MOBILIZING *the* PAST *for a* DIGITAL FUTURE

The Potential of Digital Archaeology

Edited by
Erin Walcek Averett
Jody Michael Gordon
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Preface & Acknowledgments

This volume stems from the workshop, "Mobilizing the Past for a Digital Future: the Future of Digital Archaeology," funded by a National Endowment for the Humanities Digital Humanities Start-Up grant (#HD-51851-14), which took place 27-28 February 2015 at Wentworth Institute of Technology in Boston (http://uwm.edu/mobilizing-the-past/). The workshop, organized by this volume's editors, was largely spurred by our own attempts with developing a digital archaeological workflow using mobile tablet computers on the Athienou Archaeological Project (http://aap.toumazou.org; Gordon *et al.*, Ch. 1.4) and our concern for what the future of a mobile and digital archaeology might be. Our initial experiments were exciting, challenging, and rewarding; yet, we were also frustrated by the lack of intra-disciplinary discourse between projects utilizing digital approaches to facilitate archaeological data recording and processing.

Based on our experiences, we decided to initiate a dialogue that could inform our own work and be of use to other projects struggling with similar challenges. Hence, the "Mobilizing the Past" workshop concept was born and a range of digital archaeologists, working in private and academic settings in both Old World and New World archaeology, were invited to participate. In addition, a livestream of the workshop allowed the active participation on Twitter from over 21 countires, including 31 US states (@MobileArc15, #MobileArc).[1]

[1] For commentary produced by the social media followers for this event, see: https://twitter.com/electricarchaeo/status/571866193667047424, http://shawngraham.github.io/exercise/mobilearcday1wordcloud.html, https://twitter.com/electricarchaeo/status/571867092091338752, http://www.diachronicdesign.com/blog/2015/02/28/15-mobilizing-the-past-for-the-digital-future-conference-day-1-roundup/.

Although the workshop was initially aimed at processes of archaeological data recording in the field, it soon became clear that these practices were entangled with larger digital archaeological systems and even socio-economic and ethical concerns. Thus, the final workshop's discursive purview expanded beyond the use of mobile devices in the field to embrace a range of issues currently affecting digital archaeology, which we define as the use of computerized, and especially internet-compatible and portable, tools and systems aimed at facilitating the documentation and interpretation of material culture as well as its publication and dissemination. In total, the workshop included 21 presentations organized into five sessions (see program, http://mobilizingthepast.mukurtu.net/digital-heritage/mobilizing-past-conference-program), including a keynote lecture by John Wallrodt on the state of the field, "Why paperless?: Digital Technology and Archaeology," and a plenary lecture by Bernard Frischer, "The Ara Pacis and Montecitorio Obelisk of Augustus: A Simpirical Investigation," which explored how digital data can be transformed into virtual archaeological landscapes.

The session themes were specifically devised to explore how archaeological data was digitally collected, processed, and analyzed as it moved from the trench to the lab to the digital repository. The first session, "App/Database Development and Use for Mobile Computing in Archaeology," included papers primarily focused on software for field recording and spatial visualization. The second session, "Mobile Computing in the Field," assembled a range of presenters whose projects had actively utilized mobile computing devices (such as Apple iPads) for archaeological data recording and was concerned with shedding light on their utility within a range of fieldwork situations. The third session, "Systems for Archaeological Data Management," offered presentations on several types of archaeological workflows that marshal born-digital data from the field to publication, including fully bespoken paperless systems, do-it-yourself ("DIY") paperless systems, and hybrid digital-paper systems. The fourth and final session, "Pedagogy, Data Curation, and Reflection," mainly dealt with teaching digital methodologies and the use of digital repositories and linked open data to enhance field research. This session's final paper, William Caraher's "Toward a Slow Archaeology," however, noted digital archaeology's successes in terms of time and money saved and the collection of more data, but also called for a more measured consideration of the significant changes that these technologies are having on how archaeologists engage with and interpret archaeological materials.

