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Editorial Introduction: Web-based Archaeology and Collaborative Research

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Introduction

Archaeology is collaborative, ongoing, and iterative. Our workflows are not unidirectional, but rather we work back and forth between the field, labs, and dissemination. With the advent of digital technologies, not only are workflows becoming faster and more numerous, collaborations are also spread wider, often global. Fieldwork teams comprise data recording experts using diverse non-digital and digital methods that in turn produce increasingly entangled datasets. While digital technologies have been part of archaeology for more than fifty years (Chenhall 1968; Richards 1998; Whallon 1972), archaeologists still look for more efficient methodologies to integrate digital practices of fieldwork recording with data management, analysis, and ultimately interpretation.

Digital technologies such as terrestrial and airborne laser scanning and photogrammetry allow us to acquire data rapidly from excavations, structures, and landscapes (Forte and Campana 2016; Galeazzi 2016; Remondino and Campana 2014; Doneus et al. 2011); however, resultant datasets require not only large storage capabilities, but they often also require customized digital tools for post-processing and dissemination (Galeazzi et al. 2016; Matshusita et al. 2014; Opitz et al. 2016; Richards-Rissetto and von Schwerin 2017; von Schwerin et al. 2016; Vincent et al. 2013; von Schwerin et al. 2016). Fortunately, recent advancements in web technology afford new ways to access, integrate, and work with archaeological data because they utilize web browsers as effective computation and visualization platforms. For example, web browsers can now efficiently execute JavaScript code, which enables faster and greater processing on the client side, and thus requires less memory storage than web servers. Moreover, the HTML5 standard includes WebGL (a JavaScript API for rendering interactive 2D and 3D computer graphics in browsers without plugins) that allows for efficient web-based 2D and 3D data visualization. Programming languages, data standards, and best practices combined with open source software extend the potential for web technology to reshape archaeological practice even further through quick and efficient integration of data acquired from fieldwork and lab work for analysis.

This Special Issue of the *Journal of Field Archaeology* gathers international scholars affiliated with universities, organizations, and commercial enterprises working in the field of Digital Archaeology. Our goal is to offer a discussion to the international academic community and practitioners. While the approach is interdisciplinary, our primary audience remains readers interested in web technology and collaborative platforms in archaeology. The Special Issue is divided into three sections. Part I: Web-

based Collaborative Platforms and Archaeology, Part II: 3D Web and Archaeology, and Part III: Online Research Infrastructures and Publishing in Archaeology.

In Part I on “Web-based Collaborative Platforms and Archaeology,” contributors focus on the potential roles of web-based infrastructure (platforms) to facilitate and transform archaeological practice. Desktop applications that run programs locally have been the norm in archaeology because they typically afford greater storage, computational, and visualization possibilities. While real-time transfer and visualization of 3D models over the Web is possible, it requires high-resolution models to be optimized (or decimated) making them less useful for analytical purposes (Ponchio and Dellepiane 2015; Fernández-Palacios et al. 2013).

Recent advances in cloud computing alongside increasingly linked data and new software make web applications viable alternatives (Fernández-Palacios et al. 2013; Kansa et al. 2014; Wells et al. 2014), and yet fundamental challenges still exist. To confront some of these challenges, contributors in Part I explore the potential of web-based platforms to facilitate collaborative archaeological research taking into account whether a single, all-encompassing platform is the best solution. They also discuss the roles of standards and best practices in developing web infrastructure that brings together legacy and newly-acquired field data.

Building on the ideas developed in Part I, contributors in Part II focus on “3D Web and Archaeology” turning specifically to 3D data captured in field and lab work. They discuss the potential of web-based technologies to facilitate real time remote collaboration with offsite researchers seeking to integrate and analyze 3D data. Such discussion is essential because 3D technologies are becoming a mainstay in archaeological practice. While specialists have been using terrestrial laser scanning to acquire 3D data for over two decades (Galeazzi 2016; Remondino and Campana 2014; Lerma et al. 2010; McPherson et al. 2009; Vico et al. 2006), recent advances in photogrammetry alongside a burgeoning of low-cost and reliable Unmanned Aerial Vehicles (UAVs), particularly drones, are allowing non-specialists to collect large amounts of 3D field data (Campana 2017; Fernández-Hernandez et al. 2015). However, many of these 3D datasets are not used to their full potential. Often inefficient use stems from a lack of tools and techniques to integrate 3D data seamlessly with other archaeological data for efficient analysis and interpretation. Moreover, these hurdles prohibit the creation of interactive visualizations to share with others (Kehl 2015; Richards-Rissetto and von Schwerin 2017; Verhoeven 2016).

In Part III on “Online Research Infrastructures and Publishing in Archaeology,” contributors focus on challenges of

working with, and bridging, archaeological data, analysis, and visualization requirements on the back-end (server-side) and front-end (client-side). One emerging concern related to data accessibility regards the publication of digital data. A great challenge focuses on 3D models, notably their association with source data, and to complicate things further, specialists grapple with how (if) to include interpretations (Bentkowska-Kafel et al. 2016; Galeazzi et al. 2016; Münster et al. 2016; Opitz et al. 2016). To address these challenges, contributors discuss bridging web-based data management with tools to integrate field data, visualizations, and interpretations. They also point out that we need to consider interdisciplinary human networks to develop sustainable solutions.

Numerous public and private institutions, foundations, and organizations such as the European Research Council, National Science Foundation (USA), and National Endowment for the Humanities (USA) are funding research to support web-based approaches to cultural heritage. This global support emphasizes awareness of web-based solutions to promote collaborative archaeological research. To be sure, there is a long legacy of digital development for archaeologists, and we now turn to a brief history of web-based archaeology to contextualize the challenges and opportunities we currently face.

History of Web-based Archaeology

The World Wide Web provides a revolutionary medium for digital communication, transforming the ways to access, visualize, and analyze archaeological data. Institutions and organizations around the world use the Web to archive materials and make archaeological information accessible and yet web tools for real-time integration and dissemination of field data are still lacking.

