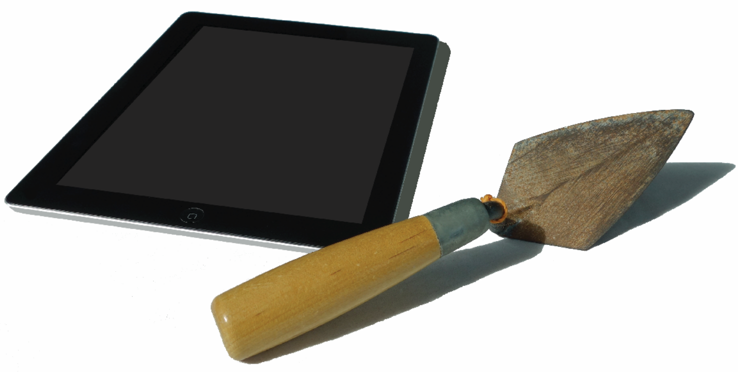
MOBILIZING *the* PAST *for a* DIGITAL FUTURE

The Potential of Digital Archaeology



Edited by
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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).

Invaluable financial and logistical support was also generously provided by the Department of Fine and Performing Arts and Sponsored Programs Administration at Creighton University (Omaha, NE). In particular, we are grateful to Fred Hanna (Chair, Fine and Performing Arts) and J. Buresh (Program Manager, Fine and Performing Arts), and to Beth Herr (Director, Sponsored Programs Administration) and Barbara Bittner (Senior Communications Management, Sponsored Programs Administration) for assistance managing the NEH grant and more. Additional support was provided by The University of Wisconsin-Milwaukee; in particular, David Clark (Associate Dean, College of Letters and Science), and Kate Negri (Academic Department Assistant, Department of Art History). Further support was provided by Davidson College and, most importantly, we express our gratitude to Michael K. Toumazou (Director, Athienou Archaeological Project) for believing in and supporting our research and for allowing us to integrate mobile devices and digital workflows in the field.

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

1.1.
Why Paperless: Technology and Changes in Archaeological Practice, 1996–2016

John Wallrodt

The documentation process for academic field projects is constantly changing. Academics are not bound by the same strict documentation practices of cultural resource management (CRM) firms. The requirements of the host countries in which we work allow a great deal of flexibility. Academic archaeologists (as opposed to CRM archaeologists) are also in a near constant state of experimentation. The various principal investigators (PI) have their own research interests that might propel them to push the envelope in terms of remote sensing, excavation technique, and environmental survey, to offer some examples. Even a single PI can run two consecutive projects of the same type, temporal focus, and geographic region, and adjust their research design, sometimes drastically, between projects.

As an archaeologist who has managed datasets for many short- and long-term field survey and excavation projects in the Mediterranean conducted by the Department of Classics at the University of Cincinnati and other institutions over the last two decades, my task is to take into account the PI's research design and expectations for data recording, the project's resources, the team members' collective technological comfort levels, and the overall project culture, to develop the best documentation methodology possible for the project. There is no single *industrial* approach to academic archaeological documentation processes. Instead, each project has a unique combination of constraints and opportunities tied to research design and resources, such that the documentation process is *crafted* to each individual project.

Over the past two decades I have helped to effect the progress from analog to digital field recording for academic projects. Almost all of these projects have been conducted in locations where there is no electricity on the site, and often without the benefit of even a good cellular connection that would allow data transfer over a network. With the exception of 1.5 days in Pompeii, all of the solutions I have developed have been for offline, battery-only field projects. What follows is a narrative concerning how we went from analog pieces of data to a more integrated digital data model that many field projects—including several discussed in this volume—are pursuing. This is not a review of the *introduction* of new technology into field archaeology, but a review of how field archaeologists have *used* technology. Notably, introduction is not the same as adoption. While my overall approach to archaeological documentation is comprehensive (i.e., each step has a purpose that leads toward better analysis, publication, and archiving), the focus of this review is the use of digital recording by the people actually standing in the dirt.