The workshop's overarching goal was to bring together leading practitioners of digital archaeology in order to discuss the use, creation, and implementation of mobile and digital, or so-called "paperless," archaeological data recording systems. Originally, we hoped to come up with a range of best practices for mobile computing in the field – a manual of sorts – that could be used by newer projects interested in experimenting with digital methods, or even by established projects hoping to revise their digital workflows in order to increase their efficiency or, alternatively, reflect on their utility and ethical implications. Yet, what the workshop ultimately proved is that there are many ways to "do" digital archaeology, and that archaeology as a discipline is engaged in a process of discovering what digital archaeology should (and, perhaps, should not) be as we progress towards a future where all archaeologists, whether they like it or not, must engage with what Steven Ellis has called the "digital filter."

So, (un)fortunately, this volume is not a "how-to" manual. In the end, there seems to be no uniform way to "mobilize the past." Instead, this volume reprises the workshop's presentations—now revised and enriched based on the meeting's debates as well as the editorial and peer review processes—in order to provide archaeologists with an extremely rich, diverse, and reflexive overview of the process of defining what digital archaeology is and what it can and should perhaps be. It also provides two erudite response papers that together form a didactic manifesto aimed at outlining a possible future for digital archaeology that is critical, diverse, data-rich, efficient, open, and most importantly, ethical. If this volume, which we offer both expeditiously and freely, helps make this ethos a reality, we foresee a bright future for mobilizing the past.

* * *

No multifaceted academic endeavor like *Mobilizing the Past* can be realized without the support of a range of institutions and individuals who believe in the organizers' plans and goals. Thus, we would like to thank the following institutions and individuals for their logistical, financial, and academic support in making both the workshop and this volume a reality. First and foremost, we extend our gratitude toward The National Endowment for the Humanities (NEH) for providing us with a Digital Humanities Start-Up Grant (#HD-51851-14), and especially to Jennifer Serventi and Perry Collins for their invaluable assistance through the application process and beyond. Without the financial support from this grant the workshop and this publication would not have been possible. We would also like to thank Susan Alcock (Special Counsel for Institutional Outreach and Engagement, University of Michigan) for supporting our grant application and workshop.

The workshop was graciously hosted by Wentworth Institute of Technology (Boston, MA). For help with hosting we would like to thank in particular Zorica Pantić (President), Russell Pinizzotto (Provost), Charlene Roy (Director of Business Services), Patrick Hafford (Dean, College of Arts and Sciences), Ronald Bernier (Chair, Humanities and Social Sciences), Charles Wiseman (Chair, Computer Science and Networking), Tristan Cary (Manager of User Services, Media Services), and Claudio Santiago (Utility Coordinator, Physical Plant).

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The workshop itself benefitted from the help of Kathryn Grossman (Massachusetts Institute of Technology) and Tate Paulette (Brown University) for on-site registration and much more. Special thanks goes to Daniel Coslett (University of Washington) for graphic design work for both the workshop materials and this volume. We would also like to thank Scott Moore (Indiana University of Pennsylvania) for managing our workshop social media presence and his support throughout this project from workshop to publication.

This publication was a pleasure to edit, thanks in no small part to Bill Caraher (Director and Publisher, The Digital Press at the University of North Dakota), who provided us with an outstanding collaborative publishing experience. We would also like to thank Jennifer Sacher (Managing Editor, INSTAP Academic Press) for her conscientious copyediting and Brandon Olson for his careful reading of the final proofs. Moreover, we sincerely appreciate the efforts of this volume's anonymous reviewers, who provided detailed, thought-provoking, and timely feedback on the papers; their insights greatly improved this publication. We are also grateful to Michael Ashley and his team at the Center for Digital Archaeology for their help setting up the accompanying Mobilizing the Past Mukurtu site and Kristin M. Woodward of the University of Wisconsin-Milwaukee Libraries for assistance with publishing and archiving this project through UWM Digital Commons. In addition, we are grateful to the volume's two respondents, Morag Kersel (DePaul University) and Adam Rabinowitz (University of Texas at Austin), who generated erudite responses to the chapters in the volume. Last but not least, we owe our gratitude to all of the presenters who attended the workshop in Boston, our audience from the Boston area, and our colleagues on Twitter (and most notably, Shawn Graham of Carlton University for his word clouds) who keenly "tuned in" via the workshop's livestream. Finally, we extend our warmest thanks to the contributors of this volume for their excellent and timely chapters. This volume, of course, would not have been possible without such excellent papers.