Since the 1980s, several projects have supported research and development of digital tools for archaeological fieldwork. However, these early tools used desktop applications that typically required manual digitization of field data after the field season limiting possibilities of real-time data checking or sophisticated analysis during the field season (e.g. Rice 1982; Williams 1997; Davis et al. 1998; Dibble et al. 2000; Di Giuseppantonio et al. 2012).

In 1997, The Mobile Computing in a Fieldwork Environment (MCFE) project began developing “Enhanced Reality” tools for timely communication between desktops and hand-held mobile devices (Ryan et al. 1999). Inspired by Brown’s (1995: 260) Stick-e note metaphor where notes are associated with specific environments and information is triggered when users enter specific environmental contexts, MCFE developed an electronic equivalent of a Post-it note. This note could “be posted in any position in the space covered by the location-sensing technology, and which the user sees every time she visits that position” (Brown 1995: 260). Importantly, the tool automatically generated text notes in HTML with associated metadata that could easily be transferred as “bundled data” from GPS (Global Positioning Systems) units to computers for basic geospatial analysis (Ryan et al. 1997: 272). This approach moved real-time fieldwork towards a web-based approach.

While GPS enabled archaeologists to collect rapidly and accurately georeferenced spatial data, the introduction of Geographical Information System (GIS) platforms in the 1980s revolutionized the acquisition, manipulation,

visualization management, and analysis of archaeological data (Aldenderfer 1996: 4; Allen 1990). During the 1990s, GIS represented the largest growth area in computer applications in archaeology (Richards 1998), and yet GIS continued to primarily focused on landscape archaeology management (Kvamme 1989: 162). Until the turn of the 21st century intra-site GIS analyses were few and far between (Richards 1998: 338). In great part, this lag in adoption for intra-site applications (particularly excavation) could be ascribed to its confinement to desktop applications, which do not allow real-time data sharing and analysis during fieldwork. Generally speaking there are several reasons for the lag in real-time GIS applications for fieldwork: GIS requires high-performance computing requirements making mobile options limited; early GIS software required users to know computer programming (e.g. ArcInfo, GRASS), and; once a user-friendly GIS became widely available, the PC-only desktop software, ESRI’s ArcView, was proprietary, limiting possibilities to expand platforms. However, in 2009, version 1.0 of QGIS (Quantum GIS)—a cross-platform free and open-source desktop geographic information system (GIS)—was released allowing for rapid, “crowd-sourced” and flexible development along with a user-friendly GUI available in 48 languages and cross-platform use.

Along these lines, as we have settled into the 21st century, there has been a greater expectation for remote and open access spatial data to promote data sharing and interoperability. In 2007, the INSPIRE Directive sought to develop a spatial infrastructure to encourage people to share environmental datasets (i.e., INSPIRE [<http://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX:32007L0002>]) incentivized the development of European infrastructure projects focused on cultural heritage such as CARARE (<http://www.carare.eu/>), EUROPEANA (<https://www.europeana.eu/portal/en>), and the recently launched ARIADNE Portal (<http://ariadne-portal.dcu.gr/>). In the United States, the GSA’s Open Government Initiative includes DATA.GOV to promote data sharing (including spatial), and in fact, federally funded projects mandate Open Geospatial Consortium (OGC) data standards.

However, data sharing extends beyond open access. Smart mobile devices have led to a proliferation of “internet of things,” that is, the networked interconnection of everyday objects, (Xia et al. 2012). This widespread diffusion of mobile devices in conjunction with an increasing number of online repositories for archaeological data (e.g. Archaeology Data Service, tDAR) and linked open data (e.g. Open Context, DINAA) (Kansa et al. 2014; Wells et al. 2014) is leading to innovative web-based applications that facilitate real-time links between archaeological data captured in the field and off-site data repositories. This networked interaction via the internet also affords archaeologists’ opportunities for global real-time interaction with colleagues while in the field.

An important part of the chain to link archaeological field practices to global networks is WebGIS, which allows the implementation of GIS applications on map servers to enable interaction with spatial data via the web rather than desktop or local networks. One example is the Raptor project, which built a geodatabase and WebGIS to computerize and standardize the spatial data procedures of the Italian Superintendence for Archaeological Research (Frassine and Naponiello 2012; Frassine and De Francesco 2015). WebGIS, commonly used for the visualization of 2D geospatial data in archaeology with projects as ORBIS and PLEIADES (Isaksen et al. 2014;

Meeks and Grosner 2012; Sarris et al. 2008; Vandenbulcke et al. 2016), has been also recently applied to the visualization of 3D data (Calori et al. 2005; Agugiaro et al. 2011). But it is only with the advent of WebGL technology (a JavaScript API for rendering interactive 2D and 3D computer graphics in browsers without plugins) as a HTML5 standard that web browsers have become an effective computational platform also for 3D data (Auer et al. 2014; Galeazzi et al. 2016; see also this issue Bezzi et al. 2018, and Jensen 2018). Additionally, with the advent of cloud computing web-based data analysis is becoming more commonplace (e.g. Google Earth Engine) because it enables “big data,” or computationally heavy processes, to be processed server-side rather than client-side and provides greater access to cultural contents through application services, data services, and infrastructure services (Vecchio et al. 2015). Remote storage and processing directly lends itself to new archaeological practices in the field that streamline onsite and offsite connections and collaborations via the web. Currently, the state of the field for web-based collaborative platforms in archaeology shows further promise.

State of the Field

New and emerging technologies contribute immensely to data acquisition, analysis, visualization, and dissemination in archaeology: but what role are web-based applications and platforms playing as archaeologists seek to integrate datasets and redefine archaeological methods and theory? This section considers the multiple uses of web technology in archaeology today. We emphasize that tool and technology selection should depend on user requirements and desired outcomes, and thus a serious commitment to long-range planning at the forefront of research.

