 3D models of representative types of medieval ceramics provides additional options that can facilitate the analysis and sharing of results. The selection of ceramics for 3D modeling was based on the following criteria:

- Fragments that represent the most common types of decorated and undecorated wares;
- Fragments that represent less well-known types of wares;
- Sherds that exhibit variation of basic features in shape and size;
- State of preservation: preference is given to well-preserved fragments that can provide information about the main attributes of the vessel;
- Significance of a particular type for establishing a classification, especially of coarse wares.

For decorated ceramics of this time period, there is an established classification scheme based on decorative techniques, e.g., glazed, painted, incised, slip painted (Morgan 1942). However, there is little published comparative material for medieval coarse wares, which constitute the majority of the finds (e.g., MacKay 1967). Thus, the Nemea collection can also contribute to this end, to document coarse wares

Figure 2. Nemea FF23.10.50 siphon handle 3D model.

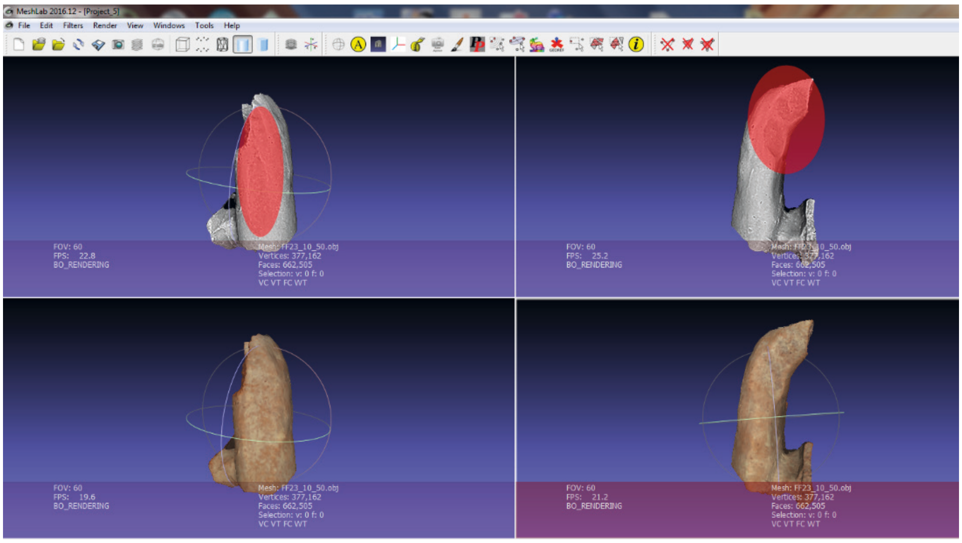

Figure 3. Nemea FF23.10.50 3D model in regular and radiance scaling rendering. The red ovals indicate areas with finger marks.

that were common in rural areas and facilitate the development of a typology.

3D Modeling and Archaeological Analysis

In the course of three summers, over two hundred 3D models of diagnostic ceramics have been completed. The 3D models were created with a Next Engine 3D laser scanner (Brown 2010; White 2015). It is a portable, affordable scanner, which can accurately record small to medium sized objects, with a precision of 0.13–1.66 mm (Polo and Felicísimo 2012). The texture is not high resolution, for example, it is not as good as the texture that photogrammetry provides. However, this equipment produces high-fidelity models in a fraction of the time required for photogrammetric processing. Multiple views are needed to create a complete model. The 3D model requires editing (trimming, aligning, fusing) and, depending on the complexity of the object, it can take from half hour to two hours for a complete edited model. The scanner records surface lines, indentations, breaks, imperfections, etc. that may facilitate different types of analysis (e.g., manufacturing methods). Thus, the specific traits of the NextEngine 3D desktop laser scanner make it very useful to archaeological research, since it is lightweight, affordable, easy to operate and accurate. It has been used successfully to create 3D models of a variety of archaeological materials including ceramics (e.g. Kaneda 2009; Means, McCuiston & Bowles 2013).