As this list of collaborators demonstrates, the discipline of archaeology and its digital future remains a vital area of interest for people who value the past's ability to inform the present, and who recognize our ethical responsibility to consider technology's role in contemporary society. For our part, we hope that the experiences and issues presented in this volume help to shape new intra-disciplinary and critical ways of mobilizing the past so that human knowledge can continue to develop ethically at the intersection of archaeology and technology.

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October 1, 2016

How To Use This Book

The Digital Press at the University of North Dakota is a collaborative press and *Mobilizing the Past for a Digital Future* is an open, collaborative project. The synergistic nature of this project manifests itself in the two links that appear in a box at the end of every chapter.

The first link directs the reader to a site dedicated to the book, which is powered and hosted by the Center for Digital Archaeology's (CoDA) Mukurtu.net. The Murkutu application was designed to help indigenous communities share and manage their cultural heritage, but we have adapted it to share the digital heritage produced at the "Mobilizing the Past" workshop and during the course of making this book. Michael Ashley, the Director of Technology at CoDA, participated in the "Mobilizing the Past" workshop and facilitated our collaboration. The Mukurtu.net site (https://mobilizingthepast.mukurtu.net) has space dedicated to every chapter that includes a PDF of the chapter, a video of the paper presented at the workshop, and any supplemental material supplied by the authors. The QR code in the box directs readers to the same space and is designed to streamline the digital integration of the paper book.

The second link in the box provides open access to the individual chapter archived within University of Wisconsin-Milwaukee's installation of Digital Commons, where the entire volume can also be downloaded. Kristin M. Woodward (UWM Libraries) facilitated the creation of these pages and ensured that the book and individual chapters included proper metadata.

Our hope is that these collaborations, in addition to the open license under which this book is published, expose the book to a wider audience and provide a platform that ensures the continued availability of the digital complements and supplements to the text. Partnerships with CoDA and the University of Wisconsin-Milwaukee reflect the collaborative spirit of The Digital Press, this project, and digital archaeology in general.

Abbreviations

AAI	Alexandria Archive Institute
AAP	Athienou Archaeological Project
ABS	acrylonitrile butadiene styrene (plastic)
ADS	Archaeological Data Service
Alt-Acs	Alternative Academics
API	application programming interface
ARA	archaeological resource assessment
ARC	Australian Research Council
ARIS	adaptive resolution imaging sonar
ASV	autonomous surface vehicle
BLM	Bureau of Land Management
BLOB	Binary Large Object
BOR	Bureau of Reclamation
BYOD	bring your own device
CAD	computer-aided design
CDL	California Digital Library
CHDK	Canon Hack Development Kit
cm	centimeter/s
CMOS	complementary metal-oxide semiconductor
CoDA	Center for Digital Archaeology
COLLADA	COLLAborative Design Activity
CRM	cultural resource management
CSS	Cascading Style Sheet
CSV	comma separated values
DBMS	desktop database management system
DEM	digital elevation model
DINAA	Digital Index of North American Archaeology
DIY	do-it-yourself
DoD	Department of Defense
DVL	doppler velocity log
EAV	entity-attribute-value
EDM	electronic distance measurement
EU	excavation unit/s
FAIMS	Federated Archaeological Information Management System
fMRI	functional magnetic resonance imaging
GIS	geographical information system
GCP	ground control point
GNSS	global navigation satellite system
GPR	ground-penetrating radar