I focus particularly on the examples of Troy (1988–2002), the Pompeii Archaeological Research Project: Porta Stabia (PARP:PS, 2008–), and the Keos Archaeological Regional Survey (KARS, 2012–). The examination of the use of technology in archaeological fieldwork from multiple perspectives (that of specialists, excavators, and data managers) reveals four stages of adoption: (1) the commoditization of hardware, (2) the early adoption of this hardware by specialists, especially as personal equipment, (3) the increased mass of field data that required purely digital workflows, and then, finally, (4) learning from that experience and applying it to direct digital entry inside the trench during excavation and out in the landscape during survey.

Pieces of Data

Archaeologists adopt technology piecemeal. Although early photography was a difficult and costly process, it was adopted almost immediately, long before it became convenient (Harp 1975). The benefits were incalculable, but the resulting photographs were kept in sleeves, albums, or shoeboxes separate from other records. Similarly, although various forms of electronic distance measurements (EDMs) were used early on, the resulting spatial data gathered by surveyors and architects, and the plans that they produced, were separate from the scaled drawings produced in the field. Forms were introduced in the 1970s as a way to standardize the data traditionally recorded in narrative form in notebooks and they quickly increased in number (Pavel 2010: 35). As such, this proliferation of forms—long before the ubiquity of desktop computers—predated their maximum potential. Examining the records of a particular context on paper required an entire table to display the various notebooks, forms, finds analysis pages, plans, contact sheets, photographs, and specialist reports.

In the past decade, the most exciting advances in field recording have mostly to do with these various pieces of technology coming together *to talk to each other*. This shift has been facilitated primarily because all of the information is now in the same state: digital. There are a great number of things that you can do with data once it can talk to other data. Photographs, for instance, can be recorded into a database in such a way that every subject in the photograph can be linked to its associated data, even that of different types. A single image can include objects linked to a finds table, people linked to a people table, and geography tied to stratigraphic units. Moreover, everything we know about a photograph can be exported from that database and installed into the metadata area inside the photograph itself, making the image file a stand-alone document with everything we know about it embedded in the image, and independently searchable (Wallrodt 2011).

Early Paperless Solution at Troy (1996)

An example of the adoption of digital-born technology can be seen in the Troy excavations, conducted from 1988 to 2002, a critical period for born-digital data as it saw the introduction of portable networks and digital photography. Computing at Troy focused on the metadata from the excavation. Excavators used paper forms in the field, and rather than entering the contents of those forms into a database, they were scanned and distributed as PDF documents (the workflows for each of these is documented on Paperless Archaeology, http://paperlessarchaeology.com). The Troy database recorded only data about the finds, their associated metadata (drawings and photography), and field photography. Those finds, however, required a lot of tracking from place to place and that required many paper forms. The Troy project was chronologically divided into two teams: the Bronze Age (BA) team and the Post Bronze Age (PBA) team.

The workflow for an artifact was as follows: (a) the item was given a field serial number by the excavator; (b) went to the BA registrar for entry into a master database table named "Master Behälter"; (c) was given to the PBA registrar; (d) was sent to conservation; (e) was given a second inventory number and full description by the registrar; (f) was sent to photography; (g) was sent to the government representative; and (h) was then sent either to storage in the on-site depot or in the Çanakkale Museum.

In order to track the artifacts through these eight steps the team used 10 separate forms (picking up at c above):

1 (c): "UC Fundheft Form." Form used to record the existence and the context of an item.
2 (c, h): "Small Finds Tracking Form." A second list for the same finds, but this one is meant to track the item through the conservation, registration, photography, government review, and storage phases.
3 (d): Conservation Logs. A basic logbook for tracking items in and out of conservation.
4 (e): "Inventory Form." A form recording standard inventory information for most small finds in two pages.
5 (e): "Inventoried Lamps Form." (4 pages) A form created to records information for this specific artifact type to prepare for publication.
6 (e): The Green Book. A hard-bound green ledger book with pre-written inventory numbers.
7 (f): "Photoliste." Form used to record black and white negative photos and color slides.
8 (g): "Final Tracking List."9. "Container Tracking Form." Form used for recording post-inventory movement of items.
10. "Inventory Addendum Form." Form used for edits to the existing record.