The production of high-fidelity 3D models is a

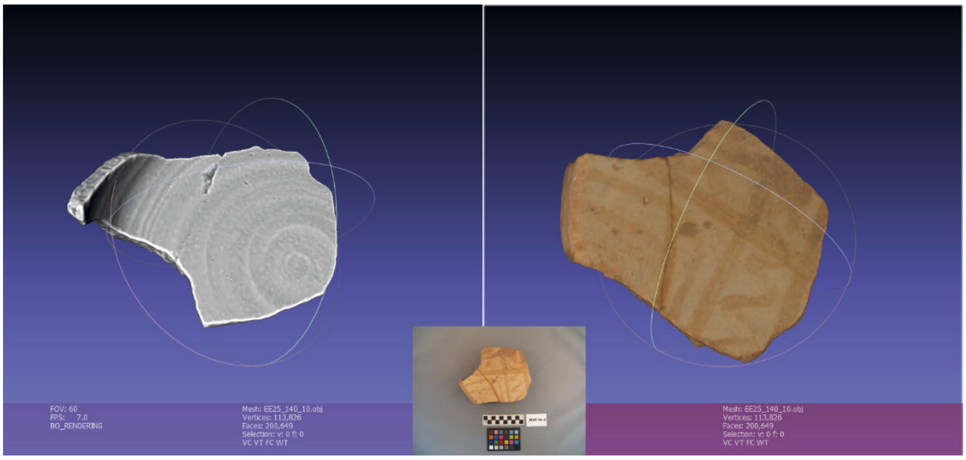

Figure 4. Nemea EE25.140.10-3D model in regular and radiance scaling rendering.

starting point for further analysis and interpretations of the ceramic material. These models enhance the detailed examination of the artifacts, and aid classification and documentation of the stylistic variability within each type. Also, the 3D models assist in the study of manufacturing techniques, facilitate measurements, and reconstruction of representative types. They offer new possibilities, as one can examine details that are not visible in 2D photographs or even on the artifact itself, when viewed under standard lighting conditions. For example, a unique artifact in the collection is a large fragment of a hollow tube (Nemea FF23.10.50; Figure 2). This interesting object was part of a special vessel, a siphon, designed to draw liquids through suction from large containers. The handle/tube was handmade and its surface preserves finger imprints from the manufacturing process. However, these features become visible only when the 3D model is processed with special filters, such as the radiance scaling filter available in Meshlab, which enhances the 3D model's concavities and convexities (Figure 3; Vergne et al. 2011).

Another unusual shape is a flat-bottom flask (Nemea EE25.140.10). The base is decorated with matt-painted intersecting lines and zig-zags. It is a fragment of a special type of water-transporting vessel known as an *askodavla*, a flask derivative (Bakirtzis 2003). This vessel was manufactured on a potter's wheel, in separate pieces that were then joined together. The base interior preserves features, wide concentric grooves/lines that resulted from the manufacturing process on the wheel. These become visible when the 3D model is processed with the radiance scaling filter (Figure 4).

A 3D model of a chafing dish, a more common shape, can also be enhanced with shading tools in order to accentuate its surface features, which consist of incised and relief decoration (Nemea FF23.10.45, Figure 5). This shape combines a shallow dish set on top of a stand with a lid; it was used to serve food and keep it warm (Sanders 2003). Multiple views of this fragment are needed in order to document its characteristics and the methods of manufacture for this type of vessel. Thus, the 3D models improve this process, provide detailed views that reveal manufacturing methods, facilitate the classification of this pottery, as well as comparisons with similar material. Furthermore, by exporting the 3D models in different formats and converting them to widely supported files such as PDF, a variety of views and cross-sections can be generated by the user. For example, the 3D model of a globular juglet with sieve can be shown with its cross-section at different points to allow accurate documentation, identification and comparison (Nemea FF23.10.75, Figure 6). Thus, documentation is a critical phase for the classification of archaeological ceramics, especially those that have not been studied extensively.