GUI	graphic user interface
ha	hectare/s
hr	hour/s
Hz	Hertz
HDSM	high-density survey and measurement
ICE	Image Composite Editor (Microsoft)
iOS	iPhone operating system
INS	inertial motion sensor
IPinCH	Intellectual Property in Cultural Heritage
IT	information technology
KAP	Kaymakçı Archaeological Project
KARS	Keos Archaeological Regional Survey
km	kilometer/s
LABUST	Laboratory for Underwater Systems and Technologies (University of Zagreb)
LAN	local area network
LIEF	Linkage Infrastructure Equipment and Facilities
LOD	linked open data
LTE	Long-Term Evolution
m	meter/s
masl	meters above sea level
MEMSAP	Malawi Earlier-Middle Stone Age Project
MOA	memoranda of agreement
MOOC	Massive Online Open Course
NGWSP	Navajo-Gallup Water Supply Project
NeCTAR	National eResearch Collaboration Tools and Resources
NEH	National Endowment for the Humanities
NHPA	National Historic Preservation Act
NPS	National Park Service
NRHP	National Register of Historic Places
NSF	National Science Foundation
OCR	optical character reader
OS	operating system
PA	programmatic agreement
PAP	pole aerial photography
PARP:PS	Pompeii Archaeological Research Project: Porta Stabia
PATA	Proyecto Arqueológico Tuti Antiguo
PBMP	Pompeii Bibliography and Mapping Project
PDA	personal digital assistant

PIARA	Proyecto de Investigación Arqueológico Regional Ancash
PKAP	Pyla-Koutsopetra Archaeological Project
Pladypos	PLAtform for DYnamic POSitioning
PLoS	Public Library of Science
PQP	Pompeii Quadriporticus Project
PZAC	Proyecto Arqueológico Zaña Colonial
QA	quality assurance
QC	quality control
QR	quick response
REVEAL	Reconstruction and Exploratory Visualization: Engineering meets ArchaeoLogy
ROS	robot operating system
ROV	remotely operated vehicle
RRN	Reciprocal Research Network
RSS	Rich Site Summary
RTK	real-time kinetic global navigation satellite system
SfM	structure from motion
SHPO	State Historic Preservation Office
SKAP	Say Kah Archaeological Project
SLAM	simultaneous localization and mapping
SMU	square meter unit/s
SU	stratigraphic unit/s
SVP	Sangro Valley Project
TCP	traditional cultural properties
tDAR	the Digital Archaeological Record
UAV	unmanned aerial vehicle
UNASAM	National University of Ancash, Santiago Antúnez de Mayolo
UQ	University of Queensland
USACE	U.S. Army Corp of Engineers
USBL	ultra-short baseline
USFS	U.S. Forest Service
USV	unmanned surface vehicle
UTM	universal transverse mercator
XML	Extensible Markup Language

2.2.
The Things We Can Do with Pictures: Image-Based Modeling and Archaeology

Brandon R. Olson

It has been five years—a near eternity in technology years—since Agisoft publically launched PhotoScan, the first cost efficient and intuitive image-based modeling software, and two years have passed since the first wave of peer-reviewed studies implementing and testing the applicability of such software for archaeological purposes (i.e., Verhoeven 2011; Verhoeven *et al.* 2012a, 2012b; de Reu *et al.* 2013; Olson *et al.* 2013). The combination of these and many other publications, along with numerous colloquia, conference panels, and workshops, solidify the place of image-based modeling as an integral tool for digital archaeology. The intention here is to present a critical analysis of the technology by drawing on a set of field applications that highlight how this technology continues to transform the discipline through a diverse set of methodological and interpretive frameworks.

Image-Based Modeling: A Short Introduction

Three-dimensional modeling is not a new addition to the archaeological toolkit, as laser scanners and other 3D modeling techniques, though expensive and requiring highly trained personnel, have been available for years (Barceló *et al.* 2003; Pollefeys *et al.* 2003). The creation of digital 3D models from photographs using photogrammetric methods and various algorithms such as structure-from-motion, however, is a newer innovation. The technology, referred to here and elsewhere as image-based modeling (Olson and Caraher 2015; Roosevelt *et al.* 2015), is available through a handful of commercial (Olson *et al.* 2013: 248) and open-source software options (Green *et al.* 2014), but Agisoft