Most of these forms were handwritten, un-sortable lists of numbers, and each of these lists had to be consulted in order to locate an artifact (see the set of PDF forms titled "Troy PBA Finds Forms 1989–1996," doi:10.7945/C2F30F).

In 1996, when I joined the Troy project eight years after it began, I developed the first paperless workflow for the project, focusing on the small finds. In this new system, when artifacts came to the registrar, the first step was to create a new record in the database. The object's movement through the registration process was then tracked by a series of date stamps in the database, with a paper inventory form printed for inclusion in the files. Changes to the record were entered into the database, but not transferred to the paper forms. By my second season at the site, the entire workflow for the small finds registration was paperless, with the exception of the conservation logs, bringing the forms down from 10 to one.

At the end of the 1996 season, I wrote a lengthy report on my digital work for the project. At the end of the document I wrote a section with the header "Science Fiction":

> As computers become more useful for archaeologists, there will be more ways to use them. With the existing technology, the notebooks in the field can be replaced with hand-held Newton devices with database software. Upon entering the compound, this data can be directly imported into FileMaker Pro and the Tagebücher (including the hand-made drawings and scanned negatives) can be produced 100% electronically. Within a small period of time, and a digitized plan of the site, these finds can be mapped immediately and plans could be automatically updated throughout the season.
>
> Just something to think about.

Better Workflows Derived from New Hardware (1996–2000)

The paperless workflow described above was not possible in 1988 when the project started (Dibble and McPherron 1988). The key was the development of an inexpensive portable network, which only became available in the mid-1990s. Although Apple had developed a proprietary network protocol named AppleTalk by 1985, it did not have regular TCP/IP networking support until System 7 Pro (v.7.1.1) in 1993. Similarly, Windows 3.1 did not have TCP/IP networking until 1994 (this was initially available only for Windows for Workgroups; Young 2009; see also Gilbert 1995). Once better networking hardware became affordable, the software had to follow. While FileMaker Pro v.2 had networking in 1994, it was not until 1995 with version 3 that it got both TCP/IP network support and a relational database model. Since the new finds workflows relied upon multiple people accessing the database at the same time, networking was essential to the paperless process.

Beyond inexpensive networking, the first decade of the 21st century brought hardware advances that proved irresistible to field archaeologists: more powerful laptops, wireless networks, and digital cameras. Although laptops of the early 1990s were vastly underpowered compared to their desktop counterparts, they were absolutely necessary. This was especially true for American projects in locations abroad where power was unreliable and the data had to be brought home at the end of each season. By 2000, however, performance and price had improved enough that many academic archaeologists used laptops as their sole computer.

At the same time that laptop adoption became the norm, wireless networks also came into use. Because wired networks required a router that had a limited number of ports, access to the database was limited to computers connected to those ports. Significantly, wireless networking opened up access to databases to anybody on the project with a wireless capable laptop and the database software.

Similarly, many field projects in the 1990s experimented with digital cameras, even though their image quality was not yet good enough to replace film. The use of digital cameras was particularly vital to those working abroad. Film either had to be locally developed or transported back to home for development, and either method increased the chance of data loss. Digital photography was the only way to securely check the quality of the image before resuming fieldwork. Improved digital cameras appeared around 2000, and by 2005 digital photography had become the norm for field projects.

Specialist Uses of Tech

There are three factors that led specialists to increasingly rely on technology for digital documentation and to bring their own equipment with them to field projects: large datasets, early adoption of statistical methods to deal with those datasets, and their itinerant nature.