Part I: Web-based Collaborative Platforms and Archaeology

With increasing ease, archaeologists adopt and adapt digital technologies to capture data in the field and lab. We see the benefits of fast and efficient data collection that permits both traditional and innovative analysis and publication. However, we are also well aware that many challenges exist to make fuller use of digital data, tools, and applications for archaeology. One of the greatest challenges is streamlining data integration to facilitate real-time archaeological analysis to inform decisions in the field and lab. In some cases, archaeologists collect and integrate field data using existing technologies, but this process still requires multiple tools and intensive data processing (Berggren et al. 2015; Forte et al. 2012, 2015). In other cases, they are working to develop new field tools such as REVEAL, ArcField, and OpenNotes (Corsi et al. 2014; Smith et al. 2015; Vincent et al. 2013, 2014). In fact, no one solution fits *all* archaeological needs. Given this reality, we need to expand real-time data integration to offsite collaborations at a global scale in order to bring together interdisciplinary specialists who often cannot be in the field together, yet their decisions are integral to onsite decision making (or at least they should be). To address this major challenge, contributors in Part I of this special issue focus on web-based infrastructure (i.e., platforms) for remote integration, analysis, interpretation, and dissemination of archaeological data.

To set the stage, Zerbini tackles the issue of tool development vs. tool customization. For the Endangered Archaeology in the Middle East and North Africa (EAMENA) Project, team members opted to customize Arches (www.archesproject.org) (an open source data management platform for the heritage field) rather than develop an entirely new web-based platform. Their goal was to create a web application that stores and visualizes data from threatened cultural heritage sites in twenty countries to assist in real-time management decisions to stave off destruction or capture data before it disappears. While Arches provides the software framework, EAMENA needed to make major modifications and enhancements to the base code to adapt to specific challenges encountered in Middle Eastern and North African countries. They designed the system's data structure to be compliant with the CIDOC Conceptual Reference Model (CRM), which ultimately will enable migration to EAMENA's relational database (RDB) to linked data to facilitate interconnection and interoperability with other web-based archaeological projects.

Lukas, Engel, and Mazzucato call for web-based tools and approaches that promote a reflexive archaeology that enables scholars and the public to reinterpret archaeological data with greater nuance. However, as they highlight, reinterpretation necessitates that metadata and paradata be accessible to data consumers. While metadata standards exist for many digital data, archaeological data is notoriously heterogenous, and older projects often contain digitized legacy data lacking appropriate metadata. While CIDOC-CRM offers a Conceptual Reference Model (CRM) to facilitate data exchange and integration for cultural heritage, there is still no single CRM to provide definitions and a formal structure for describing concepts and relationships in archaeology (Doerr and Theodoridou 2011; Stead and Doerr 2015). To promote a reflexive archaeology, data reusers must also have information on how data were collected, analyzed, and interpreted. Working towards this goal, the Çatalhöyük Project, under the directorship of Ian Hodder, made its records available in an interactive web-based system that allowed users to search and query the project's many layers of digital data such as text documents, audiovisual materials, and spatial data. By using open standards, the Çatalhöyük web-based system allowed for data to be linked to other systems also using the Semantic Web approach creating many more opportunities for collaborative archaeological research.

Part II: 3D Web and Archaeology

While the evolution of digital archaeology as a field of archaeological endeavour is a phenomenon that has rapidly crystallized in the past decade, the roles that 3D technologies play is not very clear. Without question, 3D archaeology creates unique archaeological methodologies, forms of interaction, and formal content; yet an understanding of its full scale impact remains a topic for ongoing and future assessment. Researchers have begun to test and integrate 3D methodologies onsite (Koutsoudis et al. 2014; Dellepiane et al. 2012; Doneus et al. 2011); however, we still lack a comprehensive evaluation on potentials and limitations of using 3D for fieldwork and analysis. Part II of this special issue discusses the state of the art in adopting 3D techniques and methods and proposes different visions for the development of 3D

analysis systems that could enhance archaeologists' reasoning and interpretation.

Opening Part II, Jensen's contribution emphasizes that while 3D data allows for visuals that facilitate data sharing and new interpretations, proprietary desktop solutions usually afford only limited ability to convey these interpretations because they only visualize surface geometry and texture. He contends that to overcome this limitation, we need new tools and frameworks for data management and exchange of 3D archaeological content. He presents a web-based 3D platform, Archeo 3D-Viewer, that facilitates the collaborative exchange of 3D excavation content almost instantaneously, and incorporates new functionalities that allow the integration of all spatial and attribute data into one common event-based model. Archeo online infrastructure not only allows the integration of 2D GIS and 3D interactive visualization on the same platform, but also presents the augmented semantic value of integrating textual and spatial components such as the combination of the segmentation of 3D models with the semantic web and its possible use of crowd-sourced semantic annotations tools.

Bringing a commercial perspective to the utility of web-based technologies in archaeology, Bezzi and co-authors summarize the multiple uses of 3D web technologies in commercial archaeology. They describe specific case studies based on Arc-Team Archaeology (a commercial company that uses open source or free technologies for web-based applications and tool development). Generally speaking, commercial companies have a shorter timeframe to develop customized tools and technologies and they must thoroughly consider the varied needs of stakeholders. The tools and technologies for each project often vary requiring a flexible research design that takes into account three main aspects: nature of 3D data, client and target audience of application, and ultimate purpose(s) of 3D web technology. The Arc-Team's various products (e.g. 3D webGIS for archaeological project management and protection, 3D Virtual Tour web applications) exemplify the different requirements between the private sector and academic, organizational, or government sponsored research environments.

The contributions in Part II of this special issue set the stage for a unique conversation on the role that 3D technologies might play in redefining future archaeological methods and theory. Authors discuss the current state of the art in 3D web technologies providing new infrastructures and visions for the future of 3D web-based visualization in archaeology. However, it is crucial to investigate whether visualization and analytical tools should be integrated in the same platform or if analytical tools should be independent of visualization tools. Jensen proposes a combination of the two, but the discussion on the possibility of integrating visualization and analysis has just started, and will probably be one of the crucial aspects to be investigated in future 3D visualization research.