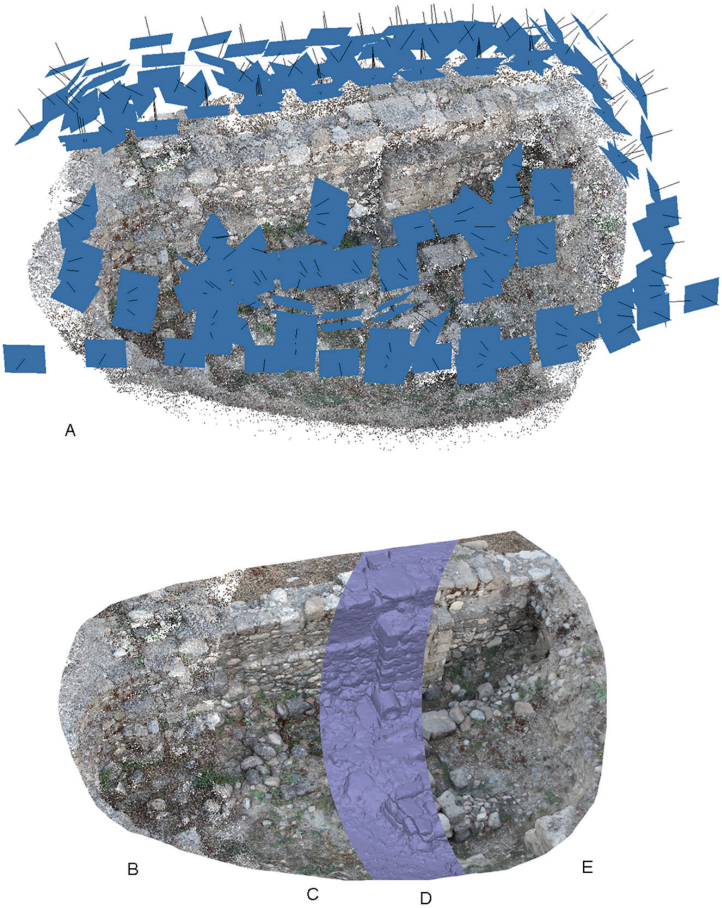

Figure 1: Image of a secondary apse from a Late Roman basilica at Polis-Chrysochous, Cyprus, depicting the five stages of creating a 3D model using an image-based modeling technique: A) Capturing strategy with automatic photo alignment; B) Aligning photographs and generating a sparse point cloud; C) Generation of a dense point cloud; D) Building a monochromatic 3D model; and E) Texturing the 3D model.

PhotoScan (www.agisoft.com) has solidified itself as the software of choice due to its ease of operation and quality outputs. The 3D model creation process is pretty straightforward, and it can be used to model 3D environments from archaeological objects to trenches and architecture (FIG. 1) to entire sites (Olson *et al.* 2014a; Roosevelt 2014; see also Wernke *et al.*, Ch. 2.3). After capturing a set of digital photographs that provides total coverage of the target, these photographs are automatically located within a locally or geolocated rectified environment (FIG. 1A). The location of the images serves to reconstruct complex spatial information from 2D data, common points are tracked across images, and their relative positions are mathematically determined. Following the creation of the sparse point cloud (FIG. 1B), the program returns to the photographic dataset to generate a dense point cloud (FIG. 1C). The dense point cloud is in fact just that, dense. Note the visual similarities in points C (the dense point cloud) and E (the 3D model with photorealistic texture) on Figure 1. The sparse and dense point clouds are essentially the skeleton of the final model, representing known points in the structure of the scene around which the computer can calculate the geometry of a monochromatic 3D model (FIG. 1D). Finally, remembering the relationship between the points in the photographs and the spatial information in the geometric model, a photorealistic texture is conformed to the 3D geometry (FIG. 1E).