True to the pattern of the adoption of experimental technology, archaeologists have used computers since the punch card days of the

1960s (Lock 2003: 9). Early uses were highly specialized and were used for discreet data sets rather than for overall project recording (for a good example, see Matheson and Koheler 1989). During the intervening decades, with the rise of processualism, characterized by empirical approaches focused on spatial analysis and environmental archaeology (e.g., Binford and Binford 1968; Clarke 1968), several specialists such as zooarchaeologists, lithic analysts, and ceramics experts adopted data collection standards tied to statistical methodologies developed for their own subjects. For example, the "Knocod" system for animal bone analysis developed by Hans-Peter Uerpmann was used at Troy during the duration of the project (Uerpmann 1978). Similarly, the BA ceramics team used coded forms for collection of statistically useful data from their ceramics (Pernicka *et al.* 2014: 565–573).

Other systems were also being developed. Clive Orton developed his "Pie-slice" analytical software for use with ceramics (Orton and Tyers 1990), but others found it useful for other materials, such as faunal remains (Moreno-Garcia *et al.* 1996). WinBASP started in the 1970s as a statistical package, and it was expanded to meet additional uses including the creation of Harris matrices (Anon. 1977). Although specialists in the 1990s increasingly looked to these digital solutions to handle what could be very large data sets, digitally-recorded data remained highly specialized and were collected in a piecemeal fashion, rather than integrated into larger databases. Moreover, many specialists actively resisted the incorporation of their data into the master data set, for fear that project directors and other archaeologists would misinterpret and misuse the results. Instead, specialists typically submitted season-end reports with summary data.

Similarly, post-excavation specialists also dealt with a different dataset than excavators. Because excavators typically focus on single-site analysis, usually concerning the description of the single unit (trench) in front of them, their data is completed on-site and stays at the site when they leave. Specialists require detailed data from multiple sites and regions in order to assess patterning in their data sets; therefore, they wanted all of their data with them all the time.

Materials specialists' appetites for digital data grew even further during the first decade of the 21st century. It was not until 2009 that Intel coined the term BYOD (bring your own device), but that is exactly the principle that was a catalyst for the acceptance of digital data to the field (Lai 2010). For example, while directors initially resisted digital photography, and therefore used digital cameras in tandem with standard film photography, sometimes for several years, this bias was largely overcome by the project specialists who incorporated digital-born data into their own personal datasets. Ceramicists did not have to wait for official project photography anymore and could take study photos of all of their objects (to their satisfaction) in a single afternoon. Digital cameras were in use at Troy as early as 2000 by ceramicists, and the project started using them for publishable finds photography in the following year. By the middle of the decade the hardware had been so commoditized that most of the specialists would arrive at Troy with their own laptops and digital cameras. They would take study photos of their objects with their cameras and create datasets directly on their computers. When they left the project for the season, they asked for information in digital format: PDFs of things that could be scanned, and read-only copies of the database that they could reference offline. They did not want photocopies of notebooks.

Field projects, in turn, benefitted from this increase in digital creation in concert with their own focus on making the core archaeological data available in database form. As project databases became more common, and the specialists saw a greater return on the integration of their data sets, specialist data started to be incorporated into the master data, and by the end of the decade, it became more common for specialists to surrender their data sets for incorporation into the whole. Not only were the data sets talking to the master field data, they were talking to each other: the data created by the finds specialists and environmental specialists could reference each other directly.

Uses of Tech in the Trench

While post-excavation specialists had been providing digital data for years, this type of born-digital data entry rarely made it into the trench. There was certainly *some* technology in the trench: point and shoot digital cameras had been adopted after specialists began using them (most by 2005), and electronic distance measurement (EDM) machines had been used for decades in the field, often by the excavators themselves (as opposed to a separate team). But the base recording methods had not evolved since the widespread use of forms instead of narrative journal entries in the 1970s. While digital technology became ubiquitous on field projects, excavators in the trenches were still using paper and pen to record their initial observations of finds and stratigraphy.