Part III: Online Research Infrastructures and Publishing in Archaeology

Despite the growth of the internet in the last two decades, archaeologists have been relatively slow to exploit fully the potentials of electronic publication. Some success in developing and integrating web-based data management and publishing tools is occurring in the humanities with open-

source web publishing platforms for sharing digital collections and creating media-rich online exhibits such as Scalar (<https://scalar.usc.edu/>) and Omeka (<https://omeka.org/>) (Blanke et al. 2014; Coble et al. 2014; Richards et al. 2011; Tracy 2016). In archaeology, academic journals are making moves to integrate digital data and applications into publications; however, digital data such as 3D models become ancillary despite often being, particularly with born digital data, integral to analysis, interpretation, and scholarly explanation. In part, this problem arises because field collection tools and strategies typically do not consider data dissemination and publication as an integral step in archaeological process; it is something we consider post-fieldwork, but such an approach is short-sighted and ultimately insufficient and inefficient.

A problematic result is that the growing number of online archaeological databases available today are rarely linked to final publications. Data are often archived for storage and preservation rather than for re-analysis, reuse, and re-purposing, which limits validity and replicability checks and opportunities for alternative and re-interpretation. New practices should include the development of flexible and open infrastructures that can be easily adapted to or customized for different excavation, documentation, and analysis approaches that afford digital publications with linked data (Galeazzi et al. 2016; Kansa and Kansa 2014; Richards and Hardman 2008; Sullivan and Snyder 2017).

In Part III, contributors present a critical but often overlooked aspect: we must move beyond solely technical solutions. To address many of the current challenges in the changing face of archaeological practice, human networks of interdisciplinary colleagues and stakeholders (i.e., authors, editors, technologists, and designers) are essential. Using a human-centered perspective, Wright explores issues of data preservation, sustainability, and accessibility in archaeology. From her expertise as European Project Manager for the Archaeology Data Service (ADS), she provides insight into the complex relationships and active collaborations required to develop successful web-based projects with effective infrastructures. ADS is a data archive working at a national level in the United Kingdom to ensure archaeologists have access to high quality and dependable digital resources, including openly licensed legacy data available for reuse. ADS participates in international aggregation infrastructure projects like Europeana (<https://pro.europeana.eu/>) and ARIADNE (<http://www.ariadne-infrastructure.eu/>), which allow users to access resources held in many countries from a single interface. Wright, too, reflects on an often overlooked but critical component of successful web-based projects, the networks of people involved in the projects. She describes the issues involved in the developing collaborative online research infrastructures for archaeological data including lessons learned, challenges and opportunities.

Opitz begins with a bold statement calling for archaeology to "re-envision the excavation report" to expand its role in archaeology and beyond (see Hodder 1989). Along these lines, she reiterates the need to develop new interdisciplinary publication practices that promote the creation of contextualized data that encourage reinterpretation. New modes of publication must consider the interlinking of text, media, and data, and require sustained collaboration among authors, editors, technologists, and designers. Publications with

appropriately linked data and visualizations can be avenues to rethink and re-evaluate archaeological interpretations serving as virtual research environments in their own right. New publication strategies and infrastructures should facilitate reuse and reinterpretation of data for specialists and allow non-specialists to critically inspect our interpretative processes. Opitz uses the Gabii Goes Digital Project to argue for multi-layered publications (Opitz et al. 2016; Opitz and Johnson 2016) that aim to be credible with specialists as well as engaging non-specialists. The Gabii Team has been and continues to work with Michigan University Press to design and implement a digital publication that reinvents the excavation report using narrative and linked data to allow readers to see connections between data, arguments, and interpretations (Opitz et al. 2016). In doing so, they seek to reach wider and more diverse audiences to facilitate greater engagement in archaeology.

In Part III, both Wright and Opitz identify the need to develop new forms of digital publication that link data to interpretations and promote long-term and sustained interaction with publications, and they emphasize the importance of both human and technological approaches to deal with challenges in web-based archaeology.

Conclusions

Digital tools and technologies influence archaeological practice in fieldwork, labwork, and beyond. All stages of archaeology including data acquisition, processing, analysis, visualization, and dissemination are experiencing interconnectivity and a fundamental transformation in workflow. While digital archaeology is not new (Chenhall 1968; Richards 1998; Whallon 1972), widespread use of a diversity of digital tools for old and new purposes is relatively recent, and the adoption of digital hardware and software necessitates changes in archaeological practice. We cannot simply develop new digital tools, but importantly we need to design shareable methodologies and community practices that allow for the integration of digital and non-digital practices.

The contributions in this Special Issue highlight the challenges and opportunities of web-based approaches for shaping collaborative archaeological practice. Some key ideas include: Recognizing and working through the “tug of war” between standardization/standards and flexibility in data types, data structure, software, and infrastructure; Dynamic is the “buzzword.” Static infrastructure is a problem!; The conversation of Open Source vs. Proprietary must move towards data migration strategies; Is there a “middle-ground?” Yes, let’s talk about Tool Customization vs. Tool Development, and; Solutions require both people and technology.

We suggest four paths forward. First, archaeological practice must be reflexive and iterative. Archaeologists must consciously reflect on and document the methods, data types, data models, technologies, tools, and other components of archaeology. In turn they must use these reflections/observations to improve iteratively the pipelines between field, lab, and dissemination.

Second, we must continue to push technological limits. While we realize that new tool development is sometimes required, to promote long-term operability/accessibility and interoperability of archaeological data, a best practice is to

customize or build on to existing tools. In this way, we begin to promote data, schema, and infrastructure standardization along with workflows to permit flexibility in interoperability across or out of platforms and software. In this regard, we need to develop workflows and infrastructure to foster dynamic and real-time exchange of archaeological data that simultaneously engages with new technological approaches.