From the processed 3D model, several outputs are possible, the most useful for archaeological purposes are 3D PDF, GeoTIFF, and Wavefront OBJ. The accuracy of the outputs depends on numerous factors (e.g., resolution of the photographs, software settings, spatial extent), but studies have shown spatial accuracy levels of 1–3 cm for areas up to 700 m^2 and sub-centimeter for areas less than 25 m^2 in area (de Reu *et al.* 2013: 1111; Olson *et al.* 2013: 257; Prins *et al.* 2014: 193; Quartermaine *et al.* 2014: 116, 124; Roosevelt *et al.* 2015: 340). Processing times vary from less than an hour to days depending on scene size, the number of images captured, software settings, and the performance of the computer processing the model.

Archaeology, as the study of the past via material culture, is a discipline centered on objects (Hodder 2012; Olsen 2012). The ability to photorealistically generate a 3D model of an object has opened up new avenues of artifactual analysis. Several scholars have commented on the visual merits of high-fidelity photorealistic 3D models, which have recently been followed up by studies offering critical assessments of their interpretive value (Roussou *et al.* 2015; Caraher, Ch. 4.1). For example, Olson and colleagues used image-based modeling software to create 3D models of prehistoric handaxes (Olson *et al.* 2014b). These models were then converted into a printer friendly format (PLY) and three-dimensionally printed (see also McKnight *et al.* 2015). Using both qualitative and quantitative methods, the authors demonstrated that a handaxe printed in both ABS (acrylonitrile butadiene styrene) plastic and resin retained the features a lithics specialist would need to read and study the object (Olson *et al.* 2014b: 171). The authors proved that 3D models, printed from digital models produced with an image-based approach, as opposed to laser scanning, can in theory stand in for the original.

Rabinowitz, however, cogently points out that digital renderings, and by extension their printed outputs, are not true "surrogates" of the original because their creation, unlike line drawings and sketches, lacks an interpretive framework (Rabinowitz 2015: 34). Manual illustration and recording strategies force a level of archaeological engagement and interpretation (e.g., stratigraphic relationships, architectural associations), while digital recording does not necessarily require such a level of preliminary interpretation (Rabinowitz 2015; Caraher, Ch. 4.1). On the other hand, the handaxe modeling experiment also indicates that whether the interpretive process occurs before, during, or after the crafting of a 3D model of an object, the resulting digital and tangible 3D models clearly have intrinsic scholarly value.

Bevan and colleagues adopted an image-based approach to model various features of the terracotta warriors found at Qin Shihuangdi's mausoleum in China (Bevan *et al.* 2014). The 3rd-century B.C. site contains life-sized replicas of an estimated 8,000 soldiers, 520 chariot horses, and 150 cavalry horses, all of which were constructed from terracotta using sets of standardized molds (Portal 2007). Artists would also add clay to the face and ears to add a level of individuality to each warrior. Bevan and colleagues modeled certain features to undertake a 3D morphometric analysis of the warriors, focusing primarily on ears, but also hands and faces. In adopting a comparative taxonomic approach, the authors are able to identify a series of micro-styles achieved through subtle variations in construction techniques (Bevan *et al.* 2014: 251–254). Beyond mere visual inspection, the authors devised a method for examining a distance matrix expressing dissimilarity of certain ear features to others within the assemblage by using the model's dense point cloud. The method is based on the real-world assumption that ear morphology exhibits variation among humans to such a degree that it can be used as a forensic identifier akin to dentition and finger prints (Pflug and Busch 2012; Abaza *et al.* 2013). Bevan and colleagues conclude that although there are a series of core shapes, there is also abundant subtle variation and no two ears are exactly the same (Bevan *et al.* 2014: 254). Their work shows that significant resources were spent by Qin Shihuangdi and his court to individualize the terracotta army in an attempt to mimic a real military force. This study, as well as others like it (Clarkson *et al.* 2014; Shipton and Clarkson 2015 on Hawaiian adzes; Grosman *et al.* 2014; Spring and Peters 2014 on ancient lithics), demonstrate the potential of image-based modeling and 3D modeling in general for morphological and taxonomic analyses of objects.