Paper to digital has been the normal workflow for almost as long as there have been forms. There are many problems with this approach, but the single fatal flaw that affects all paper to digital workflows is the revision process. Data that had been written, then typed, cannot be adequately tracked when revisions are made in either direction. This was evident even in fully paper-based projects, and predates the ubiquitous use of databases for field data. The field forms for Troy, for example, were photocopied and kept in three separate places: Tübingen, Cincinnati, and Troy. If somebody wanted to change an earlier notebook, they had to fill out a piece of paper called the "Change to Tagebücher" form. That form was photocopied and a copy kept in all three places with the original notebook. Each project had their own workaround for this problem, but none was satisfactory.

Paper to digital is also the least efficient use of the trench supervisor's time. The trench supervisor maintains the notebooks, supervises the excavation, directs people where to dig, keeps track of the many numbers created during the project, tracks the number of buckets removed, and decides when to photograph, when to draw, and when to stop digging. The trench supervisor makes the initial stratigraphic interpretation. They write the first story of the trench. This is an often overwhelming amount of work to ask of one person, and it is most often done in the least efficient manner possible: by writing everything down on paper during the day and typing it up during the evening or weekends, thereby doubling their work.

The worst part of the paper to digital workflow is that the trench data took so long to be digitized, often months after the season ended, that errors and emendations crept into the data set. For example: initial descriptive observations can become interpretations, so "chunky, dark, loose fill" can become "interior of drain" when the form is typed into the database. Forms might be typed in but sketches were most often not digitized in any meaningful way in the field, and there was no mechanism for the field drawings to be incorporated into the data set either. The data were not speaking to each other.

Mobile Devices (2010–2015)

Mobile devices were the next big hardware leap that allowed tech to get inside the trench, but mobile devices were problematic. Some field projects had experimented with them, notably Palm devices and field based laptops. The Landscape Research Centre (UK) has been publishing work concerning their digital experiments since 1984, but even in their data flow diagram from 2010 (Powlesland and May 2010: fig. 45) there were lots of devices used: total station, personal digital assistant (PDA), flatbed scanner, digitizing tablet, and laptop. The Athenian Agora excavations also used the Palm platform to talk directly to their total stations. But as Palm changed their hardware and operating system (OS) it became difficult for them to find the hardware that was compatible with their systems (Hartzler 2009: 129) shows screenshots from their Palm Pilot use in 2005, right around the time that Palm stopped making those devices; mention of their difficulties finding hardware is from personal communication). The Agora workflow described in 2009 also required that the information in the Palm be transcribed to the notebook by hand (Hartzler 2009: 132).

Troy Excavations

I mentioned the Newton above, but it was specifically the Newton OS that I wanted to use at Troy. That would have come in the form of the eMate, a device originally marketed toward elementary schools. In 1995, Claris, the parent company that owned FileMaker Pro, announced a version of FileMaker for the Newton OS (for original press release see: http://www.ebyss.net/pages/FMCpr.html). That software already had record-level syncing, and in some ways was more useful than the solution we used in 2010 at Pompeii. Since it was designed for schools, the eMate had the ability to act as a teacher/student system. The teacher would beam (via infrared) the assignment to the students, and they would beam their answers back. In our case we wanted to collect the field data from spreadsheets on the devices and import them into the master database. But the Newton OS and the eMate were both discontinued in 1998.

The Palm OS had better developer support and more software, and while some projects used it to great effect, it suffered from a fatal flaw: all data deleted when the device ran short of power. The only intervening device worth considering was the Microsoft Tablet PC, a full-sized laptop with a touch screen that required a stylus. They were heavy, their batteries lasted only a few hours, and they were incredibly expensive.

While all of these devices were being used on some field projects, their use did not become the norm for any significant segment of archaeological fieldwork. These were devices that projects purchased for use for the duration of the fieldwork, they were not devices that scholars wanted to purchase for themselves and use in their own work.

Pompeii Archaeological Research Project: Porta Stabia

The iPhone was released in 2007, and in 2008 third-party programs were able to run on the device. In 2009 the PARP:PS team experimented with databases running on the iPhone. In 2010, with the introduction of the larger iPad, and Android-based tablets soon after, archaeologists finally had a device that worked all day, had no moving parts to break, did not require a network (although having one would be nice), and had a screen size significant enough to allow direct digital entry for any field-related task. These were the devices that scholars brought into the field themselves in true BYOD fashion. In the first nine months of sale, Apple sold 15 million iPads; more, they claimed, than every Tablet PC ever sold (from 2000–2011; see https://www.youtube.com/watch?v=TGxEQhdi1AQ at the 5:30 mark).