For example, while Geographic Information Systems (GIS) in archaeology has moved beyond data management and become integral to spatial analysis and geovisualization (Howey and Brouwer Burg 2017), its full potential remains unrecognized in archaeology. Web-GIS and 3D WebGIS has untapped potential for collaborative research in archaeology. Before Web-GIS can make a major impact on archaeological research, not only must we move from desktop to web-based applications, but also just as importantly, we can no longer think of GIS as simply a tool to perform spatial analysis and output maps. Rather we must embrace GIS as integral for hypothesis generation and knowledge-creation in archaeology (Lock and Pouncett 2017; Richards-Rissetto 2017). Moreover, HTML5 and WebGL offer new possibilities for the visualization of 3D data on the web. Compared to Web-GIS solutions, these new technologies allow more effective interaction and analysis of complex 3D data dynamically improving performance in terms of data loading, management and usability. But while this new solution has demonstrated its efficacy for the access and visualization of 3D data archived in online repositories (Galeazzi et al. 2016), its reliability as an analytical tool still needs to be tested and proved. While some research has begun to combine the analytical capabilities of GIS and Web-GIS with 3D visualization using WebGL (Auer et al. 2014), future research is necessary to investigate the potential analytical capabilities offered by the integration of HTML5 and WebGL technologies. Should we enhance visualization tools to be analytical tools or should analytical tools be independent of visualization tools?

Third, we need to investigate the effectiveness of interactive 3D models with linked attributes for data sharing and fostering new interpretations. Future research must consider developing multidisciplinary evaluation approaches to help clarify the impact that 3D technologies might have on archaeological methods and practices. Only after such comprehensive evaluation efforts will it be possible to understand clearly the limitations and potential of 3D technologies for intra-site data recording as well as the ways new 3D visualization tools can change the way we analyse and interpret data on-site. It is essential that evaluations start with archaeological needs. We can then begin to confront these needs with technological solutions.

Finally, we need to think beyond technology. People matter, a lot. We need to think about human collaboration because it can foster deep thinking about data structures to deal with, for example, heterogeneous data in archaeology, and help develop flexible solutions and facilitate data accessibility and interoperability. In this regard, we need to include representatives from academic, non-profit, and commercial archaeology as well as continue to collaborate with computer scientists, engineers, and others. Collaborative discourse can facilitate the development of tools to allow for real-time interaction and feedback in acquisition, analysis, and dissemination of 3D data.

Disclosure Statement

No potential conflict of interest was reported by the author(s).

Notes on Contributors

Fabrizio Galeazzi (PhD, 2014, University of California Merced) is a Research Associate of the Department of Archaeology at the University of York, UK. His research focuses on the use and integration of 3D technologies for the documentation, visualization and analysis of tangible heritage and how they can impact archaeological methods and theory. He is particularly interested in exploring the potential of 3D technologies and collaborative platforms for understanding phenomena of transformation of the urban landscape during periods characterised by a lack of resources and organization, such as Late Antiquity and the Early Middle Ages

Heather Richards-Risetto (PhD, 2010, University of New Mexico) is an Assistant Professor in Anthropology and Faculty Fellow in the Center for Digital Research in the Humanities at the University of Nebraska-Lincoln, USA. Her research focuses on using and developing 3D GIS tools for spatial and visual analysis to investigate relationships between spatial configurations and social engineering and to further explore how these mechanisms work in concert with the natural landscape to reflect and shape cultural processes and practices. Her publications include articles on digital heritage, digital data sustainability and accessibility, archaeological GIS, 3D WebGIS, virtual reality, and ancient landscape experience.