Landscape/Field Recording and Volumetrics

Arguably, image-based modeling has had the largest impact in the field, with numerous projects adopting the technology in various iterations at the sub-site level (Miller *et al.* 2014), site level (Quartermaine *et al.* 2013, 2014; Forte 2014a; Roosevelt *et al.* 2015; Toumazou *et al.* 2015), in underwater contexts (Demesticha *et al.* 2014; Jaklic *et al.* 2015; Buxton *et al.*, Ch. 2.4), and across landscapes (Opitz and Cowley 2013; Roosevelt 2014; Smith *et al.* 2014; Opitz and Limp 2015; Wernke *et al.*, Ch. 2.3). Of these studies, three merit special consideration here as they, in this author's humble opinion, will serve as benchmarks for future digital recording strategies.

The 3D Digging Project, which began at Çatalhöyük (Turkey) and was spearheaded by Maurizio Forte in 2009, endeavors to record in 3D complete stratigraphic profiles from a selection of excavation units in an attempt to reconstruct digitally the deposits as well as interact with them in a virtual environment (Forte 2014a: 4). Under the larger umbrellas of cyberarchaeology and teleimersive archaeology (Gordon *et al.*, Introduction; Forte 2010, 2014b; see also Levy *et al.* 2012), Forte uses the orthorectified georeferenced TIFF image (henceforth, an orthophoto—a photorealistic image with spatial distortion corrected that is embedded with a real-world coordinate system) to digitize and annotate features. For Forte, the scholarly value of image-based modeling is in its ability to generate accurate and photorealistic reproductions that aid in spatial recording and for its use with other technologies, such as laser scanning and infrared photography, within virtual reality for education, public outreach, and as a means to interact with archaeology in a new way (Forte 2014a: 26–28).

Underwater archaeology presents certain obstacles that terrestrial archaeology simply does not have to overcome (see Buxton *et al.*, Ch. 2.4). Issues such as short underwater study windows, limited visibility, the mobility of the ocean/river/lake bed, and the significant financial investment necessitate a dynamic recording system. In investigating the Mazotos Shipwreck site in Cyprus, Demesticha, Skarlatos, and Neophytou offer an image-based modeling approach that harnesses the dense point cloud and orthophoto, as opposed to the photorealistic model, as the primary basis of their recording framework (Demesticha *et al.* 2014). The authors utilize the orthophoto as the main method for basic recording, labeling, and digitizing features. Yet their innovative use of the dense point cloud as a collection of reference points to model and thereby record the remains comprising the site in three dimensions is a pioneering use of image-based modeling (Demesticha *et al.* 2014: 146–147; see also Grøn *et al.* 2015). The dense point cloud provides the outlines of individual ceramic forms, and the authors' familiarity with Hellenistic and Roman transport shapes are combined to create an accurate, true-to-scale 3D reconstruction of the underwater site. This method also allows them to approximate a ship's overall volume and inventory, and to trace the taphonomic processes following the initial wreck, simply on the basis of a systematic photography session with good ground visibility.

Any image-based modeling practitioner who has deployed this technology in the field is aware of certain limitations, especially from a mobility standpoint. The current author experienced two recurring problems at a number of Eastern Mediterranean sites. First, depending on the number of photographs taken, image-based modeling software tests the limits of even better-equipped computers and laptops. This will likely be a nonissue in the near future, but at present it is difficult to process a 3D model in the field owing to both environmental (e.g., heat, dust, and precipitation) and practical (e.g., interruption of workflow, on-site distractions, access to electricity) considerations. Second, the transfer of data from the individual processing the images to the field team and the manipulation of the 3D model and its 2D derivatives on-site can be problematic on account of large files sizes and issues related to versioning and storage location. Roosevelt and colleagues, however, have made great progress in solving these issues with the Kaymakçı Archaeological Project in Turkey (Roosevelt *et al.* 2015). Their "born digital" (Roosevelt *et al.* 2015: 326; for the term, see also Austin 2014) recording system is multi-faceted and uses the following outputs for its image-based models: orthophotos (as a reference for digitization, measuring, and the like), georeferenced digital elevation models (for spot elevation checks and vertical control), and dense point clouds (to calculate volume; for volumetrics, see Miller *et al.* 2014; Jaklic *et al.* 2015; see also Castro López *et al.*, Ch. 3.1). To alleviate the issues raised above, the authors devised a wireless communication system to exchange photographic datasets and processed models between team members on-site and those at an off-site computer lab. The wireless network was also connected to a relational database stored on a server, which permitted secure data storage and a means to reliably access previously saved data anywhere with an Internet connection. From an image-based modeling standpoint, the project's infrastructure helped alleviate issues related to the mobility of the software, while the use of the software served as an integral component to their 3D and, more importantly, volumetric approach to recording.