In 2010–2012 at PARP:PS we used iPads to enter and edit records in the database (first FM Touch and then FileMaker Go), draw scaled plans and profiles (with iDraw, then TouchDraw), keep a free-form notebook (Pages), and keep Harris matrices (OmniGraffle) up to date (the workflows for each of these is documented on *Paperless Archaeology*, http://paperlessarchaeology.com). As a result, we had our first fully digital archive of the project.

At first the data were still in pieces. They were in proxy apps: digital equivalent of their paper counterparts. There is value in the ease of use and accuracy of the proxy apps over paper, but they were still in digital pieces. The database recorded that there was a plan, but didn't actually link to it. The Harris matrices were portable, but they did not communicate with the database.

In subsequent years we learned to make the field drawings talk to the larger computer-aided design (CAD) workflow. By using CAD output as the background for all field drawings, and keeping the scale of the drawings at 1:1 (the software TouchDraw allowed infinite zoom, which meant that we could draw at full scale, which removed an entire mental process from the activity: no more mentally scaling all measurements), we were able to feed the field drawings directly back to the CAD operator, sometimes on the same day, so that we could address any areas of the drawings that were difficult to interpret (Tucker and Wallrodt 2013).

What was important is that there was finally a way to get direct observation from the trench in a digital format. The traditional workflow of paper to digital no longer applied and we opened up the field data to immediate review by the rest of the team. With immediate access to the form data, the data managers and other members of the project became immediate editors. The spatial team caught errors or inconsistencies in drawings that were immediately fed back to the field team and created a process for revisions. Similarly, the ceramics team received daily matrix information that helped them to better understand the stratigraphy and therefore better process the ceramics. More importantly, units could be tagged as "high priority," thereby allowing the post-excavation specialists to readjust their priorities.

There is no standard metric for the success of a new recording process for an archaeological project. Clearly the most important is that it satisfies the research design and can answer the questions that the PI puts to the data. As mentioned above, that is a different requirement for different projects. PARP:PS is a complex project with many voices contributing to the story of the site. Key to getting that story is the timeliness of data retrieval: What volume of dirt was brought out of these units? Which units were "sealed" contexts? How large is this feature? Is this type of feature related to these kinds of charcoal, fauna, pottery? Where is everything from this context stored? In previous years at PARP:PS these questions were time consuming to answer. In later years, there were very quickly determined. More dirt may have been moved during the paperless years at PARP:PS (see Ellis, Ch. 1.2), but that was an unexpected benefit. The main benefit is the speed at which anybody could receive answers from the data set (Wallrodt *et al*. 2015).

Keos Archaeological Regional Survey Project

This improvement in the efficiency of data retrieval was also obvious to the Project Directors at the Keos Archaeological Regional Survey (KARS) project on the island of Keos, which began in 2012. Survey teams carried iPads pre-loaded with georeferenced satellite photography (the imagery was from 2005) in a geographical information system (GIS) application. Since the iPads had GPS built in, the team leader knew their exact position and drew the tract polygon directly on the GIS (there have been several web articles written about the accuracy of consumer level GPS devices, including the iPad, and most sources have put the accuracy at within 2 m; see Hodel 2013). In previous paper-based survey projects there was often some indecision concerning the exact location of the team in relation to rough paths, temporary waterways, and electrical lines that seemed to change with surprising rapidity. Measurements and angles of movement were often inconsistently applied. Many pencil lines were erased and redrawn. The tablet technique at KARS not only allowed the teams place themselves on the correct side of these cartographical features, but they could verify their location by counting the rows of olive trees. With a swipe to their database app, they immediately added the same data that they would normally put into their notebooks. Photographs taken by the iPads were automatically geotagged. The rough GIS plans were downloaded daily, were properly snapped in the master GIS documents, and were then re-loaded into the tablets before the next day's fieldwork. The database entries were synced to the master database each day, and any records concerning the finds that were brought back to the dig house could be attached to those records immediately.