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References

- Aldenderfer, M. 1996. "Introduction." In *Anthropology, Space and Geographic Information Systems*, edited by M. Aldenderfer and H. D. G. Maschner, 3–18. New York: Oxford University Press.
- Allen, K. M., S. W. Green, and E. B. W. Zubrow. 1990. *Interpreting Space: GIS and Archaeology*. London and New York: Routledge-Taylor and Francis.
- Agugiaro, G., F. Remondino, G. Girardi, J. von Schwerin, H. Richards-Risetto, and R. de Amicis. 2011. "A Web-Based Interactive Tool for Multi-Resolution 3D Models of a Maya Archaeological Site." *ISPRS - International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, Volume XXXVIII-5/W16: 23–30.
- Auer, M., G. Agugiaro, N. Billen, L. Loos, and A. Zipf. 2014. "Web-based Visualization And Query Of Semantically Segmented Multiresolution 3D Models In The Field Of Cultural Heritage." *ISPRS Annals of the Photogrammetry, Remote Sensing and Spatial Information Sciences* II (5): 33–39.
- Bentkowska-Kafel, A., H. Denard, and D. Baker, eds. 2016. *Paradata and Transparency in Virtual Heritage – Digital Research in the Arts and Humanities Series*. London: Routledge Taylor & Francis.
- Berggren, A., N. Dell'Unto, M. Forte, S. Haddow, I. Hodder, J. Issavi, N. Lercari, C. Mazzucato, A. Mickel, and J. S. Taylor. 2015. "Revisiting Reflexive Archaeology at Çatalhöyük: Integrating Digital and 3D Technologies at the Trowel's Edge." *Antiquity* 89 (344): 433–448.
- Bezzi, L., Bezzi, A., Boscaro, C., Feistmantl, K., Gietl, R., Naponiello, G., Ottati, F., de Guzman, M. 2018. "Commercial Archaeology and 3D web Technologies." *Journal of Field Archaeology* S43: 1–15.
- Blanke, T., E. Pierazzo, and P. A. Stokes. 2014. "Digital Publishing Seen from the Digital Humanities." *Logos* 25 (2): 16–27.
- Brown, P. J. 1995. "The Stick-E Document: A Framework For Creating Context-Aware Applications." *Electronic Publishing* 8 (2&3): 259–272.
- Calori, L., C. Camporesi, M. Forte, and S. Pescarin. 2005. "VR WebGIS: An OpenSource Approach to 3D Real-Time Landscape Management." *International Conference Virtual City and Territory. 2º Congreso Internacional Ciudad y Territorio Virtual, Concepción, Chile, 12, 13 y 14 Octubre 2005*. 37–43. Concepción: Universidad del Bío-Bío.
- Campana, S. 2017. "Drones in Archaeology. State-of-the-art and Future Perspectives." *Archaeological Prospection* 24 (4): 275–296.
- Chenhall, R. G. 1968. "The Impact Of Computers On Archaeological Theory: An Appraisal and Projection." *Computers and the Humanities* 3 (1): 15–24.
- Coble, Z., S. Potvin, and R. Shirazi. 2014. "Process as Product: Scholarly Communication Experiments in the Digital Humanities." *Journal of Librarianship and Scholarly Communication* 2 (3): eP1137.
- Corsi, C., E. Gay, E. Paliou, and D. Sanders. 2014. "Old Problems and New Challenges in Archaeological Sites Data Management. The REVEAL Experience at Ammaia (Portugal)." In *Across Space and Time. Papers from the 41st Annual Conference of Computer Applications and Quantitative Methods in Archaeology (CAA), Perth, 25–28 March 2013*, edited by Arianna Traviglia, 120–128. Amsterdam: Amsterdam University Press.
- Davis, R., P. Stephen, P. C. Livingood, and V. P. Steponaitis. 1998. *Excavating Occaneechi Town. Archaeology of an Eighteenth-Century Indian Village in North Carolina*. Chapel Hill, NC: University of North Carolina Press.
- Dellepiane, M., N. Dell'Unto, M. Callieri, S. Lindgren, and R. Scopigno. 2012. "Archaeological Excavation Monitoring Using Dense Stereo Matching Techniques." *Journal of Cultural Heritage* 14 (3): 201–210.
- Dibble, H. L., S. McPherron, and B. Roth. 2000. *Virtual Dig: A Simulated Archaeological Excavation of a Middle Paleolithic Site in France*. Mountain View, CA: Mayfield Pub. Co.
- Di Giuseppantonio Di Franco, P., F. Galeazzi, and C. Camporesi. 2012. "3D Virtual Dig: A 3D Application for Teaching Fieldwork in Archaeology." *Internet Archaeology* 32.
- Doerr, M., and M. Theodoridou. 2011. CRMdig: A Generic Digital Provenance Model for Scientific Observation. In *Proceedings of TaPP'11: 3rd. USENIX Workshop on the Theory and Practice of Provenance*. <http://www.cidoc-crm.org/docs/CRMdig-TAPP11.pdf>.
- Doneus, M., G. Verhoeven, M. Fera, C. Briese, M. Kucera, and W. Neubauer. 2011. "From Deposit To Point Cloud. A Study Of Low-Cost Computer Vision Approaches For The Straightforward Documentation Of Archaeological Excavation." *XXIII International CIPA Symposium on Geomatics* 6: 81–88.
- Fernández-Hernandez, J., D. González-Aguilera, P. Rodríguez-González, and J. Mancera-Taboada. 2015. "Image-Based Modelling from Unmanned Aerial Vehicle (UAV) Photogrammetry: An Effective, Low-Cost Tool for Archaeological Applications." *Archaeometry* 57: 128–145.
- Fernández-Palacios, B., C. Stefani, J. Lombardo, L. De Luca, and F. Remondino. 2013. "Web Visualization Of Complex Reality-Based 3D Models with NUBES." In *Proceedings of the IEEE Conference Digital Heritage, Marseille, France, 28 Oct–1 Nov*, Vol. 1, edited by A. C. Addison, L. De Luca, G. Guidi and S. Pescarin, 701–704. Piscataway, NJ: Institute of Electrical and Electronics Engineers.
- Forte, M., N. Dell'Unto, J. Issavi, L. Onsurez, and N. Lercari. 2012. "3D Archaeology at Çatalhöyük." *International Journal of Heritage in the Digital Era* 1 (3): 351–378.
- Forte, M., N. Dell'Unto, K. Jonsson, and N. Lercari. 2015. "Interpretation Process at Çatalhöyük using 3D." In *Assembling Çatalhöyük (Themes in Contemporary Archaeology)*, edited by I. Hodder and A. Marciniak, 43–57. New York: Routledge.
- Forte, M., and S. R. L. Campana, eds. 2016. *Digital Methods and Remote Sensing in Archaeology: Archaeology in the Age of Sensing. Quantitative Methods in the Humanities and Social Sciences*. Cham, Switzerland: Springer International Publishing.
- Frassine M., and S. De Francesco. 2015. "Il webGIS RAPTOR e la Tutela del Patrimonio Archeologico di Milano." *Atti del Seminario Milano Archeologia per EXPO 2015. Verso una valorizzazione del patrimonio archeologico di Milano, LANX*, vol. 19. 137–149.
- Frassine M., and G. Naponiello. 2012. "RAPTOR: Archeologia e Tutela. Verso la Pubblica Amministrazione Digitale." *Archeologia e Calcolatori* 23: 81–99.
- Galeazzi, F., M. Callieri, M. Dellepiane, M. Charno, J. Richards, and R. Scopigno. 2016. "Web-based Visualization for 3D Data in Archaeology: The ADS 3D Viewer." *Journal of Archaeological Science: Reports* 9: 1–11.
- Galeazzi, F. 2016. "Towards the Definition of Best 3D Practices in Archaeology: Assessing 3D Documentation Techniques for Intra-Site Data Recording." *Journal of Cultural Heritage* 17: 159–169.