Both the Kaymakçı Archaeological Project and the excavations at Cástulo (Spain) are using dense point clouds to create watertight volumetric renderings of stratigraphic units (Roosevelt *et al.* 2015: 337–339; Castro López *et al.*, Ch. 3.1). Having processed dense point clouds with PhotoScan, the projects use separate 3D modeling programs (CloudCompare for Kaymakçı and Blender for Cástulo) to develop a closed volumetric entity representing the 3D area of the unit modeled. Both projects acknowledged the potential of volumetric recording for ongoing excavation. On-site manual drafting is mostly replaced with image-based modeling, whereby the software is tasked to record the tops and bottoms of all units. The records are then combined and modeled using PhotoScan and either CloudCompare or Blender to generate volumetric records. This process is revolutionary for on-site recording as it provides a truly accurate digital 3D record of excavations and can take the human element out of stratigraphic recording, which, as noted above, has both positive and negative implications.

Conclusions and Musings on Future Directions

As the number of presentations at the "Mobilizing the Past for a Digital Future: The Potential of Digital Archaeology" workshop made abundantly clear, image-based modeling in archaeology has evolved from a simple means of visual display to a legitimate analytical tool by means of its combination with other technologies, recording strategies, and interpretive frameworks at site and object scales. Its deployment in the field has led to faster and more accurate data recording with comparatively small financial investment. Yet, the technology's scholarly value as more than a tool for simple visualization is contingent upon its interaction with, and ultimately assimilation into, existing modes of artifactual analysis (e.g., seriation, taxonomy, taphonomy) and systems of recording. Its adoption as a component to larger digital recording systems is underway, and one would expect to see development in the future along the lines of Forte (2014a), Roosevelt and colleagues (Roosevelt *et al.* 2015), Opitz and Limp with high-density survey and measurement (HDSM; Opitz and Limp 2015), Castro and colleagues (Castro López *et al.*, Ch. 3.1), and the most recent iterations of Reconstruction and Exploratory Visualization: Engineering meets ArchaeoLogy (REVEAL; for an introduction, see Fabbri and Kimia 2010; Galor *et al.* 2010; Gay *et al.* 2010; Kimia 2010). Granted, these reports vary intellectually and practically, but they have a shared view in that image-based modeling can and should be utilized in the same way as a total station, differential GPS unit, geographical information system (GIS) software, or digital camera. Given its many benefits image-based archaeological recording is here to stay, and in the immediate future, the question of how to integrate it into existing or redeveloped methods and practices will likely be a subject of scholarly discussion and debate. Ideally, such pluralist discourse will inform best practices.

On the technological side, faster processors, larger memory capacity, and more robust graphics cards will speed up processing times in the future. Since its initial public offering in December 2010 with version 0.7.0, Agisoft has released 45 updates to PhotoScan. Some updates are simple bug fixes, while others are significant revamps that introduce new tools. With an average of a new version every five weeks, companies like Agisoft make a concerted effort to keep the technology current, which will likely continue given the demand. It is also possible that the process itself, which consists of five steps (not including exporting outputs), will be streamlined either within the software or with the development of hardware capable of processing models immediately after photo capture. Needless to say, the pace of change in technology is rapid, and there is nothing to suggest that image-based modeling has reached its floruit in technological or archaeological terms.

https://mobilizingthepast.mukurtu.net/collection/22-things-we-can-do-pictures-image-based-modeling-and-archaeology

http://dc.uwm.edu/arthist_mobilizingthepast/11

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