Conclusions

When archaeological data are unbound from their analog predecessors, they no longer exist as discrete pieces. In digital form, through data connections and transfers, we move away from multiple pieces of disconnected individual observations and toward a singular dataset. Although form data are held in databases, they can be exported for visualization in spreadsheets or other specialized software. Both CAD and GIS are separate applications for similar data, and the data is easily shared between the two. With the exception of 3D data, which is beyond the scope of this essay, any data can be printed.

Techniques of paperless data collection are still very new, and they are constantly evolving. Recalling the early adopters of field computer use, we might look to what specialists are doing. For example, voice data entry and skip logic on touch screens shows great promise for those who have to enter coded data for large data sets (Austin 2014). While custom software has been in use within archaeology for as long as there have been computers, complete desktop archaeological programs such as Intrasis are not the norm (http://www.intrasis.com/index.htm). For the majority of academic field projects, desktop and laptop computer use focuses on customized uses of commercially available software, rather than custom-developed software. The two largest database programs, Microsoft Access (Windows only) and FileMaker Pro (Windows and Mac) are middleware development platforms that allow custom solutions to be built. This is the closest that many projects come to custom software. Using off-the-shelf software solutions is the lowest barrier for entry for a new field project.

Similarly, the best archaeological uses of mobile platforms that I have seen follow this same pattern, relying primarily on off-the-shelf software, although the names of these programs might be less familiar (TouchDraw, iGIS). As a rule, they are intentionally chosen based on their ability to output data in the format needed to connect to other platforms. For example, at PARP:PS, we used TouchDraw, which can output to SVG, as an intermediary step for integration of field drawings into the CAD environment. TouchDraw can also output to PDF format for long-term archival storage. Another example comes from the KARS survey, for which iGIS was selected for use because it writes to what has become a standard spatial file format, .shp.

From the beginning of mobile field recording at PARP:PS, we focused on making sure the output of the software was usable. Although some newer notebook applications with more features than a straight word processor were available, we did not use these because they could not output the file in a reusable format. Similarly, the vector drawing applications we selected had to be able to export cleanly to other file formats while preserving their layer structure. Rather than using a standard Harris matrix program at PARP:PS, we relied on OmniGraffle because it allows export as a vector-editable PDF, even though it stores items in its own file format.

While custom-developed software is likely to increase, these solutions are not without obstacles. The two biggest roadblocks we face in the application of custom-made desktop or mobile software are (1) operating platform differences, and (2) software maintenance needs, both of which are tied to constantly evolving hardware. While it is conceivably easy to target a single platform for data collection for a single field season, one must also consider not only the diversity of devices used by various team members—such as specialists, who want to be able to work with data on their own platforms and take it with them—but also challenges of multi-year projects and long-term project needs. With the rapidly changing pace of advances in hardware and operating system in the mobile space, it is not possible to be certain that specific software will be able to function in even three years. In the past decade, we have already confronted this problem with the change from 32 to 64 bit architecture in desktops and the difficulty of Android devices to upgrade to later operating systems. For example, because WinBASP did not make the change to 64 bit architecture, it was abandoned. Hardware component makers will not stop innovating, and this necessitates changes in operating systems and changes to the application programming interfaces (APIs) that software relies upon.

All of these considerations—custom designed versus commercially available software, cross-platform capability, usability, output, and data integration—are all carefully considered parts of the overall data collection and retention scheme developed by the projects's data architect. Because the data management scheme is tailored to the research design and the technical acumen of the team members, the use of mobile devices to create digital born data is a decision that each project should make for themselves. It is the newest tool in the archaeologists' kit and one of the most exciting new tools introduced in the past two decades that has allowed us to rethink the best practices that we use to record and interpret the past.

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