- Hodder, I. 1989. "Writing Archaeology: Site Reports in Context." *Antiquity* 63 (239): 268–274.
- Howey, M., and M. Brouwer Burg, eds. 2017. "Archaeological GIS Today: Persistent Challenges, Pushing Old Boundaries, and Exploring New Horizons." *Journal of Archaeological Science* 84: 1–136.
- Jensen, P. 2018. "Semantically Enhanced 3D: A Web-Based Platform for Spatial Integration of Excavation Documentation at Alken Enge, Denmark." *Journal of Field Archaeology* 43: 1–14.
- Kansa, E., S. Kansa, and B. Arbuckle. 2014. "Publishing and Pushing: Mixing Models for Communicating Research Data in Archaeology." *International Journal of Digital Curation* 9 (1): 57–70.
- Kansa, S., and E. Kansa. 2014. "Data Publishing and Archaeology's Information Ecosystem." *Near Eastern Archaeology. Special Issue: Cyber-Archaeology* 77 (3): 223–227.
- Kehl, C. 2015. "Disseminating Large-Scale Semantic 3D Landscape Models Using Open Visualisation Platforms." *European Journal of Geography* 6 (2): 51–68.
- Koutsoudis, A., B. Vidmar, G. Ioannakis, F. Arnaoutoglou, G. Pavlidis, and C. Chamzas. 2014. "Multi-image 3D Reconstruction Data Evaluation." *Journal of Cultural Heritage* 15: 73–79.
- Kvamme, K. L. 1989. "Geographic Information Systems In Regional Archaeological Research And Data Management." In *Archaeological Method and Theory*, Vol. 1, edited by M. B. Schiffer, 139–204. Tucson: University of Arizona Press.
- Isaksen, L., R. Simon, E. T. E. Barker, and P. de Soto Cañamares. 2014. "Pelagios and the Emerging Graph of Ancient World Data. In *WebSci '14: Proceedings of the 2014 ACM conference on Web science*." 197–201. New York City: ACM.
- Lerma, J. L., S. Navarro, M. Cabrelles, and V. Villaverde. 2010. "Terrestrial Laser Scanning And Close Range Photogrammetry For 3D Archaeological Documentation: The Upper Palaeolithic Cave Of Parpallo As A Case Study." *Journal of Archaeological Science* 37: 499–507.
- Lock, G., and J. Pouncett. 2017. "Spatial Thinking In Archaeology: Is GIS The Answer?" *Journal of Archaeological Science* 84: 129–135.
- Matsushita, R., H. Suita, and Y. Yasumuro. 2014. "Digital Archive System with 3D Web Portal Interface." In *Digital Heritage. Progress in Cultural Heritage: Documentation, Preservation, and Protection, Proceedings of the 5th International Conference, EuroMed 2014, Limassol, Cyprus, November 3–8, 2014, Lectures Notes in Computer Science 8740 (2014)*, edited by M. Ioannides, N. Magnenat-Thalmann, E. Fink, R. Žarnić, A.-Y. Yen and E. Quak, 564–571. Cham, Switzerland: Springer.
- McPherron, S. P., T. Gernat, and J.-J. Hublin. 2009. "Structured Light Scanning For High Resolution Documentation Of In Situ Archaeological Finds." *Journal of Archaeological Science* 36: 19–24.
- Meeks, E., and K. Grossner. 2012. "ORBIS: An Interactive Scholarly Work on the Roman World." *Journal of Digital Humanities* 1 (3).
- Münster, S., M. Pfarr-Harfst, P. Kuroczyński, and M. Ioannides, eds. 2016. *3D Research Challenges in Cultural Heritage II: How to Manage Data and Knowledge Related to Interpretative Digital 3D Reconstructions of Cultural Heritage*. Lecture Notes in Computer Science, vol 10025. Cham, Switzerland: Springer.
- Opitz, R. S., and T. D. Johnson. 2016. "Interpretation at the Controller's Edge: Designing Graphical User Interfaces for the Digital Publication of the Excavations at Gabii (Italy)." *Open Archaeology* 1 (1): 274–290.
- Opitz, R., M. Mogetta, and N. Terrenato, eds. 2016. *A Mid-Republican House from Gabii*. Ann Arbor: University of Michigan Press.
- Ponchio, F., and M. Dellepiane. 2015. "Fast Decompression For Web-Based View-Dependent 3D Rendering." In *Web3D 2015: Proceedings of the 20th International Conference on 3D Web Technology*, 199–207. New York: ACM.
- Remondino, F., and S. Campana, eds. 2014. *3D Recording and Modelling in Archaeology and Cultural Heritage*. BAR International Series 2598. Oxford: Archaeopress.
- Rice, P. C. 1985. "Using a Simulated Site to Teach Data Analysis in Archaeology." *Anthropology & Education Quarterly* 16 (4): 301–305.
- Richards, J. D. 1998. "Recent Trends in Computer Applications in Archaeology." *Journal of Archaeological Research* 6 (4): 331–382.
- Richards, J. D., and C. S. Hardman. 2008. "Stepping Back From The Trench Edge: An Archaeological Perspective On The Development Of Standards For Recording And Publication." In *The Virtual Representation of the Past*, edited by M. Greengrass and L. Hughes, 101–112. Farnham: Ashgate Publishing Company.
- Richards, J. D., J. Winters, and M. Charno. 2011. "Making the LEAP: Linking Electronic Archives and Publications." In *On the Road to Reconstructing the Past: Proceedings of the 36th International Conference on Computer Applications and Quantitative Methods in Archaeology (CAA)*, Budapest, Hungary, 2008, edited by E. Jerem, F. Redo, and V. Szevényi, 470–475. Budapest: Archaeolingua Foundation.
- Richards-Rissetto, H. 2017. "What Can GIS + 3D mean for Landscape Archaeology?" *Journal of Archaeological Science* 84: 10–21.
- Richards-Rissetto, H., and J. von Schwerin. 2017. "A Catch 22 of 3D Data Sustainability: Lessons in 3D Archaeological Data Management & Accessibility." *Journal of Digital Applications in Archaeology and Cultural Heritage* 6: 38–48.
- Ryan, N., J. Pascoe, and D. Morse. 1999. "Enhanced Reality Fieldwork: the Context Aware Archaeological Assistant." In *Archaeology in the Age of the Internet, Computer Applications and Quantitative Methods in Archaeology. Proceedings of the 25th Anniversary Conference, University of Birmingham, April 1997 (BAR International Series 750)*, edited by L. Dingwall, S. Exon, V. Gaffney, S. Laflin and M. van Leusen, 269–274. Oxford: Archaeopress.
- Sarris, A., V. Trigkas, G. Papadakis, M. Papazoglou, E. Peraki, N. Chetzoyiannaki, M. Elvanidou, E. Karimali, K. Kouriat, M. Katifori, G. Kakoulaki, E. Kappa, K. Athanasaki, and N. Papadopoulos. 2008. "A Web-GIS Approach to Cultural Resources Management in Crete: The Digital Archaeological Atlas of Crete." In *Layers of Perception. Proceedings of the 35th International Conference on Computer Applications and Quantitative Methods in Archaeology (CAA)*, edited by A. Posluschny, A. K. Lambers and I. Herzog. Bonn: Dr. Rudolf Habelt GmbH. https://proceedings.caaconference.org/paper/74_sarris_et_al_caa2007/
- Smith, N., M. Howland, and T. Levy. 2015. "Digital Archaeology Field Recording In The 4th Dimension: Archfield C++ A 4D GIS For Digital Field Work." In *Proceedings 2015 Digital Heritage*, Granada Vol. 1, edited by F. Remondino, P. Brunet, J. Barceló, L. Duranti and S. Hazan, 251–258. Piscataway, NJ: Institute of Electrical and Electronics Engineers.
- Stead, S., and M. Doerr. 2015. CRMInf: the Argumentation Model. An Extension of CIDOC-CRM to Support Argumentation. <http://www.ics.forth.gr/isl/CRMext/CRMInf/docs/CRMInf-0.7.pdf>.
- Sullivan, E., and L. Snyder. 2017. "Digital Karnak: An Experiment in Publication and Peer Review of Interactive, Three-Dimensional Content." *Journal of the Society of Architectural Historians* 76 (4): 464–482.
- Tracy, D. 2016. "Assessing Digital Humanities Tools: Use of Scalar at a Research University." *Libraries and the Academy* 16: 163–189.
- Vandenbulcke, A., S. Van Ackere, M. Decock, C. Stal, and A. De Wulf. 2016. "Preservation of the Archaeological Heritage of the North Sea Using webGIS." In *International Multidisciplinary Scientific GeoConference-SGEM*, 375–382. Sofia, Bulgaria: Stef92 Technology.
- Vecchio, P., F. Mele, L. T. De Paolis, I. Epicoc, M. Mancini, and G. Aloisio. 2015. "Cloud Computing and Augmented Reality for Cultural Heritage." In *LNCS*, edited by L. T. De Paolis and A. Mongelli, 51–60. Cham: Springer.
- Vico, L., A. Moro, F. Galeazzi, M. Di Ioia, and N. Dell'Unto. 2006. "Integrated Methodologies for Data Elaboration and Real Time: Villa of Livia (Via Flaminia Project)." In *The e-Volution of Information Communication Technology in Cultural Heritage. Where Hi-Tech Touches the Past: Risks and Challenges for the 21st Century*, CIPA/VAST/EG/EuroMed 2006, Nicosia, Cyprus, 30 October – 4 November 2006, edited by M. Ioannides, D. Arnold, F. Nicolucci, and K. Mania, 219–224. Budapest: Archeolingua.
- von Schwerin, J., H. Richards-Rissetto, F. Remondino, and G. Aguiario. 2013. "The MayaArch3D Project: A 3D WebGIS for Analyzing Ancient Maya Architecture and Landscapes at Copan, Honduras." *Literary and Linguistic Computing* 28 (4): 736–753.
- von Schwerin J., M. Lyons, L. Loos, N. Billen, M. Auer, and A. Zipf. 2016. "Show Me the Data!: Structuring Archaeological Data to Deliver Interactive, Transparent 3D Reconstructions in a 3D WebGIS." In *3D Research Challenges in Cultural Heritage*, edited by S. Münster, M. Pfarr-Harfst, P. Kuroczyński, M. Ioannides. Lecture Notes in Computer Science, vol 10025. Cham, Switzerland: Springer.
- von Schwerin, J., H. Richards-Rissetto, F. Remondino, M. Grazia Spera, M. Auer, N. Billen, L. Loos, L. Stelson, M. Reindel. 2016. *Airborne LiDAR Acquisition, Post-Processing and Accuracy-Checking for a*