The incorporation of 3D technology has aided this research project. At this time of transition from well-established practices of 2D drawings and photographs of artifacts to 3D recording, it is fair to say that the 3D models offer a number of advantages: 1) The 3D models are high fidelity digital reproductions, superior to 2D renderings. 2) They provide visually effective means for documenting the composition of the assemblage. 3) They provide a substantial amount of information for the viewer that the researcher does not filter. Many applications of 3D modeling apply primarily to display and

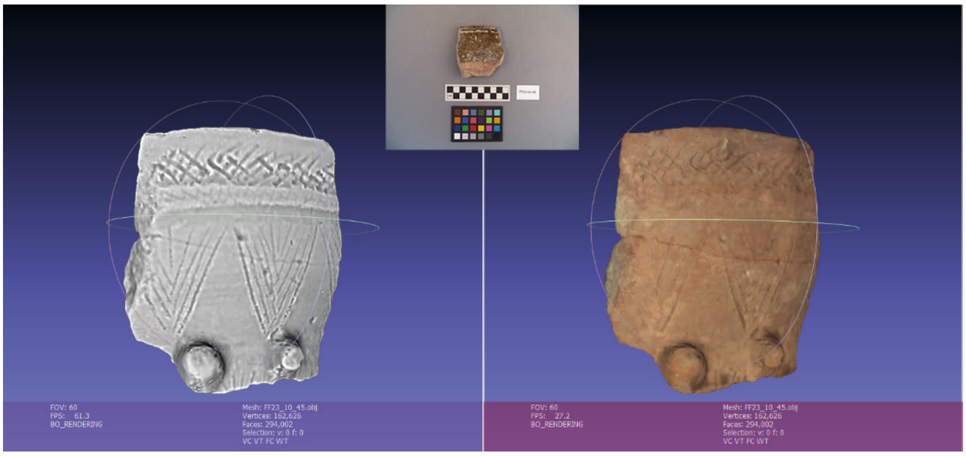

Figure 5. Nemea FF23.10.45, chafing dish 3D model in regular and radiance scaling rendering.

presentation of data (Newhard 2015:12). However, visualization is intertwined with analysis, and, as Opitz (2015:77) suggests, is part of the interpretive process. The 3D modeling process produces digital reproductions of artifacts that can be used for a variety of typological, functional, and other kinds of analyses. So far, we have highlighted typological aspects and manufacturing methods. To date these deposits from Nemea are the key in our effort to refine the chronology, especially of coarse wares, and reconstruct daily activities at the site. The next step, however, will be to concentrate on social aspects, including food preparation, storage, and the reconstruction of consumption patterns and regional trade networks. The 3D models provide high-quality information to achieve these goals and are central to the next phase of the project, dissemination. This is a significant archaeological assemblage that, so far, has been available only to specialists. Currently, a substantial selection of 3D models from this archaeological collection is readily available through Sketchfab. In the near future, the whole assemblage will become available via a digital archive using the 3D Heritage Online Presenter (3DHOP) (Galeazzi et al. 2016; Potenziani et al. 2015). Although the immediate plans are for a digital archive that will highlight this particular collection, there is a need for a broader initiative, a database that will bring together material from several regions. Such an effort can provide solutions to a common challenge, the identification and comparison of similar material from different sites and regions. The development of a multi-regional digital archive can streamline the search for particular types of medieval pottery using standardized terms. It will facilitate different types of analyses and ensure that the next phase of research stands on firm ground.

Digital Preservation and the Future

3D technology has a transformative role when it comes to sharing of results and inviting public interaction. Digital modeling is becoming as indispensable to archaeology and museums as photography in the late 19th century (Garstki 2016). Many museums are investing in engaging exhibits which incorporate 3D technology. One of the notable examples is the Smithsonian's X 3D project (3d.si.edu), which makes available to the public 3D models of a wide variety of objects from its collections that can be downloaded and printed (Rabinowitz 2015:27). This is one of the novel qualities of 3D technology, that the digital models can be duplicated easily and displayed in multiple locations. 3D digital artifacts offer accurate, high quality data to researchers, without the need to visit museums or storage facilities or to handle original finds. Thus, they enhance preservation, as the digital copies provide faithful substitutes of the artifacts. The act of creating a 3D model is a step towards digital preservation. A 3D model can potentially serve as an enduring record of an artifact. So, certainly, artifact analysis, and digital preservation are benefiting from 3D technology. 3D modeling methods are generating novel kinds of datasets and are creating a new category of objects, "digital surrogates" which have their own independent reality and require their own documentation and explanation

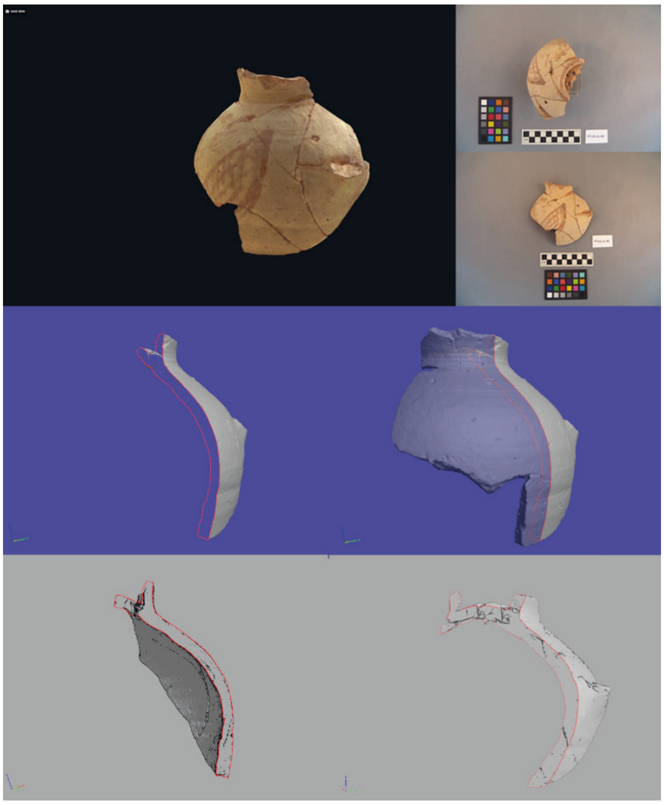

Figure 6. Nemea FF23.10.75, juglet with sieve, 3D model and cross sections at different points.

(Rabinowitz 2015:36). "Digital surrogate" is a term used in libraries and archives to refer to any digital representation of a work that exists in the physical world (a thumbnail, a metadata record, a digital image). More commonly, however, the term indicates a faithful digital copy that seeks to represent an analogue original as accurately and in as much detail as possible (Rabinowitz 2015:29).

Many questions remain, as we are still assessing the impact of digital technologies, and 3D modeling in particular. For example, the longevity of these datasets remains uncertain, as storage space requirements, support of current digital infrastructure, and long-term data accessibility and preservation are matters that do not have standardized solutions yet, rather require extensive ongoing dialogue and collaboration. Rabinowitz (2015:34-36) offers four basic principles to guide publication and archiving in order to ensure the future scholarly usefulness of 3D digital surrogates. Some of these have become common practices, while others require the development of new tools: 1) Measurements: the models have to include some user-accessible information about scale and units. 2) Inclusion of raw data for reuse wherever possible. 3) Metadata: The raw data are of limited use without comprehensive metadata that indicate what the raw data represent. 4) Process history: Specific information on how a model was generated and processed.

Well-established initiatives such as Digital Antiquity and tDAR, the Archaeology Data Service (UK), and Open Context are providing leadership in the area of preservation, and long-term access to archaeological information (e.g., Clarke 2015; Kansa, Kansa & Arbuckle 2014; Niven 2017; Richards 2017; Stylianidis and Remondino, 2016). New initiatives, such as the Community Standards for 3D Data Preservation (CS3DP), aim to develop consensus on standards that include best practices, management, storage, metadata, access, copyright/owners and general workflows for 3D creation services and discoverability. This is an active area of research which in addition to the development of best practices, also addresses data sustainability, accessibility, and reuse (Richards-Rissetto and von Schwerin 2017). 3D modeling technology has become an integral part of archaeological practice. The challenge ahead is to find sustainable solutions that can ensure the continued use of these large and diverse datasets for future research.

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