- 3D WebGIS of Copan, Honduras. *Journal of Archaeological Science: Reports*. Volume 5. February 2016, 85–104. <http://doi.org/10.1016/j.jasrep.2015.11.005>
- Verhoeven, G. 2016. “Mesh is More—Using All Geometric Dimensions For The Archaeological Analysis And Interpretative Mapping Of 3D Surfaces.” *Journal of Archaeological Method and Theory* 24 (4): 999–1033.
- Vincent, M., F. Kuester, and T. Levy. 2013. “OpenDig: In-field Data Recording For Archaeology And Cultural Heritage.” In *Proceedings of the IEEE Conference Digital Heritage, Marseille, France, 28 Oct–1 Nov*, Vol. 1, edited by A. C. Addison, L. De Luca, G. Guidi and S. Pescarin, 539–542. Piscataway, NJ: Institute of Electrical and Electronics Engineers.
- Vincent, M., F. Kuester, and T. Levy. 2014. “OPENDIG: Digital Field Archaeology, Curation, Publication, and Dissemination.” *Near Eastern Archaeology* 77 (3): 204–208.
- Wells, J., E. C. Kansa, S. W. Kansa, S. J. Yerka, D. G. Anderson, T. G. Bissett, K. Noack Myers, and R. Carl DeMuth. 2014. “Web-based Discovery And Integration Of Archaeological Historic Properties Inventory Data: The Digital Index of North American Archaeology (DINAA).” *Literary and Linguistic Computing* 29 (3): 349–360.
- Whallon, R. 1972. “The Computer in Archaeology: A Critical Survey.” *Computers in the Humanities* 7: 29–45.
- Williams, N. 1997. The Virtual Field Course. <http://www.geog.le.ac.uk/vfc/>
- Xia, F., L. Yang, L. Wang, and A. Vinel. 2012. “Internet of Things.” *International Journal of Communication Systems* 25: 1101–1102.